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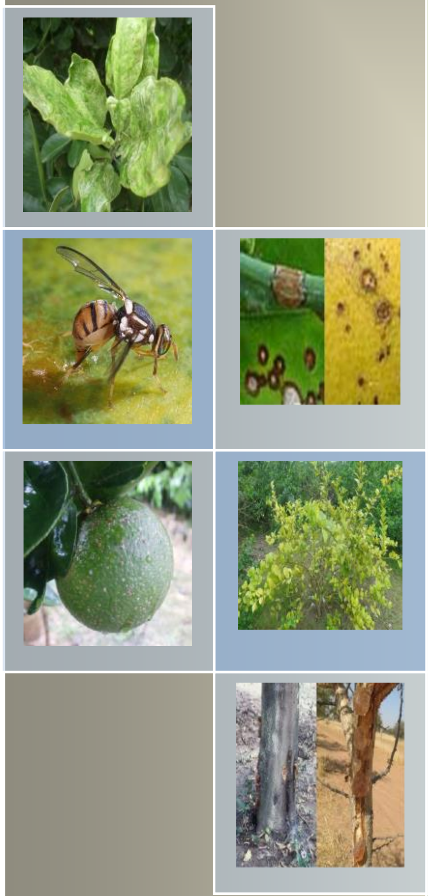

Final Report

Pest Risk Analysis (PRA) of Citrus in Bangladesh

November-2014

Final Report

For

Pest Risk Analysis (PRA) of Citrus under Strengthening Phytosanitary Capacity in Bangladesh Project (SPCB), DAE

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ABBREVIATIONS AND ACRONYMS

AAEO	**Assistant Agriculture Extension Officer**
ISPM	**International Standard for Phytosanitary Measures**
NATP	**National Agricultural Technology Project**
NCDP	**Northern Crop Diversification Project**
NPPO	**National Plant Protection Organization**
PC	**Phytosanitary Certificate**
PPS	**Plant Protection Specialist**
PPW	**Plant Quarantine Wing**
PQ	**Plant Quarantine**
PRA	**Pest Risk Analysis**
PSO	**Principal Scientific Officer**
RARS	**Regional Agricultural Research Station**
SAAO	**Sub Assistant Agriculture Officer**
SAPPO	**Sub Assistant Plant Protection Officer**
SPCB	**Strengthening Phytosanitary Capacity in Bangladesh Project**
TOR	**Terms of Reference**

GLOSSARY

Additional declaration	A statement that is required by an importing country to be entered on a Phytosanitary Certificate and which provides specific additional information on a consignment in relation to regulated pests
Authority	The National Plant Protection Organization, or other entity or person officially designated by the government to deal with matters arising from the responsibilities set forth in the Code
Beneficial organism	Any organism directly or indirectly advantageous to plants or plant products, including biological control agents
Certificate	An official document which attests to the phytosanitary status of any consignment affected by phytosanitary regulations
Commodity	A type of plant, plant product, or other article being moved for trade or other purpose
Commodity pest list	A list of pests occurring in an area which may be associated with a specific commodity
Consignment	A quantity of plants, plant products and/or other articles being moved from one country to another and covered, when required, by a single phytosanitary certificate (a consignment may be composed of one or more commodities or lots)
Country of origin	Country where a type of plant or plant product were grown or derived
Ecosystem	A dynamic complex of plant, animal and micro-organism communities and their abiotic environment interacting as a functional unit
Endangered area	An area where ecological factors favor the establishment of a pest whose presence in the area will result in economically important loss
Entry (of a pest)	Movement of a pest into an area where it is not yet present, or present but not widely distributed and being officially controlled
Eradication	Application of phytosanitary measures to eliminate a pest from an area
Establishment	Perpetuation, for the foreseeable future, of a pest within an area after entry
Exotic	Not native to a particular country, ecosystem or eco-area (applied to organisms intentionally or accidentally introduced as a result of human activities). As the Code is directed at the introduction of biological control agents from one country to another, the term "exotic" is used for organisms not native to a country
Host pest list	A list of pests that infest a plant species, globally or in an area
Host range	Species capable, under natural conditions, of sustaining a specific pest or other organism
Import permit	Official document authorizing importation of a commodity in accordance with specified phytosanitary import requirements
Inspection	Official visual examination of plants, plant products or other regulated articles to determine if pests are present and/or to determine compliance with phytosanitary regulations
Interception (of a Consignment)	The refusal or controlled entry of an imported consignment due to failure to comply with phytosanitary regulations
Interception (of a	The detection of a pest during inspection or testing of an imported

pest)	consignment
Introduction	The entry of a pest resulting in its establishment
Official control	The active enforcement of mandatory phytosanitary regulations and the application of mandatory phytosanitary procedures with the objective of eradication or containment of quarantine pests or for the management of regulated non-quarantine pests
Pathway	Any means that allows the entry or spread of a pest
Pest	Any species, strain or biotype of plant, animal or pathogenic agent injurious to plants or plant products
Pest categorization	The process for determining whether a pest has or has not the characteristics of a quarantine pest or those of a regulated non-quarantine pest
Pest risk assessment (for quarantine pests)	Evaluation of the probability of the introduction and spread of a pest and the magnitude of the associated potential economic consequences
Pest risk management (for quarantine pests)	Evaluation and selection of options to reduce the risk of introduction and spread of a pest
Phytosanitary certificate	Certificate patterned after the model certificates of the IPPC
Phytosanitary measure (agreed interpretation)	Any legislation, regulation or official procedure having the purpose to prevent the introduction and/or spread of quarantine pests, or to limit the economic impact of regulated non-quarantine pests
Plant quarantine	All activities designed to prevent the introduction and/or spread of quarantine pests or to ensure their official control
Point of entry	Airport, seaport or land border point officially designated for the importation of consignments, and/or entrance of passengers
Prohibition	A phytosanitary regulation forbidding the importation or movement of specified pests or commodities
Quarantine	Official confinement of regulated articles for observation and research or for further inspection, testing and/or treatment
Quarantine pest	A pest of potential economic importance to the area endangered thereby and not yet present there, or present but not widely distributed and being officially controlled
Quarantine station	Official station for holding plants or plant products in quarantine
Regulated article	Any plant, plant product, storage place, packaging, conveyance, container, soil and any other organism, object or material capable of harboring or spreading pests, deemed to require phytosanitary measures, particularly where international transportation is involved
Systems Approach(Es)	The integration of different risk management measures, at least two of which act independently, and which cumulatively achieve the appropriate level of protection against regulated pests
Treatment	Official procedure for the killing, inactivation or removal of pests, or for rendering pests infertile or for devitalization

Executive Summary

The Plant Quarantine Wing of Department of Agricultural Extension under the Ministry of Agriculture has developed a project on Strengthening Phytosanitary Capacity in Bangladesh (SPCB) and as a part of the project an activity entitled "Conducting Pest Risk Analysis (PRA) of Citrus in Bangladesh" for this project as per DPP has been undertaken through open bidding of qualified Consulting firms. However, Center for Resource Development Studies Limited (CRDS) was finally offered for Conducting Pest Risk Analysis (PRA) of Citrus in Bangladesh. The major objectives of the project included recording of major and minor insect pests of citrus, major and minor diseases of citrus with causal organisms and listing of quarantine pests and diseases of citrus. The project identified 20 districts namely Sylhet, Moulvibazar, Habiganj, Narsingdi, Gazipur, Dhaka, Manikganj, Mymensingh, Tangail, Sherpur, Comilla, Chittagong, Khagrachari, Rangamati, Bandarban Pabna, Rajshahi, Jessore, Chuadanga, and Jhenaidah as study areas. Two to Six upazilas under each district were also identified for field survey and data collection on insect pests and diseases of citrus (Table 1). In each upazila 10 blocks and under each block, 10 farmers were selected for data collection.

As many as 9 citrus fruits namely lemon (elachi lebu), lime (kagozi lebu), pummelo (batabi lebu), mandarin (kamola), malta (sweet orange), satkara, jamir (citron), ada lebu (citron) and jara lebu (citron) were included in the study (Appendix II).

The study was done following several approaches such as interview of farmers, DAE/BARI personnel and specialists, scanning of reports and Internet searching. Questionnaire and Formats for respective group were developed for field survey and data collection (Appendix XIII to XVI). Accordingly 100 farmers and the concerned DAE/BARI personnel were interviewed and necessary information/data were collected from all the selected upazilas of respective districts. Similarly field data on available insect pests and diseases following the Format were also collected from the field with available crops. The collected information and data were compiled, assessed and interpreted and finally processed for the preparation of reports.

Most of the insect pests were common for all citrus fruits. Lemon was found to be infested by 17 insect pests, of which lemon butterfly and citrus leaf miner were major and the rests were minor. Similarly there were 15 insect pests for lime with lemon butterfly and citrus leaf miner as major. Mandarin, malta, batabi lebu, jamir, satkara, ada lebu and jara lebu had 19, 18, 17, 12, 11, 11 insect pests (Table 2)

Nine citrus fruits had many common diseases and three major diseases namely dieback, canker and gummosis were common to all citrus fruits. There were 11, 10, 8, 9, 13, 7, 4, 8 and 8 diseases recorded on lemon, lime, pummelo, malta, orange, jamir, satkara, ada lebu and jara lebu respectively (Table 3).

Field survey was done during June and July, 2014 and the citrus available in the field were included in the study. Recording of insect pests and diseases were also done during field survey. Data were collected from all the selected upazilas. A detailed report on insect pests and diseases recorded during visit was prepared. Appendix IV showed the insect pests of citrus and Appendix V showed the diseases of citrus.

Field survey and the interviews of farmers and DAE/BARI personnel was done on all the selected upazilas of all the districts. Elaborate report was presented in Appendix VI to Appendix X. It appeared that the farmers growing citrus had wide variation in educational background, farming experience and agricultural trainings. They also reported various insect pests and diseases of citrus they encountered and the control measures they adopted.

There were altogether 36 insect pests of citrus which were recorded in different countries of the world. Of them, 17 were considered as major. Internet searching revealed that most of the insect pests had worldwide distribution and more than 60 countries included in the distribution list of each insect pest (Appendix XI). Fifteen insect pests like brown citrus aphid, California citrus thrips, South African citrus thrips, African citrus psyllid, citrus snow scale, cottony cushion scale, Asian fruit fly, Mediterranean fruit fly, Asian papaya fruit fly, Queensland fruit fly, white spotted longicorn beetle, fruit sucking moth, southern fire ant, citrus gall wasp and Lewis spider mite were absent in Bangladesh. Thus 15 insect pests mentioned above were considered as quarantine pests of citrus for Bangladesh (Table 4).

A total of 25 diseases of citrus were recorded in different countries of the world was listed. The list of diseases and their distribution was shown in Appendix XII. The majority of the listed diseases were considered as major. Of the world recorded 25 diseases, 14 diseases were found in Bangladesh with variation in incidences and severity. Eleven diseases are absent in Bangladesh. However, considering the ecology and biology of the organisms and their damage potentiality, seven diseases namely greening (African form), stubborn, black spot, pesudocercospora spot, mal secco, leprosis and Indian citrus ringspot were identified as quarantine diseases for Bangladesh (Table 5). These diseases are serious in Australia, China, Japan, North America, South America, South Africa, India, Pakistan and some other countries. The identified 22 hazard organisms are listed in Table 6.

Study reports showed that as many as 21 insect pests were found to attack the citrus fruits (Table 7) while a total of 14 diseases were recorded on citrus (Table 8). The major insect pests were lemon butterfly, leaf miner, citrus mealybug, oriental fruit fly and orange spined bug, and the major diseases were die-back, canker, gummosis, scab and greening (Tables 7 and 8).

Pest Risk Analysis (PRA) consists of three stages such as initiating the process for analyzing risk, assessing pest risk and managing pest risk. Initiating the process involves identification of pests or pathways for which the PRA is needed. Pest risk assessment determines whether each pest identified as such, or associated with a pathway, is a quarantine pest characterized in terms of likelihood of entry, establishments, spread and economic importance. Pest risk management involves developing, evaluating, comparing and selecting options for reducing the risk. All the three stages were elaborately discussed in the report. The quarantine insect pests and diseases of citrus were also identified and included in the report with causal organisms and status. The report included the pest risk management of quarantine pests of citrus with specific approaches and methods in detail. It is now, necessary to follow the recommended quarantine practices while exporting and importing citrus.

1.0 Introduction

Citrus belonging to the family Rutaceae is one of the most important nutritious fruit crops of the world. It is the third largest fruit industry of the world and occupies 6 per cent of the total area under various fruits. World annual production of citrus fruits in 2012 was 131.28 million metric ton (Mmt). Total production in Asia was 57.25 Mmt, which is the highest compared to the production in other continent. In Bangladesh, the total acreage under citrus fruits (2010-2011) is about 5995 ha while the total production is around 1, 36,756 mt (Appendix III).

The majority of the Citrus species belong to the sub-tropical and tropical regions of South-East Asia, especially China, India etc. The principal producing countries of the world are Algeria, Australia, Argentina, Brazil, China, Cyprus, Greece, India, Israel, Italy, Japan, Lebanon, Mexico, Morocco, South Africa, Spain, Egypt, Tunisia, Turky, U.A.E., U.S.A. etc. The climate of Bangladesh is very congenial to the year round production of citrus. But Bangladesh does not play any significant role in the world trade as most of the nation's production is consumed within the country and only small quantity is exported to European Union and Middle East countries. The exported citrus fruits from Bangladesh include jara lebu, lemon, ada lebu, satkara, pummelo etc. The main citrus growing areas of Bangladesh are Chittagong, Khagrachari, Rangamati, Bandarban, Noakhali, Sylhet, Moulvibazar, Habigonj, Dhaka, Gazipur, Mymensingh, Kushtia, Dinajpur, Rajshahi and Rangpur.

The introduction of insect pests, plant diseases and weeds is brought about mainly during the accelerated agricultural development in different countries, when plants and plant materials were brought into, or sent out with little or no concern for the insect pests, diseases and weeds that were transported along with them. There are many instances of accidental introductions of insect pests and diseases from one country to another. Extensive damages, often sudden in nature, have been caused not by indigenous pests, but with exotic ones introduced along with plants, plant parts or seeds in the normal channel of international trade or individual interest. Instances may be cited of the introduction of grape diseases *(Phylloxera vitifolia*) from the U.S.A. to France which caused destruction of French vineyards; Mexican boll weevil (*Anthonomus grandis)* whose original home was in Mexico or Central America, round about 1892 entered the U.S.A. and later to various countries in the world, causing extensive damage to cotton; European corn borer (O*strinia nubilalis)* which reached North America probably through broom corn from Italy or Hungary and has since become a major pest there.

Pink ball worm (*Pectinophora gossypiella*) considered to be one of the six most destructive insects of the world probably a native of India is now established as a highly destructive pest in nearly all cotton growing areas of the world. Downy mildew of grape (*Plasmopara viticola*) introduced in France from the U.S.A. was responsible for the destruction of grape vines till the discovery of Bordeaux mixture. Blight disease of chestnut (*Endothia parasitica*) introduced into the U.S.A. from Europe completely wiped out chestnut plants.

In India the san jose scale (*Aspidiotus perniciosus*) is a pest of apple introduced about 60 years ago, now causing concern to apple growers in Himachal Pradesh, Jammu and Kashmir, potato tuber moth (*Gnorimoschema operculella*) which entered from Italy in 1900 is an established field and storehouse pest of potato all over the country; wooly aphis (*Eriosoma lanigerum*) an introduced serious pest of apple; fluted scale (*Icerya purchasi*), a native of Australia introduced through Ceylon in 1928 now a serious pest of *citrus spp;* leaf rust of coffee (*Hemileia vastatrix*) introduced from Ceylon in 1876; fire blight of apple and pear (*Erwinia amylovora)* introduced from England in 1940, now a serious disease in Uttar Pradesh; flag smut of wheat (*Urocystis agropyri*) introduced from Australia now established in the Punjab, Rajasthan and Uttar Pradesh; bunchy top of banana introduced from Ceylon in 1940 causing serious damage to dwarf Cavendish varieties in different parts of India; wart of potato (*Synchytrium endobioticum*) introduced from Holland in 1952; golden nematode of potato (*Heterodera rostochienssis*) in the last 20 years and onion smut (*Urocystis cepulae*) introduced recently are examples showing how many destructive diseases and pests have entered into this country and have established themselves causing extensive damage.

Plant Quarantine regulations in order to be effective have to be based on sound scientific principles. The biology and ecology of the organism against which quarantine measure is proposed to be enforced should be known. Besides it has to be determined whether: (a) in the absence of any quarantine measure, the organism is likely to be introduced into the country; (b) the event of its introduction whether the organism is likely to be established and cause damage. (c) quarantine regulations can be framed on scientific lines and enforced satisfactorily; and (d) it is economical to introduce the legislative measure in terms of benefit likely to be derived. Biological, legal and economic aspects of the problem have to be clearly understood to place the measures on a sound footing.

International quarantine regulations which aim to prevent entry of new pathogenic organisms and insect pests may; (a) completely prohibit entry of certain plants or plant materials; (b) allow import of certain plants or plant materials if they are certified to be free from certain specific insect pests and pathogenic organisms, by a competent authority of the country of origin; and (c) allow entry of plants and plant materials provided they are accompanied by certificates of free from pests and diseases by the competent authority of the country of origin. The importing countries may also impose restrictions on the mode of transport (air, ship or postal mail), and wrapping materials (soils etc.). They also have the right to examine the materials before they can be allowed to be introduced, even if accompanied by the certificate from the country of origin. Fumigation or any other treatment may be enforced. For this purpose the plants and plant materials to be brought into a country need to be channelized through certain specific ports of entry.

The enforcement of legislative measures to check the entry of destructive diseases and insect pests from other countries can be successfully done through the cooperation of Governments of different countries. Almost every country of the world has passed Quarantine Acts with specific provisions. Mutual respect of the provision of the Act is necessary for the successful promulgation.

2.0 Methodologies

The Project on "Pest Risk Analysis" of Citrus fruits included 20 districts covering 60 upazilas as shown in Table-1

Table 1: List of Districts and Upazilas Identified for Citrus Fruits for PRA Studies

Sl. no.	District	Upazila
1	Sylhet	Golapganj
		Gowainghat
		Jaintiapur
		Balaganj
		Bianibazar
2	Moulvibazar	Sreemangal
		Kulaura
		Juri
		Barlekha
3	Habigonj	Chunarughat
		Bahubal
		Sadar
4	Narsingdi	Shibpur
		Monohardi
		Belabo
		Raipura
5.	Gazipur	Kaligong
		Kapasia
6	Dhaka	Savar
		Dhamrai
7	Manikganj	Singair
		Saturia
8	Mymensingh	Sadar
		Gauripur
		Ishwarganj
		Haluaghat
9	Tangail	Sakhipur
		Modhupur
		Dhanbari
		Delduar
10	Sherpur	Sadar
		Nalitabari
11	Comilla	Chandina
		Daudkandi
		Burichang
12	Chittagong	Potiya
		Mirsharai
		Shitakunda
13	Khagrachari	Sadar
		Dighinala
		Panchari

Sl. no.	District	Upazila
		Mahalchari
		Ramgarh
		Matiranga
14	Rangamati	Kaptai
		Langadu
		Bagaichari
15	Bandarban	Sadar
		Lama
		Ruma
16	Pabna	Ishwardi
		Atgharia
17	Rajshahi	Paba
		Puthia
18	Jessore	Bagherpara
		Jhikorgacha
19	Chuadanga	Sadar
		Alamdanga
20	Jhenaidah	Sadar
		Kaliganj

Under each district 2-6 upazilas were selected based on major growing area and production of the crop (Table-1). Under each upazila there were 10 Blocks and under each Block 10 Farmers were selected from whom the relevant information were collected.

With the assistance of DAE, ten farmers were selected and interviewed by using a structured questionnaire. The concerned Upazila Agriculture Officer, Sub-Assistant Agriculture Officer and the Station-in-Charge of BARI research stations were also interviewed and necessary information were collected by using a format. The Field Researchers also met the Deputy Director, Department of Agriculture Extension of the concerned district and recorded their views on pests and diseases of citrus of their areas. Altogether 6000 citrus growers were interviewed and their citrus crops were visited to record the insect pests and diseases.

Pest Risk Analysis (PRA) study refers to two major groups of plant menaces namely insect pests and diseases. An extensive program was chalked out to record insect pests and diseases of Citrus of selected areas. To record and collect detail information on insect pests and diseases a questionnaire and also information formats were developed for farmers and DAE/BARI personnel. In addition, to conduct a field survey to record the incidence and severity of insect pests and diseases of citrus plants presently available in the field, a data recording format was prepared and supplied to the Field Researchers. All Formats and Questionnaire are included in the Appendix, XIII XIV XIV and XVI.

Appointment and Training of Field Researchers:

Twenty persons having Bachelor degree in agriculture were appointed as Field Researchers and they were trained on identification of insect pests and diseases symptoms of citrus through power point presentation by the Senior Entomologist and Plant Pathologist of BARI. Handouts describing each insect pests and disease were also supplied. The theory presentation was followed by a practical training on the next day in the field of BARI, Gazipur. Another training was arranged to train the Field Researchers to collect the appropriate information from the Farmers, SAAO, UAO, DD and Researchers using the Questionnaire and Formats.

Field Survey and Primary Data Collection:

Ten teams having two members in each team made field survey and collected necessary information based on questionnaire and format from the farmers and concerned officials of 20 districts. Each team was supplied with colored pictures of damage symptom for diseases and insect pests.

Secondary Data Collection:

The secondary data on insect pests and diseases of Citrus were collected from BARI and DAE, published reports and internet. These data were checked with primary data and the final list of insect pests and diseases were prepared.

Internet Searching:

The Internet searching was done on countries of export and import of Citrus and recorded insect pests and diseases of those countries. Finally by using primary and secondary data and Internet information, a list of quarantine pests and diseases were determined.

Interpretation of results

The collected data on insect pests and diseases of citrus from different locations were analyzed and interpreted with the aim to find out variations in respect of incidence and status of each pest against each crop including variety as well as location and seasonal effect. The most vulnerable stage of plant growth for insect pests and disease attack was also determined based on both primary and secondary data.

A check list was prepared based on locally available insect pests and diseases of Citrus in comparison with other countries of export and import importance of respective crop.

Figure-1 shows the major Citrus growing areas of Bangladesh, while Figure 2 represents the selected areas of Citrus under study.

Figure 1: Map Showing the Major Citrus Growing Areas in Bangladesh

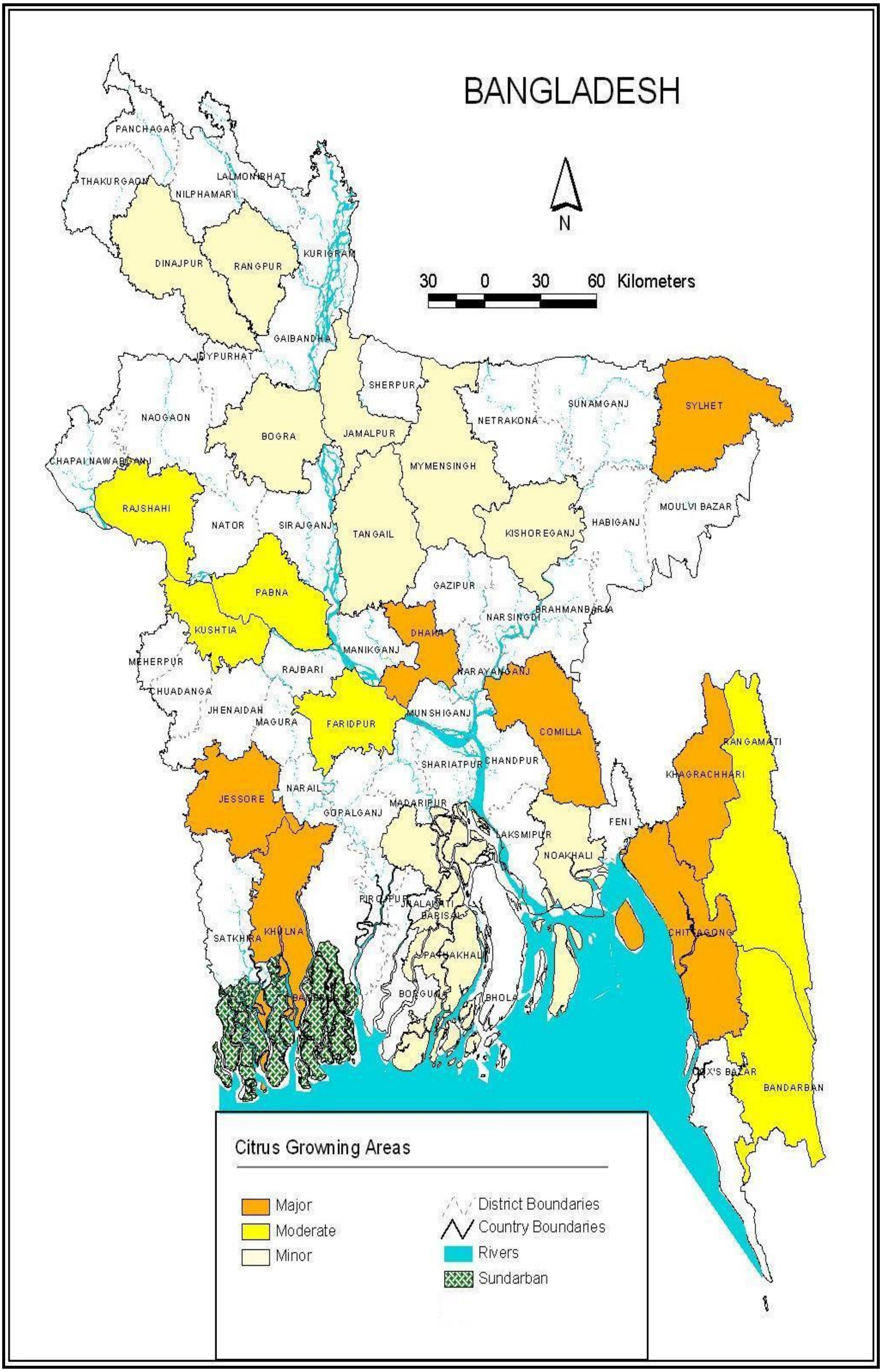
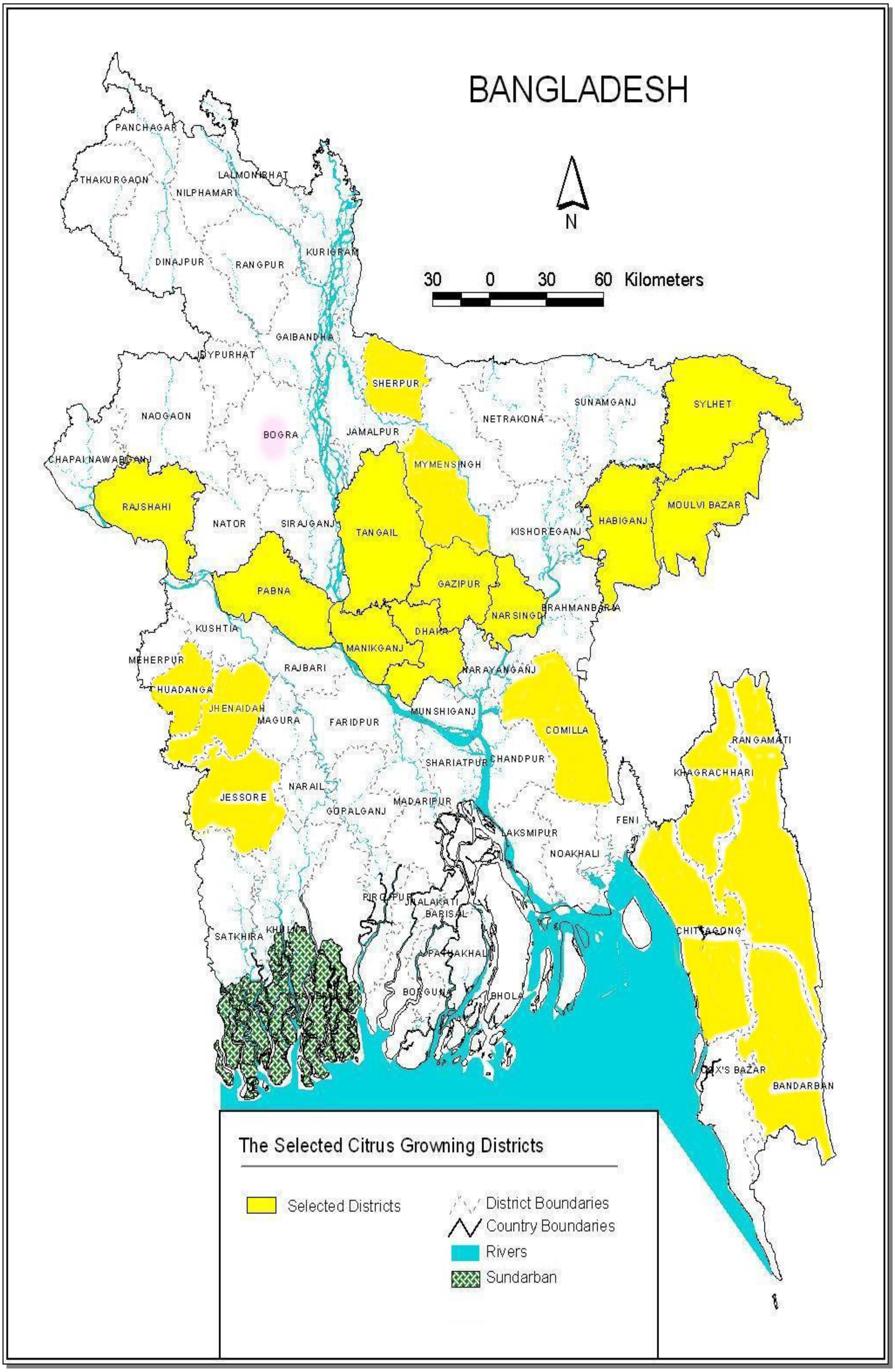


Figure-2: Map Showing the Selected 20 Districts of Citrus under Study



3.0 Pests and Diseases of Citrus in Bangladesh

The insect pests and diseases of citrus were studied by using published reports of BARI, other concerned organizations, scientific personnel and internet searching. A summary list of insect pests and diseases of citrus were prepared and discussed herein.

3.1 Crop-wise Insect Pests of Citrus

The recorded insect pests of nine citrus crops are shown in Table 2.

Table 5: Crop-wise Insect Pests of Citrus in Bangladesh

Sl. No.	Name of Crops	Name of insect pests	Scientific name	Status
01.	Lemon (*Citrus limon*) Elachi lebu, Colombo lebu	Lemon butterfly	*Papilio demoleus* L.	Major
		Lemon butterfly	*Papilio polytes* L.	Minor
		Citrus Leaf miner	*Phyllocnistis citrella* St.	Major
		Citrus red scale	*Aonidiella aurantii* Maskel	Minor
		Citrus yellow scale	*Aonidiella citrina* Coq.	Minor
		Citrus mealybug	*Pseudococcus filamentosus* Cockrell	Minor
		Citrus mealybug	*Planococcus citri* Risso	Minor
		Asian citrus psyllid	*Diaphornia citri* Kuwayana	Minor
		Black citrus aphid	*Toxoptera aurantii* Boyer de Fonscolombe	Minor
		Citrus blackfly	*Aleurocanthus woglumi* Ashby	Minor
		Citrus whitefly	*Dialeurodes citri* Ashmead	Minor
		Citrus leaf folder	*Psorosticha zizyphi* Stainton	Minor
		Bark and stem borer	*Indarbela quadrinotata* (Walker)	Minor
		Citrus stem borer	*Chelidonium cinctum* Guerin-Meneville	Minor
		Citrus thrips	*Scirtothrips dorsalis* Hood	Minor
		Termite	*Odontotermes obesus* Rambur	Minor
		Citrus red mite	*Panonychus citri* (McGregor)	Minor
02.	Lime (*Citrus aurantifolia*) Kagozi lebu	Lemon butterfly	*Papilio demoleus* L.	Major
		Lemon butterfly	*Papilio polytes* L.	Minor
		Citrus Leaf miner	*Phyllocnistis citrella* St.	Major
		Citrus red scale	*Aonidiella aurantii* Maskel	Minor
		Citrus yellow scale	*Aonidiella citrina* Coq.	Minor
		Citrus mealybug	*Pseudococcus filamentosus* Cockrell	Minor
		Citrus mealybug	*Planococcus citri* Risso	Minor
		Citrus mealybug	*Pseudococcus virgatus* Cockrell	Minor
		Asian citrus psyllid	*Diaphornia citri* Kuwayana	Minor
		Citrus blackfly	*Aleurocanthus woglumi* Ashby	Minor
		Citrus Leaf folder	*Psorosticha zizyphi* Stainton	Minor
		Bark and stem borer	*Indarbela quadrinotata* (Walker)	Minor
		Citrus thrips	*Scirtothrips dorsalis* Hood	Minor
		Termite	*Odontotermes obesus* Rambur	Minor
		Citrus red mite	*Panonychus citri* (McGregor)	Minor
		Lemon butterfly	*Papilio demoleus* L.	Minor

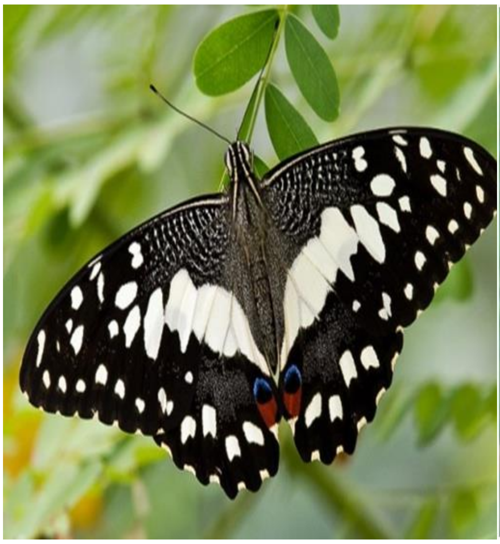
Sl. No.	Name of Crops	Name of insect pests	Scientific name	Status
03.	Mandarin (*Citrus reticulata)* Kamola	Lemon butterfly	*Papilio polytes* L.	Minor
		Citrus Leaf miner	*Phyllocnistis citrella* St.	Major
		Citrus red scale	*Aonidiella aurantii* Maskell	Minor
		Citrus yellow scale	*Aonidiella citrina* Coq.	Minor
		Citrus mealybug	*Pseudococcus filamentosus* Cockrell	Minor
		Citrus mealybug	*Planococcus citri* Risso	Minor
		Asian citrus psyllid	*Diaphornia citri* Kuwayana	Minor
		Oriental fruit fly	*Bactrocera dorsalis* Hendel	Major
		Black citrus aphid	*Toxoptera aurantii* Boyer de Fonscolombe	Minor
		Citrus blackfly	*Aleurocanthus woglumi* Ashby	Minor
		Citrus leaf folder	*Psorosticha zizyphi* Stainton	Minor
		Citrus bug	*Rhynchocoris humeralis* Thunberg	Minor
		Orange spined bug	*Biprorulus bibax* Breddin	Major
		Bark and stem borer	*Indarbela quadrinotata* (Walker)	Minor
		Citrus stem borer	*Chelidonium cinctum* Guerin-Meneville	Minor
		Citrus thrips	*Scirtothrips dorsalis* Hood	Minor
		Termite	*Odontotermes obesus* Rambur	Minor
		Citrus red mite	*Panonychus citri* (McGregor)	Minor
04.	Sweet orange (*Citrus sinensis*) Malta	Lemon butterfly	*Papilio demoleus* L.	Major
		Lemon butterfly	*Papilio polytes* L.	Minor
		Citrus Leaf miner	*Phyllocnistis citrella* St.	Major
		Citrus red scale	*Aonidiella aurantii* Maskell	Minor
		Citrus yellow scale	*Aonidiella citrina* Coq.	Minor
		Citrus mealybug	*Pseudococcus filamentosus* Cockrell	Minor
		Citrus mealybug	*Planococcus citri* Risso	Minor
		Asian citrus psyllid	*Diaphornia citri* Kuwayana	Minor
		Oriental fruit fly	*Bactrocera dorsalis* Hendel	Major
		Black citrus aphid	*Toxoptera aurantii* Boyer de Fonscolombe	Minor
		Citrus blackfly	*Aleurocanthus woglumi* Ashby	Minor
		Citrus leaf folder	*Psorosticha zizyphi* Stainton	Minor
		Orange spined bug	*Biprorulus bibax* Breddin	Major
		Bark and stem borer	*Indarbela quadrinotata* (Walker)	Minor
		Citrus stem borer	*Chelidonium cinctum* Guerin-Meneville	Minor
		Citrus thrips	*Scirtothrips dorsalis* Hood	Minor
		Termite	*Odontotermes obesus* Rambur	Minor
		Citrus red mite	*Panonychus citri* (McGregor)	Minor
05.	Pummelo (*C. maxima*) Batabi lebu	Lemon butterfly	*Papilio demoleus* L.	Major
		Lemon butterfly	*Papilio polytes* L.	Minor
		Citrus leaf miner	*Phyllocnistis citrella* St.	Major
		Citrus red scale	*Aonidiella aurantii* Maskell	Major
		Citrus yellow scale	*Aonidiella citrina* Coq	Minor
		Citrus mealybug	*Pseudococcus filamentosus* Cockrell	Major

Sl. No.	Name of Crops	Name of insect pests	Scientific name	Status
		Citrus mealybug	*Planococcus citri* Risso	Major
		Citrus mealybug	*Pseudococcus virgatus* Cockrell	Minor
		Asian citrus psyllid	*Diaphornia citri* Kuwayana	Minor
		Oriental fruit fly	*Bactrocera dorsalis* Hendel	Minor
		Citrus blackfly	*Aleurocanthus woglumi* Ashby	Minor
		Citrus leaf folder	*Psorosticha zizyphi* Stainton	Minor
		Bark and stem borer	*Indarbela quadrinotata* (Walker)	Minor
		Citrus stem borer	*Chelidonium cinctum* Guerin-Meneville	Minor
		Citrus thrips	*Scirtothrips dorsalis* Hood	Minor
		Termite	*Odontotermes obesus* Rambur	Minor
		Citrus red mite	*Panonychus citri* (McGregor)	Minor
06.	Citron (*C. jamhiri*) Jamir	Lemon butterfly	*Papilio demoleus* L.	Major
		Lemon butterfly	*P. polytes* L.	Minor
		Citrus leaf miner	*Phyllocnistis citrella* St.	Major
		Citrus red scale	*Aonidiella aurantii* Maskel	Minor
		Citrus yellow scale	*Aonidiella citrina* Coq.	Minor
		Citrus mealybug	*Pseudococcus filamentosus* Cockrell	Minor
		Citrus mealybug	*Planococcus citri Risso*	Minor
		Asian citrus psyllid	*Diaphornia citri* Kuwayana	Minor
		Citrus blackfly	*Aleurocanthus woglumi* Ashby	Minor
		Citrus leaf folder	*Psorosticha zizyphi* Stainton	Minor
		Citrus thrips	*Scirtothrips dorsalis* Hood	Minor
		Citrus red mite	*Panonychus citri* (McGregor)	Minor
07.	Satkara (*C. macroptera*)	Lemon butterfly	*Papilio demoleus* L.	Major
		Lemon butterfly	*P. polytes* L.	Minor
		Citrus leaf miner	*Phyllocnistis citrella* St.	Major
		Citrus red scale	*Aonidiella aurantii* Maskel	Minor
		Citrus yellow scale	*Aonidiella citrina* Coq.	Minor
		Citrus mealybug	*Pseudococcus filamentosus* Cockrell	Minor
		Asian citrus psyllid	*Diaphornia citri* Kuwayana	Minor
		Citrus blackfly	*Aleurocanthus woglumi* Ashby	Minor
		Citrus leaf folder	*Psorosticha zizyphi* Stainton	Minor
		Citrus thrips	*Scirtothrips dorsalis* Hood	Minor
		Citrus red mite	*Panonychus citri* (McGregor)	Minor
08.	Ada lebu *(C. assamensis*)	Lemon butterfly	*Papilio demoleus* L.	Major
		Lemon butterfly	*P. polytes* L.	Minor
		Citrus leaf miner	*Phyllocnistis citrella* St.	Major
		Citrus red scale	*Aonidiella aurantii* Maskel	Minor
		Citrus yellow scale	*Aonidiella citrina* Coq.	Minor
		Citrus mealybug	*Pseudococcus filamentosus* Cockrell	Minor
		Asian citrus psyllid	*Diaphornia citri* Kuwayana	Minor
		Citrus blackfly	*Aleurocanthus woglumi* Ashby	Minor
		Citrus leaf folder	*Psorosticha zizyphi* Stainton	Minor
		Citrus thrips	*Scirtothrips dorsalis* Hood	Minor
		Citrus red mite	*Panonychus citri* (McGregor)	Minor

Sl. No.	Name of Crops	Name of insect pests	Scientific name	Status
09.	Jara lebu (*C. pennivesiculata)*	Lemon butterfly	*Papilio demoleus* L.	Major
		Lemon butterfly	*P. polytes* L.	Minor
		Citrus leaf miner	*Phyllocnistis citrella* St.	Major
		Citrus red scale	*Aonidiella aurantii* Maskel	Minor
		Citrus yellow scale	*Aonidiella citrina* Coq.	Minor
		Citrus mealybug	*Pseudococcus filamentosus* Cockrell	Minor
		Asian citrus psyllid	*Diaphornia citri* Kuwayana	Minor
		Citrus blackfly	*Aleurocanthus woglumi* Ashby	Minor
		Citrus leaf folder	*Psorosticha zizyphi* Stainton	Minor
		Citrus thrips	*Scirtothrips dorsalis* Hood	Minor
		Citrus red mite	*Panonychus citri* (McGregor)	Minor

Table-2 shows the crop wise insect pests of citrus in Bangladesh. It is evident from the above two tables that a total number of nine different crops, namely lemon (elachi lebu), lime (kagozi lebu), mandarin (kamola), sweet orange (malta), pummelo (batabi lebu), jamir (citron), satkara, ada lebu and jara lebu and 21 different species of insect pests viz. two species of lemon butterfly, citrus leaf miner, citrus leaf folder/roller, black citrus aphid, citrus blackfly, citrus red scale, citrus yellow scale, two species of citrus mealybug, Asian citrus psyllid, oriental fruit fly, two species of orange bug, bark and stem borer, citrus stem borer, citrus thrips, termite and citrus red mite were found in this study. Among these pests lemon butterfly and citrus leaf miner are the major insect pests of all the citrus varieties while the others are minor. The incidence of *Papilio demoleus* species of lemon butterfly is more as compared to that of *Papilio polytes*. Similarly, oriental fruit fly, black citrus aphid and orange spined bug were found as major pests of mandarin and as compared to other varieties of citrus.

Figure-3: Photographs of Major Insect pests of Citrus



Lemon butterfly

Larva on leaf

Infested leaves

Leaf miner infested leaves

Infested fruit

Asian citrus psyllid nymphs infested twig

Red scale insect infested malta fruit

Citrus mealybug infested lime fruits

Fire ant and their nest on citrus

Fire ant infested citrus twig

Oriental fruit fly infested malta fruit

3.2 Diseases of Citrus

A number of diseases of different citrus fruits were compiled from different published reports. Lists of diseases of nine citrus fruits are shown in Table-3.

Table 6: Crop-wise Diseases of Citrus with Causal Organisms in Bangladesh

SL. No	Crop	Disease	Causal Organism	Status
01.	Lemon (*Citrus limon*) Elachi lebu	Die-back	*Colletotrichum gloeosporioide, Diplodia natalensis, Fusarium spp.*	Major
		Scab	*Elsinoe fawcetii* Bitancourt and Jenk.	Minor
		Canker	*Xanthomonas axonopodis* pv. *citri* (Hasse) Vauterin *et al.*	Major
		Tristeza	*Citrus tristeza virus*	Major
		Psorosis	Citrus psorosis virus	Minor
		Greening	*Candidatus Liberibacter asiaticus*	Minor
		Blue/Green mold	*Penicillium sp.*	Minor
		Damping-off	*Pythium* spp., *Rhizoctonia solani*	Minor
		Sooty mold	*Capnodium citricola*	Minor
		Melanose	*Diaporthe citri* F.A. Wolf	Minor
		Nematode	*Tylenchus semepenitrans, Pratylenchus* sp., *Radopholus similis*	Minor
02.	Lime (*Citrus aurantifolia*) Kagozi lebu	Die-back	*Colletotrichum gloeosporioide, Diplodia natalensis, Fusarium spp.*	Major
		Gummosis	*Phytophthora citrophthora*	Minor
		Canker	*Xanthomonas axonopodis* pv. *citri* (Hasse) Vauterin *et al.*	Major
		Greening	*Candidatus Liberibacter asiaticus*	Major
		Blue/Green mold	*Penicillium sp.*	Minor
		Scab	*Elsinoe fawcettii* Bitancourt and Jenk.	Minor
		Anthracnose	*Colletotrichum gloeosporioide*	Minor
		Sooty mold	*Capnodium citricola*	Minor
		Melanose	*Diaporthe citri* F.A. Wolf	Minor
		Nematode	*Tylenchus semepenitrans, Pratylenchus* sp., *Radopholus similis*	Minor
03.	Pummelo (*C. maxima*) Batabi lebu	Gummosis	*Phytophthora citrophthora*	Major
		Die-back	*Colletotrichum gloeosporioide, Diplodia natalensis, Fusarium spp.*	Major
		Anthracnose	*Colletotrichum gloeosporioide*	Minor
		Greening	*Candidatus Liberibacter asiaticus*	Major
		Tristeza	*Citrus tristeza virus*	Major
		Psorosis	Citrus psorosis virus	Minor
		Sooty mold	*Capnodium citricola*	Minor
		Nematode	*Tylenchus semepenitrans, Pratylenchus* sp., *Radopholus similis*	Minor
04.	Sweet orange (*Citrus sinensis)* Malta	Die-back	*Colletotrichum gloeosporioide, Diplodia natalensis, Fusarium spp.*	Major
		Gummosis	*Phytophthora citrophthora*	Minor
		Sooty mold	*Capnodium citricola*	Minor

SL. No	Crop	Disease	Causal Organism	Status
		Canker	*Xanthomonas axonopodis* pv. *citri* (Hasse) Vauterin *et al.*	Major
		Greening	*Candidatus Liberibacter asiaticus*	Minor
		Scab	*Elsinoe fawcetii* Bitancourt and Jenk.	Minor
		Blue/Green mold	*Penicillium sp.*	Minor
		Pink disease	*Botrybasidium salmonicolor*	Minor
		Nematode	*Tylenchus semepenitrans, Pratylenchus* sp., *Radopholus similis*	Minor
05.	Mandrin (*Citrus reticulata*) Kamola	Die-back	*Colletotrichum gloeosporioide, Diplodia natalensis, Fusarium spp.*	Major
		Gummosis	*Phytophthora citrophthora*	Minor
		Canker	*Xanthomonas axonopodis* pv. *citri* (Hasse) Vauterin *et al.*	Minor
		Blue/Green mold	*Penicillium sp.*	Minor
		Pink disease	*Botrybasidium salmonicolor*	Minor
		Greening	*Candidatus Liberibacter asiaticus*	Minor
		Melanose	*Diaporthe citri* F.A. Wolf	Minor
		Scab	*Elsinoe fawcetii* Bitancourt and Jenk.	Minor
		Damping-off	*Pythium* spp., *Rhizoctonia solani*	Minor
		Foam disease	Unknown	Minor
		Tristeza	*Citrus tristeza virus*	Major
		Psorosis	*Citrus psorosis virus*	Minor
		Nematode	*Tylenchus semepenitrans, Pratylenchus* sp., *Radopholus similes*	Minor
06.	Citron (*C. jamhiri*) Jamir	Die-back	*Colletotrichum gloeosporioide, Diplodia natalensis, Fusarium spp.*	Minor
		Gummosis	*Phytophthora citrophthora*	Minor
		Greening	*Candidatus Liberibacter asiaticus*	Minor
		Scab	*Elsinoe fawcetii Bitancourt and Jenk.*	Minor
		Sooty mold	*Capnodium citricola*	Minor
		Canker	*Xanthomonas axonopodis* pv. *citri* (Hasse) Vauterin *et al.*	Minor
		Nematode	*Tylenchus semepenitrans, Pratylenchus* sp., *Radopholus similes*	Minor
07.	Citron (*C. macroptera*) Satkara	Die-back	*Colletotrichum gloeosporioide, Diplodia natalensis, Fusarium spp.*	Major
		Scab	*Elsinoe fawcetii* Bitancourt and Jenk.	Minor
		Canker	*Xanthomonas axonopodis* pv. *citri* (Hasse) Vauterin *et al.*	Minor
		Nematode	*Tylenchus semepenitrans, Pratylenchus* sp., *Radopholus similes*	Minor
08.	Citron (*C. assamensis*) Ada lebu	Canker	*Xanthomonas axonopodis* pv. *citri* (Hasse) Vauterin *et al.*	Major
		Scab	*Elsinoe fawcetii* Bitancourt and Jenk.	Major

SL. No	Crop	Disease	Causal Organism	Status
		Gummosis	*Phytophthora citrophthora*	Minor
		Die-back	*Colletotrichum gloeosporioide, Diplodia natalensis, Fusarium spp.*	Major
		Greening	*Candidatus Liberibacter asiaticus*	Minor
		Sooty mold	*Capnodium citricola*	Minor
		Pink disease	*Botrybasidium salmonicolor*	Minor
		Nematode	*Tylenchus semepenitrans, Pratylenchus* sp., *Radopholus similes*	Minor
09.	Citron (*C. pennivesiculata*) Jara lebu	Canker	*Xanthomonas axonopodis* pv. *citri* (Hasse) Vauterin *et al.*	Major
		Die-back	*Colletotrichum gloeosporioide, Diplodia natalensis, Fusarium spp.*	Major
		Scab	*Elsinoe fawcetii* Bitancourt and Jenk.	Major
		Greening	*Candidatus Liberibacter asiaticus*	Minor
		Sooty mold	*Capnodium citricola*	Minor
		Gummosis	*Phytophthora citrophthora*	Major
		Pink disease	*Botrybasidium salmonicolor*	Minor
		Nematode	*Tylenchus semepenitrans, Pratylenchus* sp., *Radopholus similes*	Minor

The available diseases of nine citrus fruits with causal organism are presented in Table-3. The nine citrus fruits included lemon, lime, pummelo, mandarin, malta, jamir, satkara, ada lebu and jara lebu. Eleven diseases on lemon, 10 diseases on lime, 8 diseases on pummelo, 9 diseases on malta, 13 diseases on mandarin, 7 diseases on jamir, 4 diseases on satkara, 8 diseases on ada lebu and 8 diseases of jara lebu were recorded in Bangladesh. In general three diseases namely die-back, scab and canker were considered as major diseases for almost all citrus fruits, but in some cases, gummosis, greening and rot-knot were important and caused severe damages. The table also showed the causal organism of each disease. It is evident that fungal diseases were dominant, but other pathogens like bacteria, nematode and viruses also cause diseases to citrus fruits.

Figure-4: Photographs of Major Diseases of Citrus

Symptom of Canker disease of citrus on leaves, fruit and twigs

Symptom of Die-back disease

Symptom of Greening disease

Symptoms of Anthracnose disease

Symptom of Sooty mold disease

4.0 Quarantine Insect Pests and Diseases of Citrus

Quarantine pest means a pest of potential economic importance to the area endangered thereby and not yet present there, or present but not widely distributed and being officially controlled. Pests here included both insect pests and pathogens causing diseases to plants. The movement of plant materials from one area to other and/or from one country to another is a regular feature for crop improvement as well as crop production. There is every chance for the new plant materials to carry harmful insect pests and diseases to new area which may create serious damages to the crops. Thus every country has framed Quarantine Regulations to prevent the entry, establishment and spread of a foreign pest in the country through legal restrictions on the movement of plant and plant products. In this context the Govt. of Bangladesh has framed a rule as "Destructive Insects and Pests Rules-1966" which was amended in the year 1989. The same rule is again under further amendment covering updated requirements.

The existing insect pests and diseases of different crops especially citrus were collected from field survey, interviews with concerned personnel, various reports, books and journals available in the country. The pest problems of other countries of citrus were collected from CABI reports, books, journals and internet. The collected information of both in country and outside were analyzed, assessed and finally identified the major and destructive insect pests and diseases of citrus grown in Bangladesh. As quarantine pests play the key role in crop production, the quarantine insect pests and diseases of citrus are discussed herein.

4.1 Quarantine Insect Pests of Citrus for Bangladesh

The prevalence of 21 insect pests was recorded in Bangladesh but there was variation in infestation rate. Fifteen insect pests like brown citrus aphid, California citrus thrips, South African citrus thrips, African citrus psyllid, citrus snow scale, cottony cushion scale, Asian fruit fly, Mediterranean fruit fly, Asian papaya fruit fly, Queens land fruit fly, white spotted longicorn beetle, fruit sucking moth, southern fire ant, citrus gall wasp and Lewis spider mite were absent in Bangladesh while citrus whitefly, citrus black fly, citrus thrips, Asian citrus psyllid, bark and stem borer, citrus red scale, citrus yellow scale and citrus bug were present but with low infestation and little effect (Table 2). Thus 15 insect and mite pests such as brown citrus aphid, California citrus thrips, South African citrus thrips, African citrus psyllid, citrus snow scale, cottony cushion scale, Asian fruit fly, Mediterranean fruit fly, Asian papaya fruit fly, Queensland fruit fly, white spotted longicorn beetle, fruit sucking moth, southern fire ant, citrus gall wasp and Lewis spider mite are considered as quarantine insect pests for Bangladesh which are shown in Table 4.

Table 7: Quarantine Insect Pests of Citrus for Bangladesh

Sl. No.	Quarantine insect pests		Crops
	Common name	Scientific name	
01.	Brown citrus aphid	*Toxoptera citricida* Kirkaldy	All *Citrus* spp. and their hybrids
02.	California Citrus thrips	*Scirtothrips citri* Moulton	All *Citrus* spp. and their hybrids
03.	South African citrus thrips	*Scirtothrips aurantii* Faure	All *Citrus* spp. and their hybrids
04.	African citrus psyllid	*Trioza erytreae* (Del Guercio)	Lemon, lime, mandarin, pummelo, sweet orange, grape fruit
05.	Citrus snow scale	*Unaspis citri* (Comstock)	Lime, lemon, sour orange, Pummelo, sweet orange, grapefruit

06.	Cottony cushion scale	*Icerya purchasi* Maskell	All citrus and woody plants
07.	Asian fruit fly	*Bactrocera invadens* Drew, Tsuruta & White	Lemon, sweet orange, mandarin, pummelo, sour orange, grapefruit
08.	Mediterranean fruit fly/ Medfly	*Ceratitis capitata* (Wiedemann)	Lime, lemon, Pummelo, sweet orange, sour orange, mandarin
09.	Asian papaya fruit fly	*Bactrocera papayae* Drew and Hancock	Lime, lemon, Pummelo, mandarin
10.	Queensland fruit fly	*Bactrocera tryoni* (Froggatt)	Lime, lemon, mandarin, rough lemon
11.	Southern fire ant	*Solenopsis xyloni* McCook	All *Citrus* spp. and their hybrids
12.	White spotted longicorn beetle	*Anoplophora chinensis* (Forster)	Pummelo, sour orange, sweet orange
13.	Fruit sucking moth	*Ophideres materna* Cramer	Mandarin, lemon, orange
14.	Citrus gall wasp	*Bruchophagus fellis* (Girault)	Lemon, orange, , rough lemon
15.	Lewis spider mite	*Eotetranychus lewisi (*McGregor)	*Citrus* spp.

See section 9.1 to 9.15 in risk analysis of potential hazards for more detail.

4.2 Quarantine Diseases of Citrus for Bangladesh

The bacteria of Huanglongbing or Greening disease reported to have three different strains viz., Asiatic, African and American strain. Asiatic strain of the bacteria is present in most of the Asian countries including Bangladesh. African strain is present in most of the African countries and also in Soudi Arabia and Yeamen. On the other hand, American form has limited distribution and reported from Brazil only. This disease is reported to occur on most of the citrus species and their hybrids, among these sweet orange, mandarin and tangelos are highly susceptible. The vector asian psyllid (*Diaphorina citri*) is present in Bangladesh which can equally transmit the African strain of the pathogen. There are chances of introducing the new strains in Bangladesh and cause devastating damage to the citrus crops. Therefore, African strain of Greening disease is considered as a quarantine pest for Bangladesh. Among other major diseases citrus variegated chlorosis, stubborn, leprosies, Indian citrus ringspot, Citrus chlorotic dwarf virus, Bacterial spot, Black spot, citrus blight, and mal secco are absent in Bangladesh. These diseases cause serious damage in different countries like Algeria, Argentina, Arizona, Australia, Brazil, China, Costa Rica, Cyprus, Egypt, India, Israel, Jordan, Libya, Mexico, Morocco, Pakistan, USA, etc. Citrus fruits are imported to Bangladesh from some of these countries. However, some of the diseases are not carried by the fruits. Seven diseases such as greening, stubborn, black spot, pseudocercospora spot mal secco, leprosis, and Indian citrus ringspot could be introduced through plants and planting materials and are considered as quarantine diseases of citrus for Bangladesh. A list of quarantine diseases for Bangladesh with causal pathogens is shown in Table 5.

Table 8: Quarantine Diseases of Citrus for Bangladesh

Sl. No.	Quarantine Diseases	Crops (Prohibited articles)
01.	Greening (African greening of citrus - *Candidatus Liberibacter africanus* (African form)	Entire or any part of the following living plants (excluding flowers, fruits, and seeds)： (1) *Calodendrum capense* (2) *Catharanthus roseus* (3) *Citrus* spp. (4) *Fortunella* spp. (5) *Poncirus* spp.
02.	Stubborn (*Spiroplasma citri*)	Entire or any part of living citrus plants, citrus fruit or cuttings
03.	Black spot (*Phyllosticta citricarpa* Teleomorph: *Guignardia citricarpa*)	Entire or any part of the following living plants (excluding flowers, fruits, and seeds)：all citrus species
04.	Mal Secco (*Phoma tracheiphila*)	Entire or any part of living citrus plants (lemon, and citron (*C. medica* L.), lime (*C. latifolia* Tan.), and bergamot (*C. bergamia* Risso)
05.	Pseudocercospora spot (*Pseudocercospora angolensis*)	Entire or any part of living citrus plants, citrus fruit or cuttings: Grapefruit, lemon, lime, orange, pummelo, and mandarin.
06.	Leprosis (Citrus leprosis virus)	Entire or any part of living citrus plants (Mexican lime, sour orange, rough lemon, Persian lime, lemon, citron, mandarins, mandarin hybrids, sweet oranges and grapefruits.)
07.	Indian citrus ringspot (*Indian citrus ringspot virus*)	Entire or any part of living citrus plants

See section 9.16 to 9.22 in risk analysis of potential hazards for more detail.

5.0 Risk Analysis for Citrus in Bangladesh

5.1 Background

Bangladesh has been importing fresh citrus fruits from Bhutan, Brazil, China, Egypt, India, Pakistan, South Africa and USA without assessing the potential risk of introduction of any exotic pests and diseases to Bangladesh. Recently, Plant Quarantine Wing, Department of Agricultural Extension felt that an analysis of the biosecurity risks of citrus pests is required. Hence the present activities were taken up. Here pests are referred to insect pests and diseases of citrus.

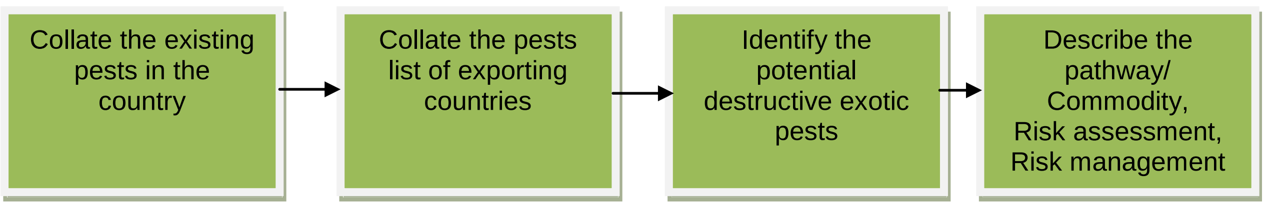
5.2 Scope of the Risk Analysis

The scope of this risk analysis is to ascertain the potential hazard organisms or diseases associated with fresh fruit of *Citrus* species imported from the countries mentioned above. Risk in this context is defined as the likelihood of the occurrence and the likely magnitude of the consequences of an effect. For the purposes of this analysis "fresh fruit" means the fruit complete with skin, flesh and seed, without attached stems or leaves. The calyx is exempt from this definition as removing this part would often deteriorate the fruit quality. It introduces the three stages of pest risk analysis – initiation, pest risk assessment and pest risk management. The standard focuses on the initiation stage. Generic issues of information gathering, documentation, risk communication, uncertainty and consistency are addressed.

5.3 Risk Analysis Process and Methodology

The process and methodology for undertaking import risk analyses are shown in Figure 5.

Figure 5: A Flow Diagram of the Risk Analysis Process.



Data on insect pests and diseases were collected through field survey of 6000 orchards or plants in the homesteads in 60 upazilas under 20 districts (Appendix I) of the country considered as PRA area and interviewing of 6000 farmers. The major citrus fruits and varieties grown in Bangladesh are presented in Appendix II. The recorded insect pests and diseases of citrus from field survey of major citrus growing areas in Bangladesh are shown in Appendix IV and V, respectively. Besides, information was collected from available publications, interview with DAE officials and researchers. World pest situation in citrus were collected from published papers and internet resources. List of insect pests and diseases in different citrus species are shown in Appendix X and XI, respectively. Through critical analysis of the collected data the potential hazards were identified.

5.4 Commodity and Pathway Description

The first step in the risk analysis process is to describe the commodity and entry pathway of the commodity. This includes relevant information on:

- The country of origin, including characteristics like climate, relevant agricultural practices, phytosanitary system;
- Pre-export processing and transport systems;
- Export and transit conditions, including packaging, mode and method of shipping;
- Nature and method of transport and storage on arrival in Bangladesh;

- Characteristics of Bangladesh climate, and relevant agricultural practices.

This information provides context for the assessment of the potential hazard organisms.

5.5 Hazard Identification

For any risk assessment the first step is to identify the hazard as the risk is related to hazard. Hazards are the unwanted organisms or diseases (pathogen) which could be introduced into Bangladesh by risk goods, and are potentially capable of causing harm to citrus production, must be identified. This process begins with the collation of a list of organisms that might be associated with the commodity in the country of origin. Such list is compared with the existing pests present in Bangladesh to prepare a list of exotic pests harmful for Bangladesh if introduce.

This list is further refined and species removed or added to the list depending on the strength of the association and the information available about its biology and life cycle. Each pest or pathogen is assessed mainly on its biological characteristics and its likely interaction with the Bangladesh environment and climate. Hitch-hiker organisms sometimes associated with a commodity, but which do not feed on it or specifically depend on that commodity in some other way are also included in the analysis. This is because there may be economic, environmental and human health consequences of these organisms entering and/or establishing. The diagrammatic representation of hazard identification is shown in figure 6.

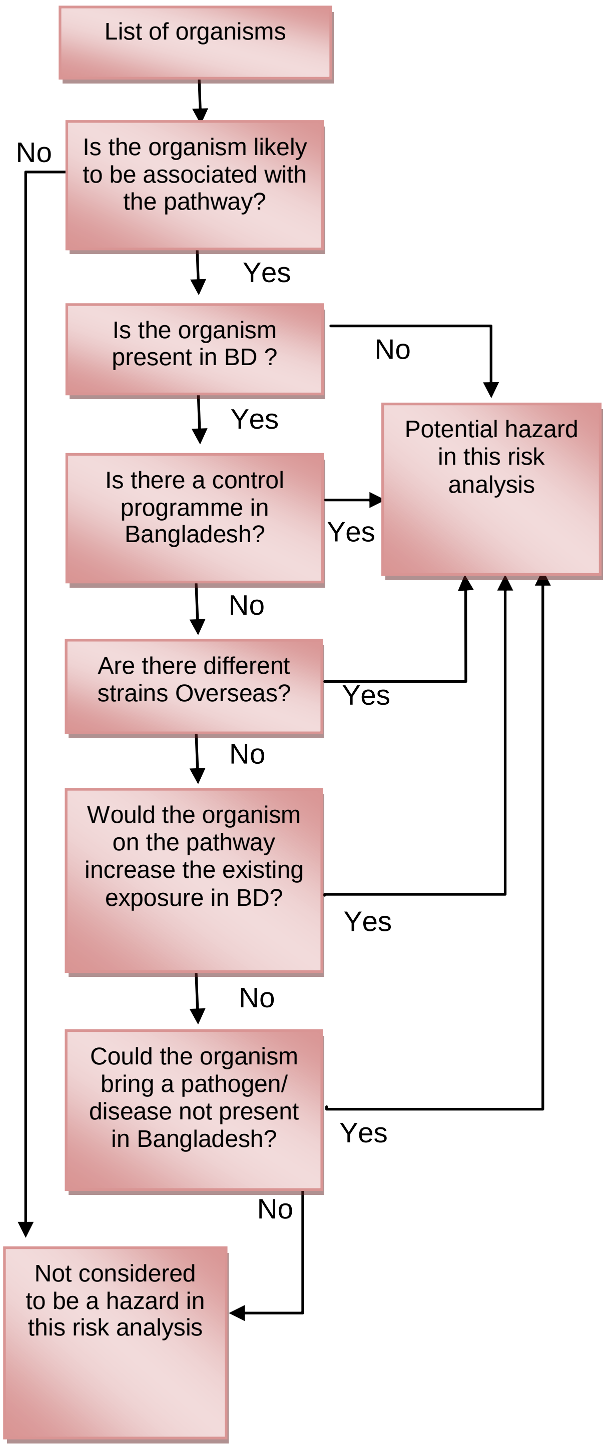
5.6 Risk Assessment of Potential Hazards

Risk assessment is the evaluation of the likelihood of entry, exposure and establishment of a potential hazard, and the environmental, economic, human and animal health consequences of the entry within Bangladesh. The aim of risk assessment is to identify hazards which present an unacceptable level of risk, for which risk management measures are required. Descriptors are used in assessing the likelihood of entry, exposure and establishment, and the economic, environmental, social and human health consequences. The approach taken in this Risk Analysis is to assume the commodity is imported without any risk management. In this risk analysis hazards have been grouped where appropriate to avoid unnecessary duplication of effort in the assessment stage of the project.

5.7 Assessment of Uncertainties

The purpose of this section is to summarize the uncertainties and assumptions identified during the preceding hazard identification and risk assessment stages. An analysis of these uncertainties and assumptions can then be completed to identify which are critical to the outcomes of the risk analysis. Critical uncertainties or assumptions are considered for further research with the aim of reducing uncertainty or removing the assumption. Where there is significant uncertainty in the estimated risk, a precautionary approach to managing risk may be adopted. In these circumstances the measures should be consistent with other measures where equivalent uncertainties exist and be reviewed as soon as additional information becomes available.

Figure 6. Diagrammatic Representation of hazard identification.



5.8 Analysis of Measures to Mitigate Biosecurity Risks

Risk management in the context of risk analysis is the process of identifying measures to effectively manage the risks posed by the hazard(s) associated with the commodity or organisms under consideration.

Since zero-risk is not a reasonable option, the guiding principle for risk management should be to manage risk to achieve the required level of protection that can be justified and is feasible within the limits of available options and resources. Risk management identifies ways to react to a risk, evaluating the efficacy of these actions, and presenting the most appropriate options.

The uncertainty noted in the assessments of economic consequences and probability of introduction should also be considered and included in the consideration of risk management options. Where there is significant uncertainty, a precautionary approach may be adopted. However, the measures selected must nevertheless be based on a risk assessment that takes account of the available scientific information. In these circumstances the measures should be reviewed as soon as additional information becomes available. It is not acceptable to simply conclude that, because there is significant uncertainty, measures will be selected on the basis of a precautionary approach. The rationale for selecting measures must be made apparent.

Each hazard or group of hazards will be dealt with separately using the following framework:

5.9 Risk Evaluation

If the risk estimate determined in the risk assessment is significant, measures can be justified.

5.10 Option Evaluation

Measures that are expected to be effective against the hazard species are considered. A package of risk management measures is likely to be required to address the risk from all identified hazards. While there are currently eight established pathways (Bhutan, Brazil, China, Egypt, India, Pakistan, South Africa and USA) for fresh *Citrus* fruit coming into Bangladesh, border interception for these pathways cannot be extrapolated to predict any possible level of slippage or efficacy of treatments. However border interceptions can be used as evidence of hazard organism association with the commodity. Each new pathway must be regarded as unique, given differing pre and post harvest practices and treatment measures. Different pest species are associated with each pathway and measures therefore must be tailored to the individual organisms.

5.11 Review and Consultation

Peer review is a fundamental component of a risk analysis to ensure it is based on the most up-to-date and credible information available. Each analysis must be submitted to a peer review process involving appropriate staff within those government departments with applicable biosecurity responsibilities, plus recognized and relevant experts from Bangladesh. The critique provided by the reviewers where appropriate, is incorporated into the analysis. If suggestions arising from the critique were not adopted the rationale must be fully explained and documented.

6.0 Import Risk Analysis

This chapter provides information on the commodity that is relevant to the analysis of biosecurity risks and common to all organisms or diseases potentially associated with the commodity. It also provides information on climate and geography of Bangladesh for assessing the likelihood of establishment and spread of potential hazard organisms.

Commodity Description

In this risk analysis fresh *Citrus* species from Bhutan, Brazil, China, Egypt, India, Pakistan, South Africa and USA is defined as the harvested individual fresh fruits of:

- *C. reticulata* Blanco (orange, mandarin/tangerine);
- *C. sinensis* (L.) Osbeck (sweet orange, malta); and

with all vegetative parts removed and that have been cultivated, harvested, packed and transported to Bangladesh.

A. Genus Description

Citrus is a genus of flowering shrubs in the Rutaceae family (Class: Magnoliopsida, Order: Sapindales). *Citrus* are evergreen shrubs or small trees, between 5-15m tall, often with sharp spines on the stems. The genus *Citrus* includes several species such as sweet orange (*Citrus sinensis*), mandarin (*Citrus reticulata)* lemon (*Citrus limon*), lime (*Citrus aurantifolia*), grapefruit (*Citrus paradisi*), pummelo (*Citrus grandis*) including different varieties and hybrids. Most *Citrus* cultivars are self-pollinated, some are parthenocarpic. Generally only tangerines and their hybrids require cross-pollination. *Citrus* can hybridize easily and to avoid the long juvenile period most commercially grown cultivars are grafted onto hardy, disease resistant rootstock.

Citrus is in cultivation either commercially or in home gardens roughly between 55°N and 55°S worldwide. Most perform best in fertile, well drained soil in a consistently sunny, humid environment, ideally subtropical climate. Typically they are not frost hardy although they can withstand short periods just below freezing. Climate affects the appearance and taste of the fruit. For instance in Mediterranean climates the peel is thicker, rougher and has a better color; the acid content is higher and sugar content lower; and on tree storage better than in subtropical climates. Subtropical climates produce fruit with a higher sugar and juice content.

All *Citrus* requires a long period to ripe (over 5-18 months) depending on the variety and growing conditions and are slow to abscise from the tree. Lemons and limes bloom throughout the year in warm, wet climates, and oranges and grapefruit may bloom several times a year in tropical climates with no cool periods or well defined dry season.

B. Species Description

Citrus reticulata Blanco – mandarin/tangerine
Synonyms: *C. tangerine.*
Common names: mandarin, mandarin orange, tangerine, naranjo mandarina, santara, mandarinier, mikan.

Citrus reticulata is native to the Philippines and Southeast Asia. It is predominantly grown in Japan, India, southern China, and the East Indies. The height of mandarin tree is generally 3-4m but very old mandarin trees may reach 7.5m. It is a sub-tropical evergreen tree. The fruit is oblate. When ripe the peel is bright orange and easily removed. The pulp is a rich orange colour. *Citrus reticulata* grow in well drained soil, are reasonably drought and cold tolerant, although fruit are sensitive to the latter. Most mandarins will bear fruit twice in the year.

Citrus sinensis (L.) Osbeck – Sweet orange (Malta)

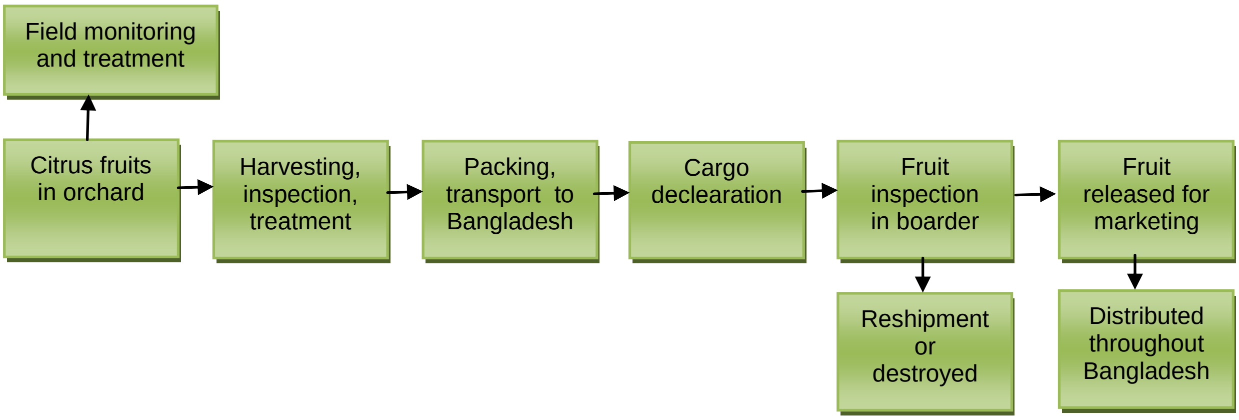
Synonyms: *C. aurantium* var. *sinensis* L., *C. macrantha* Hassk., *C. aurantium sinensis*.
Common names: navel orange, Valencia orange, sweet orange, naranja, sanguine, oranger doux, laranjeira, Apfelsine, Orangebaum, arancio dolce, moli ‘aina, narang.

Sweet Orange is probably native to southeastern Asia, in northeastern India or, more likely, in southern China and Indo-China. It has been so widely cultivated for so long that it is no longer known in a truly wild condition. Sweet orange is a medium-sized tree reach 6-15m in height with a rounded top and regular branches; twigs are angled when young, usually with slender, somewhat flexible, rather blunt spines in the axils of the leaves; leaves medium-sized, pointed at the apex, rounded at the base; petioles narrowly winged, articulated both with the twig at the base and with the leaf blade at the tip; flowers in small racemes or singly in the axils of the leaves, medium-sized with 5 petals and 20-25 stamens. Fruits are subglobose, oval or flattened globose, 4-12cm diameter with a greenish-yellow to bright orange glandular peel; peel thin, tight, not bitter, central axis (pith) solid. The fruit mature 6-9 months after bloom. In suitable conditions some sweet oranges produce flowers and fruit almost throughout the year. A tree may bear buds, flowers and ripe fruit at the same time. Usually the main flowering season is in the spring and the main harvesting period begins in late autumn - early winter for the early varieties and continues until end of spring - early summer for the late varieties. The sweet oranges can be divided into four main groups: Blonde and early sweet varieties, Valencia oranges (late juicy varieties), Navel oranges and Blood oranges. Sweet oranges prefer subtropical rather than tropical climates and well drained soils, with a defined change in seasons to encourage flowering. In the heat of the tropics the fruit remain green even when fully ripe. Although excellent in quality, due to the lack of cooler nights the fruit do not develop an orange colour in the rind. In the tropics producers treat the fruit with gas to change the colour of the rind, making it more appealing to the consumer. Especially the lower temperatures of late autumn and early winter help to deepen the colour of the rind. The darker the desired colour the cooler the nights must be. Blood oranges thrive where nights are coolest but without frost. The sweet orange is highly intolerant of freezing temperatures.

6.1 Description of Proposed Import Pathway

For the purpose of this risk analysis *Citrus* fruit are presumed to be from anywhere in Bhutan, Brazil, China, Egypt, India, Pakistan, South Africa and USA. Fruits are/ would be sea or air freighted or terrestrial to Bangladesh through any of the two Sea port-Chittagong and Mongla; three Air ports-Hazrat Shahajalal International Air port, Dhaka and Shah Amanat International Air port, Chittagong; Osmani International Air port, Sylhet; or through any of the 18 Land ports namely Darsana, Chuadanga; Benapole, Jessore; Sonamoszid, C. Nawabganj; Hili, Dinajpur; Burimari, Lalmonirhat; Tamabil, Sylhet; Bhomra, Satkhira; Rohonpur, C. Nawabgonj; Zakiganj, Sylhet; Birol,Dinajpur; Banglabandha, Panchagarh; ICD kamlapur, Dhaka; Kamalpur, Jamalpur; Belunia, Feni; Betuli, Moulvibazar; Chatlapur, Moulvibazar; Haluaghat, Mymensingh or through one River port, Narayanganj. However, it should be specified through which port the commodity would be imported. In the port of entry after Biosecurity checking if found risk free clearance would be given for distribut to any fruit markets, supermarkets, shops or street market throughout the country for sale and consumption. Diagrammatic representation of import pathways of citrus is shown in figure 7.

Figure 7: Linear Diagram of Import Pathway of Citrus



Growers intend to export their citrus fruits should be enrolled with the plant protection department of their respective countries and need to specify the location of the garden, number of trees in the garden, frequent monitoring for the occurrence of pest and diseases and record the measures taken for pest management. This information must be made available to the Govt. inspectors on demand. The harvesting of the fruit will be done by hand being twisted off the tree. Fruit on the ground will not be collected because of the likely damage and increased fungal infection that can occur. *Citrus* fruit for export will be transported from orchard to pack house with minimal delay to reduce losses from fungal infection. Fruit will be graded to select unblemished, undamaged, export quality fruit.

Pack houses wishing to pack and export *Citrus* fruit to Bangladesh will be approved and licensed by the PPQ of the country of origin. In the packing house necessary grading and sorting should be done and also need to be inspected by a completent quarantine inspector for any quarantine pests. When all the requirements are met necessary washing, waxing and packing to be done for shipment to Bangladesh.

The consignment must accompanies appropriate certification, e.g. a phytosanitary certificate attesting to the identity of the fruit, any treatments completed, or other information required helping mitigate risks. Fruit is examined at the border to ensure compliance if any fruit not complying with Bangladesh's biosecurity requirements (e.g. found harboring any quarantine pest) are either treated, re-shipped or destroyed. Consignment met all the requirements will be released for distribution throughout the country.

6.2 Geography, Climate Pest Control and Pre-Export Handling in Country of Origin

6.2.1 Bhutan

Geography and climate: Bhutan is located in the southern slopes of the eastern Himalayas. It covers an area of 38,394 square kilometers. Geographic coordinates of Bhutan is $27^0$30 N, $90^0$30 E. The country has 1,136 km land boundaries with China and India. Agriculture is the main foundation of the Bhutanese economy. It provides the livelihood base for 69% of Bhutan's total population. Agricultural production accounts for 21.4% of the GDP of Bhutan, while horticulture accounts for approximately 13% of agriculture. Citrus is the most important horticultural crop in terms of area and production. In Bhutan mandarin orange represents over 95% of Citrus fruits. The annual production of citrus is 72,071 ton of which orange is exported to India and Bangladesh. The Climate varies from tropical in southern plains; cool winters and hot summers in central valleys; severe winters and cool summers in Himalayan side. The major citrus growing districts are located in the subtropical southern regions of the country. Citrus (mainly mandarin) grows well in warm and humid climates where the average annual temperature is above 15C, the frost season is less than 115 days, and the average annual rainfall is over 1,000 mm. Fruits harvested from November to January with a peak in December.

Pest and disease control: The major insect pests of citrus in Bhutan lemon butterfly (*Papilio demoleus* L.), oriental fruit fly (*Bactrocera dorsalis* Hendel), trunk borer (*Anoplophora chinensis* (Forster)*)*, orange spined bug (*Biprorulus bibax* Breddin), Citrus green stink bug (Thunberg) and citrus leaf miner *(Phyllocnistis citrella* Stainton) (Table 6). Among the diseases the major are Huanglongbing (HLB) or citrus greening (*Candidatus Liberibacter asiaticus*), black spot (*Guignardia citricarpa*), scab *(Elsinoe fawcetii),* powdery mildew (*Acrosporium tingitaninum*) (Table 14). There is no official pest control program. However, IPM method for controlling fruit fly have been developed and after getting training citrus farmers are adopted this technology.

Pre-export handling: Regarding post harvest handling and processing for export no information was available.

Table 6. List of Important Insect Pests Citrus in Bhutan

Sl. No.	Common name	Scientific name	Order: Family
01.	Lemon butterfly	*Papilio demoleus* L.	Lepidoptera: Papilionidae
02.	Lemon butterfly (Swallowtail butterfly)	*Papilio polytes* L.	Lepidoptera: Papilionidae
03.	Citrus leaf miner	*Phyllocnistis citrella* Stainton	Lepidoptera: Gracilleridae
04.	Citrus leaf folder/roller	*Psorosticha zizyphi* Stainton	Lepidoptera: Oecophoridae
05.	Black citrus aphid	*Toxoptera aurantii* Boyer de Fonscolambe	Homoptera: Aphididae
06.	Brown citrus aphid	*Toxoptera citricida Kirkaldy*	Homoptera: Aphididae
07.	Citrus whitefly	*Dialeurodes citri* Ashmead	Homoptera: Aleyrodidae
08.	Citrus blackfly	*Aleurocanthus woglumi* Ashby	Homoptera: Aleyrodidae
09.	Citrus thrips	*Scirtothrips dorsalis* Hood	Thysanoptera: Thripidae
10.	Asian citrus psyllid	*Diaphornia citri* Kuwayana	Homoptera: Psyllidae
11.	Citrus mealybug	*Plannococcus citri* Risso	Homoptera: Pseudococcidae
12.	Citrus red scale	*Aonidiella aurantii* Maskell	Hemiptera: Diaspididae
13.	Citrus yellow scale	*Aonidiella citrina* Coq.	Hemiptera: Diaspididae
14.	Oriental fruit fly	*Bactrocera dorsalis* Hendel	Diptera: Tephritidae
15.	Asian fruit fly	*Bactrocera invadens* Drew, Tsuruta & White	Diptera: Tephritidae
16.	Citrus bug	*Rhynchocoris humeralis* Thunberg	Hemiptera: Pentatomidae
17.	Orange spined bug	*Biprorulus bibax* Breddin	Hemiptera: Pentatomidae
18.	White spotted longicorn beetle	*Anoplophora chinensis* (Forster)	Coleoptera: Cerambycidae
19.	Bark and stem borer/ Bark eating caterpillar	*Indarbela quadrinotata* (Walker)	Lepidoptera: Metarbelidae
20.	Citrus stem borer	*Chelidonium cinctum* Guerin-Meneville	Coleoptera: Cerambycidae
21.	Red imported fire ant (RIFA)	*Solenopsis invicta* Buren	Hymenoptera: Formicidae
22.	Citrus red mite	*Panonychus citri* (McGregor)	Acarina: Tetranychidae
23.	Citrus brown mite	*Eutetranychus orientalis* (Klein)	Acarina: Tetranychidae

6.2.2 Brazil

Geography and climate: Brazil is the largest nation of South America and the third largest country in continuous area in the world. Its length from north to south is 4,320 km, its width is 4,328 km and the area is 8,511,965 km2, of which over 700 million hectares are suitable for agriculture. The geographical position is $10^0$00 S, $55^0$00 W. Bordering countries are Argentina, Bolivia, Colombia, French Guiana, Guyana, Paraguay, Peru, Suriname, Uruguay. Brazil shows a great variation of climates and soil types with a nearly unlimited potential for agricultural enterprises. Citrus trees are grown everywhere in Brazil, except south of the state of Rio Grande do SuI because of freeze damage. The major commercial citrus-producing area in Sao Paulo is situated on the interior plateau within a wide belt about 300 km long and 100 km wide that extends from around Campinasto Barretos with the largest concentrations of orchards being located around Limeira, Araras, Araraquara, Matao and Bebedouro. Brazil is considered as the world leader for orange production. The total annual citrus production in 2010-11 was 22,704,500 mt. The climate of the state of Sao Paulo is extremely favorable for citrus production. Total area under citrus was 915056 hectare during 2007 of which 87% was orange.

Most of Brazil lies in the tropics. The coastal cities of Rio de Janeiro, Recife and Salvador can get extremely hot, plateau cities such as São Paulo, Brasília and Belo Horizonte have mild climates, and the southern cities of Porto Alegre and Curitiba have mild winters, but Curitiba has a warm summer due to the average elevation of 934.6 meters (3,066 ft), Porto Alegre has a hot summer, with an average elevation of only 10 meters (33 ft).

In Brazil the official record of minimum and maximum temperatures are -14 °C and 44.7 °C. In Amazon the annual average temperature is 22 to 26 °C with more than 2000 mm rainfall. Along the Atlantic coast, average temperatures range from 23 to 27 °C. In northeast, temperatures of more than 38 °C are frequently recorded during the dry season between May and November. Inland, on higher ground, temperatures are from 18 to 21 °C. South of Rio the seasons are more defined and the annual average falling between 17 and 19 °C. In São Paulo the average monthly maximum temperature ranged from 23-29°C and the average minimum from 13-20°C. Lower temperature during May to September. Average monthly rainfall is lowest in June (26.5 mm) and highest in January (205.6 mm).

Pests and disease control: Fruit flies (*Ceratitis capitata* (Wiedemann)) cause the greatest losses to the citrus industry. Other pests of importance are mitee, scales and the black citrus aphid (*Toxoptera aurantii* Boyer de Fonscolambe) (Table 7). Sprays are generally used for fruit fly control but much less frequently for other pests. Important fungus disease includes footrot, pink disease and sweet orange scab. Citrus canker, a bacterial disease is present in Brazil in a limited area, outside the commercial citrus regions and subjected to an intensive eradication program since 1957 (Table 14). Virus diseases except for tristeza are no longer problems of great importance in the Sao Paulo citrus industry as a result of the extensive use of healthy nucellar clones. Tristeza stem pitting affects the growth and reduces yields of several varieties like Pera orange, Mexican lime, grapefruit and citron. To overcome the problem, certain clones of Pera orange and Mexican lime that are now being planted, are pre-inoculated with mild tristeza strains for protection against severe strains in the field.

Pre-export handling: After harvesting citrus fruits are bring to the packinghouse in plastic crates, pre-wash with sodium hypochlorite at 200 mg L^{-1} active chlorine and neutral detergent; degreening with ethylene at 1-5 µL L^{-1} (from three to five days); another washing with sodium hypochlorite and detergent and application of wax + thiabendazole and imazalil fungicides, both at 1000 mg L^{-1}); packed in cartons (19 kg) on pallets.

Table 7. List of Important Insect Pests Citrus in Brazil

Sl. No.	Common name	Scientific name	Order: Family
01.	Lemon butterfly	*Papilio demoleus* L.	Lepidoptera: Papilionidae
02.	Lemon butterfly (Swallowtail butterfly)	*Papilio polytes* L.	Lepidoptera: Papilionidae
03.	Citrus leaf miner	*Phyllocnistis citrella* Stainton	Lepidoptera: Gracilleridae
04.	Citrus leaf folder/roller	*Psorosticha zizyphi* Stainton	Lepidoptera: Oecophoridae
05.	Black citrus aphid	*Toxoptera aurantii* Boyer de Fonscolambe	Homoptera: Aphididae
06.	Brown citrus aphid	*Toxoptera citricida Kirkaldy*	Homoptera: Aphididae
07.	Citrus whitefly	*Dialeurodes citri* Ashmead	Homoptera: Aleyrodidae
08.	Citrus blackfly	*Aleurocanthus woglumi* Ashby	Homoptera: Aleyrodidae
09.	Citrus thrips	*Scirtothrips dorsalis* Hood	Thysanoptera: Thripidae
10.	Asian citrus psyllid	*Diaphornia citri* Kuwayana	Homoptera: Psyllidae
11.	Citrus mealybug	*Plannococcus citri* Risso	Homoptera: Pseudococcidae
12.	Comstock mealybug	*Pseudococcus comstocki* Kuwana	Homoptera: Pseudococcidae
13.	Citrus red scale	*Aonidiella aurantii* Maskell	Hemiptera: Diaspididae
14.	Citrus yellow scale	*Aonidiella citrina* Coq.	Hemiptera: Diaspididae
15.	Cottony cushion scale	*Icerya purchase* Maskell	Hemiptera: Margarodidae
16.	Mediterranean fruit fly/ Medfly	*Ceratitis capitata* (Wiedemann)	Diptera: Tephritidae
17.	Red imported fire ant (RIFA)	*Solenopsis invicta* Buren	Hymenoptera: Formicidae
18.	Citrus red mite	*Panonychus citri* (McGregor)	Acarina: Tetranychidae
19.	Citrus brown mite	*Eutetranychus orientalis* (Klein)	Acarina: Tetranychidae
20.	Lewis spider mite	*Eotetranychus lewisi (*McGregor)	Acarina: Tetranychidae

6.2.3 China

Geography and climate: China is located in Eastern Asia at 35^0 00 N, 105^0 00 E, bordering the East China Sea, Korea Bay, Yellow Sea, and South China Sea, between North Korea and Vietnam. Total Area is 9,596,960 sq km. border countries**:** Afghanistan, Bhutan, Burma, India, Kazakhstan, North Korea, Kyrgyzstan, Laos, Mongolia, Nepal, Pakistan, Russia (northeast), Russia (northwest), Tajikistan, Vietnam; regional borders**:** Hong Kong, Macau. China is the world leader in gross value of agricultural output; rice, wheat, potatoes, corn, peanuts, tea, millet, barley, apples, cotton, oilseed; pork; fish and citrus. China could be divided into six administrative regions, namely North, North-east, East, Central-south, South-west and North-west China. Citrus is produced mostly in East China, Central and South-China and some in North-West China. The total annual citrus production in 2010-11 was 23,850,000 mt.

China has a great diversity of climates. The northeast experiences hot and dry summers and bitterly cold harsh winters, with temperatures known to reach as low as -20°C. The north and central region has almost continual rainfall, temperate summers reaching 26°C and cool winters when temperatures reach 0°C. The southeast region has substantial rainfall, and humid, with semi-tropical summer. Temperatures have been known to reach over 40°C although this is highly unusual, but during summer temperatures over 30°C are the norm. Winters are mild, with lows of around 10°C in January and February.

Pest and disease control: Major insect pests of China include lemon butter fly, leaf miner, psyllid, thrips, brown mite, red mite etc. (Table 8) and among the diseases the major concern are HBL or citrus greening, canker, citrus tatter leaf and black spot (Table 14). For effective pest control IPM is following and it was noted that incorporation of petroleum spray oil into citrus IPM programs provides an effective or better control of most major citrus pests than control programs based on broad-spectrum synthetic pesticides. Populations of natural enemies are also better conserved.

Pre-export handling: For exporting citrus fruits the standard activities like grading, washing, waxing, coloring and packing and cooling is followed.

Table 8. List of important Insect Pests Citrus in China

Sl. No.	Common name	Scientific name	Order: Family
01.	Lemon butterfly	*Papilio demoleus* L.	Lepidoptera: Papilionidae
02.	Lemon butterfly (Swallowtail butterfly)	*Papilio polytes* L.	Lepidoptera: Papilionidae
03.	Citrus leaf miner	*Phyllocnistis citrella* Stainton	Lepidoptera: Gracilleridae
04.	Citrus leaf folder/roller	*Psorosticha zizyphi* Stainton	Lepidoptera: Oecophoridae
05.	Black citrus aphid	*Toxoptera aurantii* Boyer de Fonscolambe	Homoptera: Aphididae
06.	Brown citrus aphid	*Toxoptera citricida Kirkaldy*	Homoptera: Aphididae
07.	Citrus whitefly	*Dialeurodes citri* Ashmead	Homoptera: Aleyrodidae
08.	Citrus blackfly	*Aleurocanthus woglumi* Ashby	Homoptera: Aleyrodidae
09.	Citrus thrips	*Scirtothrips dorsalis* Hood	Thysanoptera: Thripidae
10.	Asian citrus psyllid	*Diaphornia citri* Kuwayana	Homoptera: Psyllidae
11.	Citrus mealybug	*Plannococcus citri* Risso	Homoptera: Pseudococcidae
12.	Comstock mealybug	*Pseudococcus comstocki* Kuwana	Homoptera: Pseudococcidae
13.	Citrus red scale	*Aonidiella aurantii* Maskell	Hemiptera: Diaspididae
14.	Citrus yellow scale	*Aonidiella citrina* Coq.	Hemiptera: Diaspididae
15.	Cottony cushion scale	*Icerya purchase* Maskell	Hemiptera: Margarodidae
16.	Oriental fruit fly	*Bactrocera dorsalis* Hendel	Diptera: Tephritidae
17.	Asian fruit fly	*Bactrocera invadens* Drew, Tsuruta & White	Diptera: Tephritidae
18.	Citrus bug	*Rhynchocoris humeralis* Thunberg	Hemiptera: Pentatomidae
19.	Orange spined bug	*Biprorulus bibax* Breddin	Hemiptera: Pentatomidae
20.	White spotted longicorn beetle	*Anoplophora chinensis* (Forster)	Coleoptera: Cerambycidae
21.	Bark and stem borer/ Bark eating caterpillar	*Indarbela quadrinotata* (Walker)	Lepidoptera: Metarbelidae
22.	Citrus stem borer	*Chelidonium cinctum* Guerin-Meneville	Coleoptera: Cerambycidae
23.	Fruit sucking moth	*Ophideres materna* Cramer	Lepidoptera: Noctuidae
24.	Red imported fire ant (RIFA)	*Solenopsis invicta* Buren	Hymenoptera: Formicidae
25.	Citrus red mite	*Panonychus citri* (McGregor)	Acarina: Tetranychidae
26.	Citrus brown mite	*Eutetranychus orientalis* (Klein)	Acarina: Tetranychidae

6.2.4 Egypt

Geography and climate: Egypt is 386,650 square miles of land and the coastal is 2,450 km. The geographic position of the country is its highest point is 6,668 feet and the lowest point is 436 feet below sea level. The Mediterranean Sea forms Egypt's northern border, bringing cooler weather to the seaboard city of Alexandria and providing a coastal getaway for Cairo's residents. To the east, lies the mountainous Sinai Peninsula, which borders Israel and the Palestinian Territories; to the south, the deserts of Egypt roll into the deserts of Sudan; to the west, the Great Western Desert forms an almost seamless wilderness through Libya and beyond. The area of agricultural land in Egypt is confined to the Nile Valley and delta, with a few oases and some arable land in Sinai. The total cultivated area is 3.02 million ha, representing only 3 percent of the total land area. The climate of Egypt is desert and as such it has very hot, dry summers and mild winters. Cairo, Egypt's capital which is located in the Nile valley has an average high temperature in July is 35˚C and an average low of 9˚C in January.

Citrus is a major export product of Egypt. The total cultivated area for citrus fruit is about 222,302 ha and total production is estimated at 2,149,349 ton/year.The main varieties of citrus grown in Egypt are Seeded Baladi Orange, Seedless Baladi Orange, Valencia Orange, Blood Orange, Navel Orange, Jaffa Orange, Youssuf Soleiman Orange, Sweet Orange (Succart or Sukhary), Khalily Orange, Sour Orange, Egyptian Lemon, Grapefruit Ducan and limes. There are also small areas of other citrus such as grapefruit. The orange harvest lasts four to five months, beginning in October. Sweet lime and lemon are grown nationwide and are available all year.

Pest and disease control: The major insect pests of citrus include mediterranean fruit fly, leaf miner, scale insects, mealybugs, mites and aphids (Table 9) and among the diseases mal secco, stubborn, psorosis, tristeza are important (Table 14). Citrus fruit is sourced from commercial orchards that are registered for export. Growers will undertake orchard pest control programs to ensure that quarantine pests for Australia are adequately managed. Undertake adequate pest control program in commercial orchards that are registered for export and. growers would also be required to ensure that adequate records of spray programs are kept and that these are made available to CAPQ auditors upon request. For controlling mediterranean fruit fly pheromone trap is used.

Pre-export handling: Obtain fruit from CAPQ registered orchards. Maintain hygiene program in packing sheds. Fruits are washed in warm water for 4–5 minutes using 1.25% sodium carbonate solution or 0.1% copper sulphate or 2% potassium permanganate. Alternatively, TBZ (Thiabendazole) or Water-wax containing 22% of 2250 ppm TBZ + 2500 ppm Imazalil + 2500 ppm Guazatin may also be used. Post-harvest treatments routinely used by packing sheds include 8% borax solution at 48°C for five minutes, or a mixture of 42% Borax and 2% Boric acid in warm water. Inspected by quality control officer. Labelling the packets and perform cold disinfection. Every consignment of fresh citrus fruit from Egypt accompanies a phytosanitary certificate issued by CAPQ.

Table 9. List of important Insect Pests Citrus in Egypt

Sl. No.	Common name	Scientific name	Order: Family
01.	Lemon butterfly	*Papilio demoleus* L.	Lepidoptera: Papilionidae
02.	Lemon butterfly (Swallowtail butterfly)	*Papilio polytes* L.	Lepidoptera: Papilionidae
03.	Citrus leaf miner	*Phyllocnistis citrella* Stainton	Lepidoptera: Gracilleridae
04.	Citrus leaf folder/roller	*Psorosticha zizyphi* Stainton	Lepidoptera: Oecophoridae
05.	Black citrus aphid	*Toxoptera aurantii* Boyer de	Homoptera: Aphididae

Sl. No.	Common name	Scientific name	Order: Family
		Fonscolambe	
06.	Brown citrus aphid	*Toxoptera citricida Kirkaldy*	Homoptera: Aphididae
07.	Citrus whitefly	*Dialeurodes citri* Ashmead	Homoptera: Aleyrodidae
08.	Citrus blackfly	*Aleurocanthus woglumi* Ashby	Homoptera: Aleyrodidae
09.	Citrus thrips	*Scirtothrips dorsalis* Hood	Thysanoptera: Thripidae
10.	South African citrus thrips	*Scirtothrips aurantii* Faure	Thysanoptera: Thripidae
11.	African citrus psyllid	*Trioza erytreae* (Del Guercio)	Homoptera: Triozidae
12.	Citrus mealybug	*Plannococcus citri* Risso	Homoptera: Pseudococcidae
13.	Citrus red scale	*Aonidiella aurantii* Maskell	Hemiptera: Diaspididae
14.	Oriental scale	*Aonidiella orientalis*	Hemiptera: Diaspididae
15.	Citrus yellow scale	*Aonidiella citrina* Coq.	Hemiptera: Diaspididae
16.	Oriental fruit fly	*Bactrocera dorsalis* Hendel	Diptera: Tephritidae
17.	Mediterranean fruit fly/ Medfly	*Ceratitis capitata* (Wiedemann)	Diptera: Tephritidae
18.	Citrus red mite	*Panonychus citri* (McGregor)	Acarina: Tetranychidae
19.	Citrus brown mite	*Eutetranychus orientalis* (Klein)	Acarina: Tetranychidae

6.2.5 India

Geography and climate: India, a country in South Asia lies largely on the Indian Plate. The country is situated between 8°4' and 37°6' north latitude and 68°7' and 97°25' east longitude having a total area of 3,166,414 square km. It has a land frontier of 15,200 km and a coastline of 7,517 km. India is bordered with Pakistan, Afghanistan, Bangladesh, China, Myanmar, Bhutan and Nepal.

India enjoys versatile climatic conditions and thus agriculture of this is also versatile. India has divided into eight climatic region as- (1) Tropical Rain Forest; (2) Tropical savanna; (3) Tropical Semi-Arid Steppe Climate; (4) Tropical and Sub-Tropical Steppe; (5) Tropical Desert; (6) Humid Sub-Tropical with winter; (7) Mountain Climate and (8) drought prone area. The major citrus growing areas are Andhra Pradesh, Punjab and Maharashtra.

Andhra Pradesh climate is generally hot and humid. Summers in Andhra Pradesh last from the month of March to June and temperature generally ranges between 20 ^{0}C and 40 ^{0}C. October, November, December, January and February are the winter months in Andhra Pradesh. The range of winter temperature is generally 13 ^{0}C to 30 ^{0}C. Annual rainfall is 500-1000 mm. The total area under citrus in this province is 282300 ha and production 3883700 mt which is 40.3% of the total production in India. The climate of Maharashtra is of a tropical monsoon type with a searing heat in the summer months, and cold winter. The average annual temperature of Maharashtra remains 25 - 27 degree centigrade in most regions. Average annual rainfall ranged 400-6000 mm. The total area under citrus in Maharashtra province is 287600 ha and production 1725100 mt (29.8% of the total production).

Pest and disease control: Major insect pests of India include lemon butter fly, leaf miner, psyllid, thrips, fruit fly, red mite etc. (Table 10) and among the diseases the major concern are HBL or citrus greening, canker, citrus tatter leaf and black spot (Table 14). For effective pest control IPM is following and it was noted that incorporation of petroleum spray oil into citrus IPM programs provides an effective or better control of most major citrus pests than control programs based on broad-spectrum synthetic pesticides. Populations of natural enemies are also better conserved.

Table 10. List of important Insect Pests Citrus in India

Sl. No.	Common name	Scientific name	Order: Family
01.	Lemon butterfly	*Papilio demoleus* L.	Lepidoptera: Papilionidae
02.	Lemon butterfly (Swallowtail butterfly)	*Papilio polytes* L.	Lepidoptera: Papilionidae
03.	Citrus leaf miner	*Phyllocnistis citrella* Stainton	Lepidoptera: Gracilleridae
04.	Citrus leaf folder/roller	*Psorosticha zizyphi* Stainton	Lepidoptera: Oecophoridae
05.	Black citrus aphid	*Toxoptera aurantii* Boyer de Fonscolambe	Homoptera: Aphididae
06.	Brown citrus aphid	*Toxoptera citricida Kirkaldy*	Homoptera: Aphididae
07.	Citrus whitefly	*Dialeurodes citri* Ashmead	Homoptera: Aleyrodidae
08	Citrus blackfly	*Aleurocanthus woglumi* Ashby	Homoptera: Aleyrodidae
09.	Citrus thrips	*Scirtothrips dorsalis* Hood	Thysanoptera: Thripidae
10.	California Citrus thrips	*Scirtothrips citri* Moulton	Thysanoptera: Thripidae
11.	Asian citrus psyllid	*Diaphornia citri* Kuwayana	Homoptera: Psyllidae
12.	Citrus mealybug	*Plannococcus citri* Risso	Homoptera: Pseudococcidae
13.	Comstock mealybug	*Pseudococcus comstocki* Kuwana	Homoptera: Pseudococcidae
14.	Citrus red scale	*Aonidiella aurantii* Maskell	Hemiptera: Diaspididae
15.	Citrus yellow scale	*Aonidiella citrina* Coq.	Hemiptera: Diaspididae
16.	Cottony cushion scale	*Icerya purchase* Maskell	Hemiptera: Margarodidae
17.	Oriental fruit fly	*Bactrocera dorsalis* Hendel	Diptera: Tephritidae
18.	Asian fruit fly	*Bactrocera invadens* Drew, Tsuruta & White	Diptera: Tephritidae
19.	Citrus bug	*Rhynchocoris humeralis* Thunberg	Hemiptera: Pentatomidae
20.	Orange spined bug	*Biprorulus bibax* Breddin	Hemiptera: Pentatomidae
21.	White spotted longicorn beetle	*Anoplophora chinensis* (Forster)	Coleoptera: Cerambycidae
22.	Bark and stem borer/ Bark eating caterpillar	*Indarbela quadrinotata* (Walker)	Lepidoptera: Metarbelidae
23.	Citrus stem borer	*Chelidonium cinctum* Guerin-Meneville	Coleoptera: Cerambycidae
24.	Fruit sucking moth	*Ophideres materna* Cramer	Lepidoptera: Noctuidae
25.	Red imported fire ant (RIFA)	*Solenopsis invicta* Buren	Hymenoptera: Formicidae
26.	Citrus red mite	*Panonychus citri* (McGregor)	Acarina: Tetranychidae
27.	Citrus brown mite	*Eutetranychus orientalis* (Klein)	Acarina: Tetranychidae

6.2.6 Pakistan

Geography and climate: Pakistan is the 36th largest nation by total area. It has a 1,046km coastline along the Arabian Sea and the Gulf of Oman. Pakistan is bordered by Afghanistan, Iran, India, and

China. Pakistan is also very close to Tajikistan, separated by the Wakhan Corridor. Pakistan is strategically located between the regions of South Asia, Central Asia, and the Middle East. This prime location – combined with varied natural resources, a diverse geography, and interesting environment – make Pakistan a noteworthy country.

The three primary geographical regions are the northern highlands, the Indus River plain, and the Balochistan Plateau. The northern highlands include the famous K2, Mount Godwin Austen. At 8,611 meters, it is the second highest peak in the world.

Citrus is one of the major fruit crops of Pakistan and share of citrus fruits is 30% of all types of fruit produced in Pakistan from an area of 23%. The country is currently an important global producer and, increasingly, an exporter. But most citrus production relies on one mandarin cultivar, Kinnow, and 95% of this crop comes out of Punjab province. The total citrus production in the country was 2,213,900 mt in 2010-11. Harvesting and supply of citrus in Punjab of Pakistan is from October to April.

Pest and disease control: The major insect pests of citrus in Pakistan include lemon butter fly, asian psyllid, citrus white fly, oriental fruit fly, citrus brown mite (Table 11) and among the diseases canker, citrus greening and stubborn are worth mentioning (Table 14).

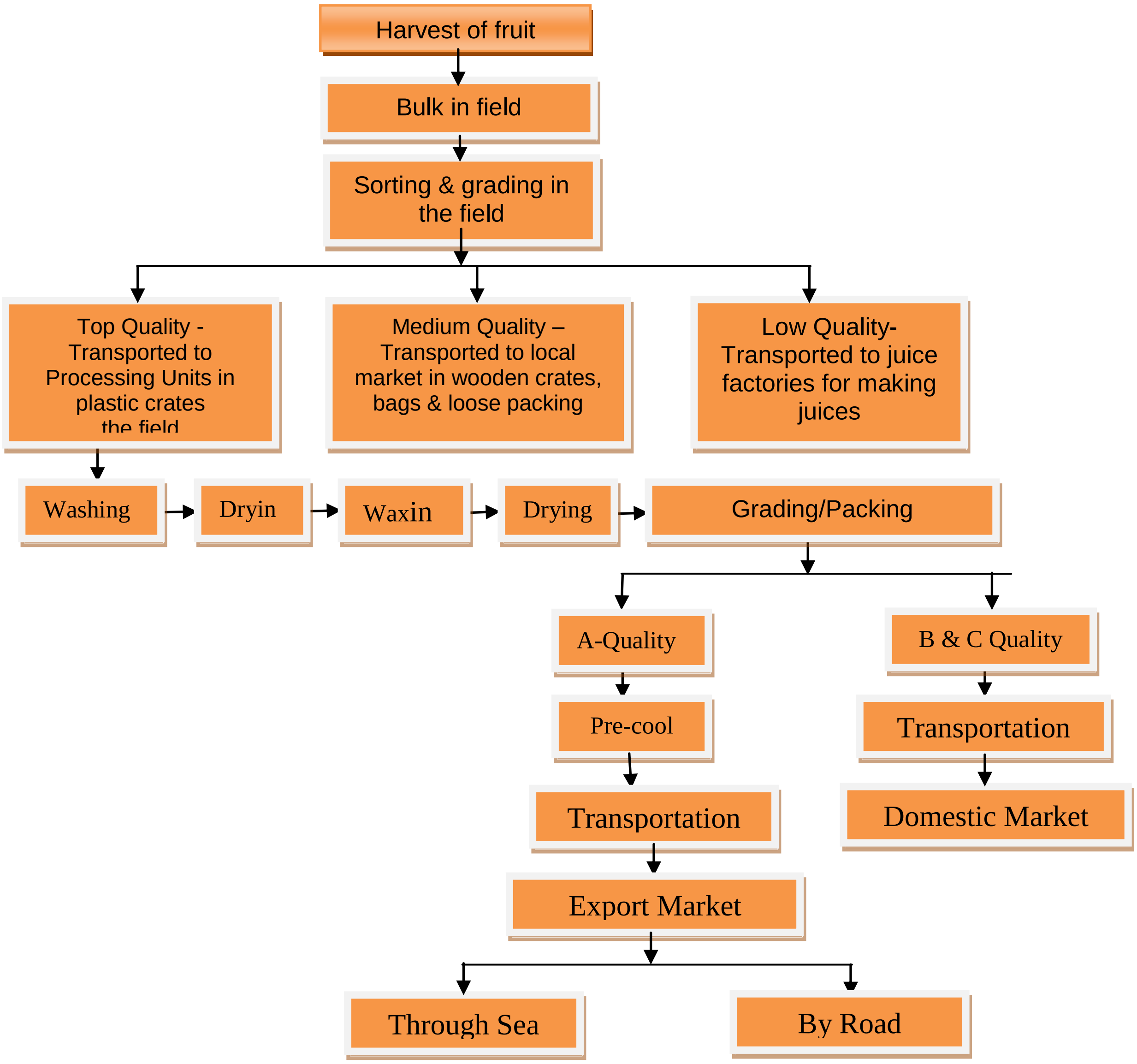
Table 11. List of important Insect Pests Citrus in Pakistan

Sl. No.	Common name	Scientific name	Order: Family
01.	Lemon butterfly	*Papilio demoleus* L.	Lepidoptera: Papilionidae
02.	Lemon butterfly (Swallowtail butterfly)	*Papilio polytes* L.	Lepidoptera: Papilionidae
03.	Citrus leaf miner	*Phyllocnistis citrella* Stainton	Lepidoptera: Gracilleridae
04.	Citrus leaf folder/roller	*Psorosticha zizyphi* Stainton	Lepidoptera: Oecophoridae
05.	Black citrus aphid	*Toxoptera aurantii* Boyer de Fonscolambe	Homoptera: Aphididae
06.	Brown citrus aphid	*Toxoptera citricida Kirkaldy*	Homoptera: Aphididae
07.	Citrus whitefly	*Dialeurodes citri* Ashmead	Homoptera: Aleyrodidae
08.	Citrus blackfly	*Aleurocanthus woglumi* Ashby	Homoptera: Aleyrodidae
09.	Citrus thrips	*Scirtothrips dorsalis* Hood	Thysanoptera: Thripidae
10.	Asian citrus psyllid	*Diaphornia citri* Kuwayana	Homoptera: Psyllidae
11.	Citrus mealybug	*Plannococcus citri* Risso	Homoptera: Pseudococcidae
12.	Comstock mealybug	*Pseudococcus comstocki* Kuwana	Homoptera: Pseudococcidae
13.	Citrus red scale	*Aonidiella aurantii* Maskell	Hemiptera: Diaspididae
14.	Citrus yellow scale	*Aonidiella citrina* Coq.	Hemiptera: Diaspididae
15.	Cottony cushion scale	*Icerya purchase* Maskell	Hemiptera: Margarodidae
16.	Oriental fruit fly	*Bactrocera dorsalis* Hendel	Diptera: Tephritidae
17.	Asian fruit fly	*Bactrocera invadens* Drew, Tsuruta & White	Diptera: Tephritidae
18.	Red imported fire ant (RIFA)	*Solenopsis invicta* Buren	Hymenoptera: Formicidae
19.	Citrus red mite	*Panonychus citri* (McGregor)	Acarina: Tetranychidae
20.	Citrus brown mite	*Eutetranychus orientalis* (Klein)	Acarina: Tetranychidae

Steps of postharvest Handling of Citrus Fruits:

The major steps of post harvest handling of citrus fruits in Pakistan are shown figure 8.

Figure 8: Flow Diagram Showing Postharvest Handling of Citrus in Pakistan.



6.2.7 South Africa

Geography and climate: South Africa occupies the southern tip of Africa, its long coastline stretching more than 2,500km from the desert border with Namibia on the Atlantic coast southwards around the tip of Africa and then north to the border of subtropical Mozambique on the Indian Ocean. South Africa is a medium-sized country, with a total land area of 1219 090 square kilometers. The country is stretching latitudinally from 22°S to 35°S and longitudinally from 17°E to 33°E. The country has nine provinces, which vary considerably in size. South Africa has a dual agricultural economy, with both well-developed commercial farming and more subsistence-based production in the deep rural areas.

Covering 1.2-million square kilometers of land, South Africa has seven climatic regions, from Mediterranean to subtropical to semi-desert. This biodiversity, together with a coastline 3000 kilometers long and served by eight commercial ports, favors the cultivation of a highly diverse range of marine and agricultural products, from deciduous, citrus and subtropical fruit to grain, wool, cut flowers, livestock and game. Total citrus production of citrus in South Africa was 1,906,000 mt in 2010-11.

The climate of South Africa varies from the sub-tropical with summer rainfall in the north to a Mediterranean-type with winter rainfall in the Western Cape which enable production of different citrus crops and the fruits are available almost throughout the year. The most popular varieties are the Valencia and novel oranges followed by grapefruit, mandarin and lemons. The most important production areas of citrus are in the Eastern Cape, Western Cape, Mpumalango and Limpopo provinces. The average temperature in major cities and towns in south Africa ranged 8-27^{0}C and monthly average rainfall ranged 414-1228 mm.

Pest and disease control: The major pests of citrus in South Africa include African psyllid, thrips, South African thrips, snow sacles and medeterian fruit fry (Table 12) and among the diseases African form of citrus greening, black spot, tatter leaf disease and citrus blight are most important (Table 14). Citrus fruits generally export from officially approved citrus black spot free areas. The exporter has to apply Good Agricultural Practices (GAPs) and procedures for specific plant pests in order to be able to export to some countries.

Pre-export handling: The procedures are as follows:

- All exporters need to register with South African Revenue Service (SARS).
- The exporter or value chain operator will need to register the farm's agricultural Production Unit Code (PUC) as a Food Business Operator (FBO) and obtain a PUC to be able to export to other countries including special markets.
- The department has negotiated bilateral agreements (protocols) with various countries for different products. These specify the requirements to reduce the risk of quarantine pests and diseases.
- Must apply for phytosanitary approval and registration of their FBO.
- All types of citrus fruits exported only from officially approved citrus black spot-free areas
- An exporter has to apply Good Agricultural Practices (GAPs) and procedures for specific plant pests in order to be able to export to some countries.
- After application for the phytosanitary registration of an orchard or pack house, the relevant unit will be inspected to determine if it comply with the conditions of the relevant importing countries.
- Wood packaging material is regulated in international trade to reduce the risk of introduction and/or spread of the associated quarantine pests.
- All consignments must be inspected by the PPECB for quality purposes before DAFF does phytosanitary inspections on products destined for export to special and other international markets.

Table 12. List of important Insect Pests Citrus in South Africa

Sl. No.	Common name	Scientific name	Order: Family
01.	Lemon butterfly	*Papilio demoleus* L.	Lepidoptera: Papilionidae
02.	Lemon butterfly (Swallowtail butterfly)	*Papilio polytes* L.	Lepidoptera: Papilionidae
03.	Citrus leaf miner	*Phyllocnistis citrella* Stainton	Lepidoptera: Gracilleridae
04.	Citrus leaf folder/roller	*Psorosticha zizyphi* Stainton	Lepidoptera: Oecophoridae
05.	Black citrus aphid	*Toxoptera aurantii* Boyer de Fonscolambe	Homoptera: Aphididae
06.	Brown citrus aphid	*Toxoptera citricida Kirkaldy*	Homoptera: Aphididae

Sl. No.	Common name	Scientific name	Order: Family
08	Citrus blackfly	*Aleurocanthus woglumi* Ashby	Homoptera: Aleyrodidae
09.	Citrus thrips	*Scirtothrips dorsalis* Hood	Thysanoptera: Thripidae
10.	South African citrus thrips	*Scirtothrips aurantii* Faure	Thysanoptera: Thripidae
11.	African citrus psyllid	*Trioza erytreae* (Del Guercio)	Homoptera: Triozidae
12.	Citrus mealybug	*Plannococcus citri* Risso	Homoptera: Pseudococcidae
13.	Comstock mealybug	*Pseudococcus comstocki* Kuwana	Homoptera: Pseudococcidae
14.	Citrus red scale	*Aonidiella aurantii* Maskell	Hemiptera: Diaspididae
15.	Citrus yellow scale	*Aonidiella citrina* Coq.	Hemiptera: Diaspididae
16.	Cottony cushion scale	*Icerya purchasi* Maskell	Hemiptera: Margarodidae
17.	Oriental fruit fly	*Bactrocera dorsalis* Hendel	Diptera: Tephritidae
18.	Asian fruit fly	*Bactrocera invadens* Drew, Tsuruta & White	Diptera: Tephritidae
19.	Mediterranean fruit fly/ Medfly	*Ceratitis capitata* (Wiedemann)	Diptera: Tephritidae
20.	Fruit sucking moth	*Ophideres materna* Cramer	Lepidoptera: Noctuidae
21.	Citrus red mite	*Panonychus citri* (McGregor)	Acarina: Tetranychidae
22.	Citrus brown mite	*Eutetranychus orientalis* (Klein)	Acarina: Tetranychidae
23.	Lewis spider mite	*Eotetranychus lewisi (*McGregor)	Acarina: Tetranychidae

6.2.8 USA

Geography and climate: The country is situated between 38.00° North and 97.00° West 8°4' having a total area of 9,629,091 square km of which 97.77% land and 2.23% water. The United States shares land borders with Canada (8,893 km) and Mexico (3,327 km) and maritime (water) borders with Russia, Cuba, and The Bahamas in addition to Canada and Mexico. USA has versatile climatic conditions, West: mostly semi-arid to desert, Northeast: humid continental, Southeast: humid subtropical, Coast of California: Mediterranean, Pacific Northwest: cool temperate oceanic, Alaska: mostly subarctic, Hawaii: tropical. and thus agriculture of this is also versatile. The major citrus producing states in the United States include Florida, California, Texas and Arizona. Of these four states, Florida produced 63 percent of the total U.S. citrus crop in 2012, California produced 34 percent, and Texas and Arizona combined produced the remaining 3 percent. Florida is the largest producer of oranges, accounting for about 70 percent of total U.S. production, and of grapefruit, producing nearly 65 percent of total production. California is the largest producer of lemons, producing more than 92 percent of production, and of tangerines, accounting for about 80 percent of production. The climate of the north and central parts of the US state of Florida is humid subtropical. South Florida has a tropical climate. There is a defined rainy season from June through September, which are the months most at risk of landfalling tropical cyclones. On average, winter time is mild to warm throughout Florida range from 5 °C to 18 °C and during the summer, temperature ranges from21 °C to 27 °C. In California, the temperature gradient between immediate coast and low-lying inland valleys in the south is about 7 °F (4 °C) in winter (the coast being warmer) and in summer roughly 25 °F (14 °C) (the interior being warmer). Northwestern California has a temperate climate with rainfall of 380 mm 1,300 mm per year. Some areas of Coast Redwood forest receive over 2,500 mm of precipitation per year.

Pest and disease control: Many insect pests attacked citrus fruits in USA, of which leaf miner, fruit flies, aphids, thrips, psyllids, scales and mites are important (Table 13). On the other hand Huanglongbing (HLB) or citrus greening and citrus canker are major diseases of citrus (Table 14). Generally, cultural, mechanical, chemical and biological methods are applied to control these insect pests and diseases. However, control measures may specific for different insect pests and diseases.

Table 13. List of important Insect Pests Citrus in USA

Sl. No.	Common name	Scientific name	Order: Family
01.	Lemon butterfly	*Papilio demoleus* L.	Lepidoptera: Papilionidae
02.	Lemon butterfly (Swallowtail butterfly)	*Papilio polytes* L.	Lepidoptera: Papilionidae
03.	Citrus leaf miner	*Phyllocnistis citrella* Stainton	Lepidoptera: Gracilleridae
04.	Citrus leaf folder/roller	*Psorosticha zizyphi* Stainton	Lepidoptera: Oecophoridae
05.	Black citrus aphid	*Toxoptera aurantii* Boyer de Fonscolambe	Homoptera: Aphididae
06.	Brown citrus aphid	*Toxoptera citricida Kirkaldy*	Homoptera: Aphididae
07.	Citrus whitefly	*Dialeurodes citri* Ashmead	Homoptera: Aleyrodidae
08.	Citrus blackfly	*Aleurocanthus woglumi* Ashby	Homoptera: Aleyrodidae
09.	Citrus thrips	*Scirtothrips dorsalis* Hood	Thysanoptera: Thripidae
10.	California Citrus thrips	*Scirtothrips citri* Moulton	Thysanoptera: Thripidae
11.	Asian citrus psyllid	*Diaphornia citri* Kuwayana	Homoptera: Psyllidae
12.	Citrus mealybug	*Plannococcus citri* Risso	Homoptera: Pseudococcidae
13.	Comstock mealybug	*Pseudococcus comstocki* Kuwana	Homoptera: Pseudococcidae
14.	Citrus red scale	*Aonidiella aurantii* Maskell	Hemiptera: Diaspididae
15.	Citrus yellow scale	*Aonidiella citrina* Coq.	Hemiptera: Diaspididae
16.	Cottony cushion scale	*Icerya purchasi* Maskell	Hemiptera: Margarodidae
17.	Oriental fruit fly	*Bactrocera dorsalis* Hendel	Diptera: Tephritidae
18.	Mediterranean fruit fly/ Medfly	*Ceratitis capitata* (Wiedemann)	Diptera: Tephritidae
19.	Bark and stem borer/ Bark eating caterpillar	*Indarbela quadrinotata* (Walker)	Lepidoptera: Metarbelidae
20.	Citrus stem borer	*Chelidonium cinctum* Guerin-Meneville	Coleoptera: Cerambycidae
21.	Fruit sucking moth	*Ophideres materna* Cramer	Lepidoptera: Noctuidae
22.	Red imported fire ant (RIFA)	*Solenopsis invicta* Buren	Hymenoptera: Formicidae
23.	*Solenopsis xyloni* McCook	*Solenopsis xyloni* McCook	Hymenoptera: Formicidae
24.	Citrus red mite	*Panonychus citri* (McGregor)	Acarina: Tetranychidae
25.	Citrus brown mite	*Eutetranychus orientalis* (Klein)	Acarina: Tetranychidae
26.	Lewis spider mite	*Eotetranychus lewisi (*McGregor)	Acarina: Tetranychidae

Table 14. Some important diseases of Citrus in eight countries from where citrus fruits are imported to Bangladesh

Sl. No.	Disease	Causal agent	Bhutan	Brazil	China	Egypt	India	Pakistan	South Africa	USA
1	Citrus canker	*Xanthomonas axonopodis* pv. *citri*		Present	Present		Present	Present		Present
2	Citrus greening	*Candidus* L. *asiaticus*	Present		Present		Present	Present		
3	Citrus greening	*Candidus L. africanum*							Present	
4	Citrus variegated chlorosis	*Xylella fastidiosa*		Present						Present
5	Stubborn disease	*Spiroplasma citri*				Present		Present		Present
7	Tristeza	Citrus tristeza virus		Present	Present	Present	Present	Present	Present	Present
8	Psorosis	Citrus psorosis virus						Present		
9	Leprosis	Citrus leprosis virus		Present						
10	Indian ringspot virus disease	Indian ringspot virus					Present			
11	Citrus **b**lack spot	*Guignardia citricarpa*	Present	Present	Present				Present	Present
12	Scab	*Elsinoe fawcettii*		Present						Present
13	Mal secco	*Phoma tracheiphila*				Present				
14	Anthracno se	*Colletotrichum gloeosporioides*		Present	Present		Present	Present	Present	Present
15	Die-back	*Colletotrichum gloeosporioides*					Present	Present		Present
16	Citrus blight disease	Unknown		Present	Present		Present	Present	Present	Present
17	Greasy spot	*Mycosphaerella citri*		Present	Present			Present		Present
18	Gummosis	*Phytophthora citrophthora*		Present	Present	Present	Present	Present	Present	Present
19	Melanose	*Diaporthe citri*		Present	Present	Present	Present	Present	Present	Present

6.2.9 Bangladesh

Geography and climate: The geographic position of Bangladesh is at $20^0$34 and $26^0$38 N, and $88^0$01 and $92^0$41-EL. Mean humidity is highest (99%) in July and lowest (36%) in December. Average annual rainfall ranged from 1429 mm to 4358 mm. However, in the major citrus producing areas in hill tracts region the average annual rainfall ranged from 2480 mm to 3082 mm and in Sylhet region from 2433 mm to 4047 mm. The rainfall in all these areas is minimum (6-13 mm) in January and maximum (426-8511mm) in July. Average Maximum and minimum temperature in winter (December-February) is 29^0C and 11^0C respectively. Highest temperature prevails during June to September when the average maximum and minimum temperature is 34^0C and 21^0C respectively. The major citrus growing areas that is Chittagong, Chittagong Hill Tracts and greater Sylhet region lies between 21.86-25.03N and 91.16 to 92.46EL. In Bangladesh orange generally harvested during December to February but Lemon and Lime is harvsted throughout the year.

Upon arrival in the port of entry the commodity must be inspected by the competent inspector and if found free from any quarantine pest would be released for marketing and distribution throughout the country.

Pest and disease control: Many insect pests attacked citrus fruits in Bangladesh of which lemon butterfly, leaf miner, fruit flies, aphids, orange spined bug, thrips, scales and mites are important (Table 16). On the other hand dieback, citrus canker, citrus greening and gummosis are important diseases of citrus (Table 17). Generally, cultural, mechanical and chemical methods are applied to control these insect pests and diseases. However, control measures may specific for different insect pests and diseases.

7.0 Hazard Identification

7.1 Potential Hazard Groups

Sixty-one organisms and pathogens are identified as potential hazards associated with citrus fruits in different citrus growing countries of the world. Of which 36 species were insects and mites (Appendix XI) and 25 species were pathogen (Appendix XII). Fifteen insect pests like Mediterranean fruit fly, Asian fruit fly, papaya fruit fly, Queensland fruit fly, brown citrus aphid, African citrus psyllid, California citrus thrips, South African citrus thrips, citrus snow scale, cottony cushion scale, fruit sucking moth, white spotted longicorn beetle, southern fire ant, citrus gall wasp and Lewis spider mite were absent in Bangladesh and considered as quarantine pests (Table 15). Seven diseases like citrus black spot, pseudocercospora spot, mal secco, greening, stubborn, leprosis and Indian citrus ringspot are absent in Bangladesh and considered as quarantine diseases (Table 15). These insect pests and pathogens have been grouped on the basis of taxonomy and biology. These organisms are considered as potential hazard groups and are used in Chapter 7:

Table 15: List of Organisms Identified as Hazards of Different Citrus Fruits for Bangladesh

Sl. No.	Hazard organisms		Citrus hosts
	Common name	Common name	
		Fruit flies	
01.	Mediterranean fruit fly/ Medfly	*Ceratitis capitata* (Wiedemann)	Lime, lemon, pummelo, malta, sour orange, mandarin
02.	Asian fruit fly	*Bactrocera invadens* Drew, Tsuruta & White	Lemon, malta, mandarin, pummelo, sour orange, grapefruit
03.	Papaya fruit fly	*Bactrocera papayae* Drew and Hancock	Lime, lemon, pummelo, mandarin
04.	Queensland fruit fly	*Bactrocera tryoni* (Froggatt)	Lime, lemon, mandarin, rough lemon
		Aphid	
05.	Brown citrus aphid	*Toxoptera citricida* Kirkaldy	All citrus spp. and their hybrids
		Psyllid	
06.	African citrus psyllid	*Trioza erytreae* (Del Guercio)	Lemon, lime, mandarin, pummelo, malta, grape fruit
		Scales	
07.	Citrus snow scale	*Unaspis citri* (Comstock)	Lime, lemon, sour orange, pummelo, malta, grapefruit
08.	Cottony cushion scale	*Icerya purchase* Maskell	all citrus and woody plants
		Thrips	
09.	California Citrus thrips	*Scirtothrips citri* Moulton	All Citrus spp. and their hybrids
10.	South African citrus thrips	*Scirtothrips aurantii* Faure	All *Citrus* spp. and their hybrids
		Moth	
11.	Fruit piercing moth	*Eudocima fullonia* Clerck	Mandarin, lemon, malta
		Beetle	
12.	White spotted longicorn beetle	*Anoplophora chinensis (*Forster)	Pummelo, sour orange, malta
		Ant	
13.	Southern fire ants	*Solenopsis xyloni* McCook	All *Citrus* spp and their hybrids
		Wasp	

Sl. No.	Hazard organisms		Citrus hosts
	Common name	**Common name**	
14.	Citrus gall wasp	*Bruchophagus fellis* (Girault)	Lemon, mandarin, malta, rough lemon
Mite			
15.	Lewis spider mite	*Eotetranychus lewisi (*McGregor)	All *Citrus* spp. and their hybrids
Bacteria			
16.	Citrus Greening	*Candidatus liberibacter africanus*	Malta, mandarin, tangelo, lemon, grapefruit, rough lemon, citron, lime and pummelo
17.	Stubborn	*Spiroplasma citri* Saglio et al.	Grapefuit, lemon, mandarin, malta, sour orange, pummelo
Fungi			
18.	Black spot	*Guignardia citricarpa* Kiely	Grapefuit, lemon, lime, mandarin, malta, sour orange
19.	Pseudocercospora spot	*Pseudocercospora angolensis* (T. Carvalho & O.Mendes)	Grapefuit, lemon, lime, mandarin, malta, sour orange
20.	Mal Secco	*Phoma tracheiphila* (Petri) Kantschaveli & Gikashvili	Lemon, lime, citron, bergamont
Virus			
21.	Leprosis	*Citrus Leprosis Virus C* (CiLV-C)	Malta, lemon, mandarin, grapefruit and hybrids
22.	Indian citrus ring spot	*Indian ringspot virus* (ICRSV)	Mandarin, mosambi, malta, sour orange, lime, rough lemon

See Section 9.1 to 9.22 in risk analysis of potential hazards for more detail.

7.2 Pests and Diseases of Citrus in Bangladesh

The recorded insect pests and diseases of citrus in Bangladesh are shown in Table 16 and 17.

Table 16: Insect Pests of Different Citrus Crops in Bangladesh

Sl. No.	Common name	Scientific name (Family and Order)	Name of the crops attacked	Status
01.	Lemon butterfly	*Papilio demoleus* L. (Lepidoptera: Papilionidae)	Lemon, lime, mandarin, malta & other citrus	Major
02.	Lemon butterfly (Swallowtail butterfly)	*Papilio polytes* L. (Lepidoptera: Papilionidae)	Lemon, lime, mandarin, malta	Minor
03.	Citrus leaf miner	*Phyllocnistis citrella* St.(Lepidoptera: Gracilleridae)	All Citrus, lemon, lime, mandarin, pummelo	Major
04.	Citrus leaf folder/roller	*Psorosticha zizyphi* Stainton (Lepidoptera: Oecophoridae)	All Citrus	Minor
05.	Black citrus aphid	*Toxoptera aurantii* Boyer de Fonscolambe (Homoptera: Aphididae)	Mandarin, malta, lemon, lime, pummelo	Major
06.	Citrus whitefly	*Dialeurodes citri* Ashmead (Homoptera: Aleyrodidae)	Lemon, lime, mandarin, pummelo, malta, grapefruit	Minor

Sl. No.	Common name	Scientific name (Family and Order)	Name of the crops attacked	Status
07.	Citrus blackfly	*Aleurocanthus woglumi* Ashby ((Homoptera: Aleyrodidae)	All Citrus	Minor
08	Citrus thrips	*Scirtothrips dorsalis* Hood (Thysanoptera: Thripidae)	All Citrus	Minor
09.	Asian citrus psyllid	*Diaphornia citri* Kuwayana (Homoptera: Psyllidae)	All Citrus	Minor
10.	Citrus mealybug	*Plannococcus citri* Risso (Homoptera: Pseudococcidae)	Lime, lemon, malta, mandarin, pummelo	Minor
11.	Comstock mealybug	*Pseudococcus comstocki* Kuwana (Homoptera: Pseudococcidae)	Lime, lemon, malta, manadarin, pummelo	Minor
12.	Citrus red scale	*Aonidiella aurantii* Maskell (Hemiptera: Diaspididae)	All Citrus	Minor
13.	Citrus yellow scale	*Aonidiella citrina* Coq. (Hemiptera: Diaspididae)	All Citrus	Minor
14.	Oriental fruit fly	*Bactrocera dorsalis* Hendel (Tephritidae: Diptera)	Mandarin, malta, pummelo, lemon	Major
15.	Citrus bug	*Rhynchocoris humeralis* Thunberg (Hemiptera: Pentatomidae)	Mandarin	Minor
16.	Orange spined bug	*Biprorulus bibax* Breddin (Hemiptera: Pentatomidae)	Mandarin, malta, pummelo	Major
17.	Bark and stem borer/ Bark eating caterpillar	*Indarbela quadrinotata* (Walker) (Lepidoptera: Metarbelidae)	Mandarin, malta, lemon, lime, pummelo and other citrus	Minor
18.	Citrus stem borer	*Chelidonium cinctum* Guerin-Meneville (Coleoptera: Cerambycidae)	Lemon, mandarin, malta, pummelo and other citrus	Minor
19.	Red imported fire ant (RIFA)	*Solenopsis invicta* Buren (Hymenoptera: Formicidae)	All *Citrus* spp. and their hybrids	Minor
20.	Termite	*Odontotermes obesus* Rambur (Termitidae: Isoptera)	All Citrus	Minor
21.	Citrus red mite	*Tetranychus* spp. (Acarina:Tetranychidae)	Lemon, lime, mandarin, malta & other citrus	Minor

Table 17: Diseases of Different Citrus Crops in Bangladesh

Sl. No.	Disease	Causal Organism	Affected Citrus
1	Die-back	*Colletotrichum gloeosporioide Diplodia natalensis, Fusarium spp.*	All citrus
2	Canker	*Xanthomonas axonopodis pv. citri*	Lemon, lime, Sweet orange, mandarin, jamir, satkara, ada lebu, jara lebu
3	Tristeza	*Citrus tristeza virus*	Sweet orange, lemon, pummelo
4	Psorosis	*Citrus psorosis virus*	Sweet orange, lemon, pummelo
5	Gummosis	*Phytophthora citrophthora*	Lime, pummelo, Sweet orange, mandarin, jamir, ada lebu, jara lebu
6	Greening	*Candidatus Liberibacter asiaticus*	Lemon, lime, pummelo, Sweet orange, mandarin, jamir, ada lebu, jara lebu
7	Scab	*Elsinoe facetii*	Lemon, lime, Sweet orange, mandarin, jamir, satkara, jara lebu, ada lebu
8	Sooty mould	*Capnodium citricola*	Lemon, lime, pummelo, mandarin, jamir, ada lebu, jara lebu
9	Anthracnose	*Colletotrichum gloeosporioide*	Lime, pummelo

10	Melanose	*Diaporthe citri* F.A. Wolf	Lemon, lime, mandarin
11	Foam disease	Unknown	Mandarin
12	Blue/Green mold	*Penicillium sp.*	Lemon, lime, Sweet orange, mandarin
13	Pink mold	*Botrybasidium salmonicolor*	Sweet orange, mandarin, jara lebu, ada lebu
14	Nematode	*Tylenchus semepenitrans, Pratylenchus* sp., *Radopholus similis*	All Citrus

7.3 Organisms Intercepted at the Border on Citrus Fruit on Existing Pathways

Bangladesh imports fresh fruits of malta, mandarin and kinnow from India, Bhutan, China, Pakistan, Egypt, South Africa and USA. In 2007-2008 fresh citrus fruits were imported from India, China, Australia, China, Thailand, Pakistan, Middle East and Brazil. No information is available about organisms intercepted at the border with citrus fruits in Bangladesh.

7.4 Other Risk Characteristics of the Commodity

Although many pests dealt with in this risk analysis have adequate information for assessment, we cannot predict future or present risks that currently escape detection for a variety of reasons.

7.4.1 Unlisted Pests

These include pests that are not yet identified. With a trend towards decreasing use of chemical products in agriculture and further reliance on Integrated Pest Management strategies it is assumed that new pests will enter the system at some time in the future.

Prolonged use of large doses of pesticides and fertilizers can lead to previously non pest species becoming economically important through resistance to pest treatments. Any of these types of organism could initially appear in very small numbers associated with the commodity, and may not be identified as hazards before their impacts become noticeable.

7.4.2 Symptomless Micro-Organisms

Pests such as microbes and fungi infect fruit before transit and may not produce symptoms making them apparent only when they reach a suitable climate to sporulate or reproduce. Many fungi can infect fruit after arrival making it difficult to distinguish the origin of saprobes and pathogens without adequate identification. Consumers tend to throw away moulded fruit rather than take it to a diagnostic laboratory so there is little data on post entry appearance of “invisible organisms.

7.5 Assumptions and Uncertainties

The major uncertainties encountered in this risk analysis are identified here. The assumptions made to take account of them are explicitly identified where relevant in the text.

7.5.1 Hazard Biology and Identification

- The biology of insects that have been reared in the laboratory for several generations is often different to wild counterparts established in field conditions. Aspects such as life cycle, preovipositional period, fecundity and flight ability, as well as cold or heat tolerance can be influenced by the highly controlled laboratory environment. Laboratory reared insects may differ in their responses to environmental stress and exhibit tolerances that are exaggerated or reduced when compared with wild relatives. For example longevity and fecundity of adult *Aphis gossypii* in a greenhouse was longer and higher than those in a growth chamber with similar conditions.

- If a pest species occurs in Bangladesh often its full host range or behavior in the colonized environment remains patchy. It is difficult to predict how a species will behave in a new environment, particularly if it has not become established as a pest elsewhere outside its natural range. Therefore there will be considerable uncertainty around the likelihood of an organism colonising new hosts or the consequences of its establishment and spread on the natural environment. Where indigenous plants are discussed as potential hosts this is extrapolated from the host range (at genus and family level) overseas and is not intended as a definitive list.
- Where there is uncertainty about the identity of an organism, e.g. Prays citri vs P. nephelomima, the more serious pest is considered in the RA. The conclusions may need to be revisited if evidence to the contrary becomes available.
- There is uncertainty around the efficacy of risk management measures for many of the hazards identified in this Risk Analysis. In some cases efficacy data for similar species has had to be used.

7.5.2 Assumption Regarding Transit Time of Fruit on the Air Pathway

An assumption is made around the time the fruit takes to get from the field in Egypt/ Pakistan/ South Africa to Bangladesh ready for wholesale if it is transported by aircarrier. It is assumed that the harvesting, treatment, packing and transit of *Citrus* fruit from imported countries, inspection and release in Bangladesh will take a minimum of 7days, and on average will take 10 days.

7.5.3 Assumption and Uncertainty around Disposal of Infested Fruit

It is not known what proportion of imported *Citrus* will be consumed or discarded. It is assumed that a proportion of *Citrus* that is infested or damaged will be disposed of in a manner that exposes any potential hazard organisms on that fruit to suitable hosts. Disposal would include discarding fruit or peel on urban or rural roadsides, in bush reserves, in open rubbish bins in public places, and on open composts in domestic areas.

7.5.4 Assumption and Uncertainty around Risk Management Measures

A lot of uncertainty exists around the efficacy of risk management measures. Interception data is one way of estimating efficacy, as records of live and dead organisms indicate the success of a treatment and the thresholds for growth and development of each individual organism. A sample audit is required to monitor efficacy. Currently this is 600 units of fruit/vegetable product per consignment. The assumption is that this monitoring will adequately record type and number of organisms associated with each fresh produce commodity.

This approach makes the following assumptions, that:

- The consignment is homogeneous (fruit are harvested inspected and packaged in similar conditions, and have received similar treatments before arrival into Bangladesh). Heterogeneous or non-randomly distributed consignments would require a higher sampling rate to achieve the same confidence levels. Level of sampling depends on the degree of heterogeneity;
- The samples are chosen randomly from the consignment;
- The inspector is 100 percent likely to detect the pest if it is present in the sample. Because of uncertain distribution of pests within the consignment some pests will not be detected if they are present outside the 600 unit sample. Some pests are difficult to detect because of their small size and behaviors;
- It is acceptable that the sampling system is based on a level (percentage) of contamination rather than a level of surviving individuals;

- Because for lines of less than 600 units, 100 percent inspection is required, it is therefore acceptable that the effective level of confidence gained by the sampling method significantly increases as the consignment size moves below 10,000. This is because a sample of around 590 provides 95 percent confidence that a contamination level of 1 in 200 (0.5 percent) will be detected in consignments larger than about 25,000 individuals.

Interception records can rarely be used quantitatively because of limitations in the identification and recording processes.

There is a paucity of information on the efficacy of the available risk mitigation options in managing the hazards associated with *Citrus*. In the absence of efficacy data, assumptions are made on the basis of data for similar species or similar treatments.

8.0 Review of Management Options

8.1 Introduction

This chapter provides background information on possible measures to mitigate the biosecurity risk associated with importing *Citrus* from India, Bhutan, China, Pakistan, South Africa, Egypt, and USA.

8.1.1 Disinfestation Treatments

Disinfestation treatments are treatments that remove or kill hazard organisms that may be contaminating commodities. Some of the treatments discussed are usually considered "stand alone" disinfestation treatments but these can also be integrated into a systems approach. This depends on a number of variables, such as the commodity type, its tolerance for the treatment/s, the biology of associated hazard organisms and what is available to the exporting country.

8.1.2 Systems Approach

A "systems approach" is the implementation of multiple safeguard actions in the country of export that result in the commodity meeting the phytosanitary standards of the importing country. These actions have a scientifically derived basis and can be used at key points in the production-to-export system. Jang and Moffit (1994) describe in detail how a systems approach can achieve quarantine security through integrating biological, physical and operational factors to reduce the incidence, viability and reproductive potential of hazard organisms. These concepts have been recently incorporated into an international standard, (ISPM-14 2002) approved by the International Plant Protection Convention (IPPC). In brief, a systems approach includes the following steps:

- consistent and effective management for reducing pest populations in the field and monitoring this management;
- prevention of contamination after harvest;
- culling in the pack house of damaged and diseased fruit;
- inspection and certification of the critical parts of the system based on effective traceback procedures;
- shipping using methods that prevent reinfestation.

The knowledge on the pest-host biology and phenology is intrinsic in the use of a systems approach. Some components of the systems approach are discussed in this chapter. Disinfestation treatments can be combined into a system to mitigate risk.

8.2 Production and Post-Harvest Measures

It is necessary to provided information about the production and post harvest procedures that *Citrus* farmers are expected to use.

8.2.1 Monitoring Programs in Production Areas

Monitoring of in-orchard pest and pathogens is the key to optimizing production while reducing pest and/or disease-related problems, for instance:

- fruit flies – trapping to monitor population levels in and around orchards;
- surface pests - regular inspection of leaves, stems, fruit etc. to monitor invertebrate population levels e.g. colored sticky boards (white, blue or yellow are attractive to thrips) are commonly used to sample thrips populations;
- disease organisms – inspection for presentation of symptoms.

Knowledge of pest levels allows for timely and appropriate control measures to be implemented, thus adding to risk reduction.

8.2.2 In-Field Sanitation

In-field sanitation requires the removal of fallen fruits, debris, weeds and other undergrowth that can harbor disease or pests from around and between *Citrus* trees. Any infected growth on *Citrus* trees should be pruned out and removed from the orchard for disposal. Regular inspection and pruning of trees facilitates the health and growth by removing dead and weak wood, reducing the incidence of various fungal diseases and allowing in more sunlight. Fallen fruits should also be removed for disposal to reduce inoculum sources for disease, and breeding sites of fruit fly. In China fruit fly infested fruit was handpicked, buried to a depth of one meter and insecticide sprayed on the soil surface. Fruit that had dropped and decayed on the ground were sprayed with insecticide to kill emerging larvae and pupae. This procedure reduced fruit fly infestations in the orchards.

8.2.3 Pest Control Measures

Commercial orchard operations usually have spray programs which operate in conjunction with monitoring. When pests or diseases reach a volume over a set percentage on the tree, the grower will use insecticide, fungicide or mineral oil sprays for control. Other forms of control that can be used are pheromone disruption for specific invertebrates such as certain moth species or scale insects, and the introduction of biocontrol agents such as entomophagic fungi or parasitizing invertebrates.

Insecticidal and/or fungicidal dips can be used as part of the pack house process. New treatments are always becoming available. For instance, Limonene (an extract from *Citrus* peel) has promise as an in-field spray treatment or post harvest dip against mealy bugs and scale as it can penetrate the insect's waxy covering. The limiting factor is phytotoxicity to certain plants and as yet *Citrus* leaves and fruit have not been tested.

8.2.4 Washing and Fruit Coatings

Harvested fruit should be trimmed of any leaves or stem and well washed to remove any superficial dirt, plant debris, pests and pathogens. The water should be clean and contain the appropriate concentration of sanitizers to minimize the transmission of pathogens from water to fruit, from infected fruit to healthy fruit within a single batch and from one batch of fruit to another batch over time. Adding surfactants to water increases the washing efficacy. Surfactants break the surface tension allowing water to reach otherwise protected areas such as under the calyx. The waxy coating on grape mealy bugs and woolly aphids were reduced when in contact with a particular organosilicone surfactant.

Coatings such as an approved food grade wax applied to fruit can be used in addition with other measures to reduce the likelihood of entry of hazard organisms. Citrus Lustr 402 has been shown to kill *Anastrepha ludens* immature in grapefruit, possibly by inhibiting gaseous exchange, but is not considered sufficient as a quarantine measure on its own. Coatings could be incorporated as a component of an integrated systems approach to quarantine security where a series of pest infestation reducing steps decrease the risk to insignificant levels.

Gould and McGuire (2000) tested 4 different coatings (2 petroleum based, 1 vegetable oil and a soap) on limes. The coatings were applied at a 3% (vol:vol) rate in 10L of water. The limes, in groups of 60 were immersed for 10 minutes, removed and rinsed with tap water for 10 minutes then held for 2-3 days. Mortality of nymphs and adult mealybugs was then assessed. Results varied between 30-65% mortality. However one petroleum oil, AMPOL (Caltex Australia, Sydney, New South Wales) provided 94% mortality, although the number of invertebrates tested is not stated. The very low number of dead and living invertebrates recovered from the treatments versus controls implied the oil repelled the invertebrates causing them to leave the fruit. As quarantine measure the AMPOL coating does not provide 99.9968% mortality (probit 9), however, applied as a postharvest dip before shipment it is thought it would reduce the number of actionable pests. An additional benefit of coating fruit is the decrease of moisture loss from the fruit during cool storage or during cold disinfestation treatment.

It was noted that limes imported into the USA from Chile undergo a soapy water wash and wax treatment against *Brevipalpus chilensis* (Chilean false spider mite). The treatment schedule specifies a 20 seconds immersion in a soapy water bath of one part soap solution to 3,000 parts water. This is followed by a pressure shower rinse to remove excess soap. The fruit is then immersed for 20 seconds into an undiluted wax coating. This coating must cover the entire fruit.

To conclude, water used for washing should be fortified with sodium hypochlorite to ensure that pathogen transfer is minimized. The use of surfactants increases the efficacy of the washing process, so will contribute to reducing risk. Wax coatings minimize risk further and provide some protection for the fruit from chilling or moisture loss.

To increase the effectiveness of washing, fruit should be submersed in the water, and brushed to remove any superficial invertebrates or dirt. Washing and coatings are a component of a systems approach towards risk mitigation of hazard organisms.

8.2.5 Visual Inspection and Culling of Imperfect Fruit

Visual inspection can happen along the whole production and post harvest pathway. In-field monitoring and selection by certain criteria at harvest are considered good orchard practice. If the washing process is conducted by hand this also allows for visual inspection to ensure the fruit meet export standard. The grading process enables a final check and selection. Each batch of fruit is then subject to quarantine inspection in the country of export. Visual inspection is useful for identifying imperfections and abnormalities in the commodity that may indicate the presence and/or effect of hazard organisms.

8.2.6 Conclusion

The production and postharvest measures, in combination with other procedures constitute elements of a systems approach, and can be combined with an approved treatment such as High Temperature Forced Air or Cold Disinfestation. Whilst information is not available to determine the degree by which production and post harvest measures would reduce the likelihood of entry of hazards associated with *Citrus* fruit, it is assumed they will reduce risk over time and can therefore be considered as a supplement to other risk management measures.

8.3 Visual Inspection at the Border of Bangladesh

Visual inspection by a trained inspector can be used in three main ways for managing biosecurity risks on goods being imported into Bangladesh, as:

- A biosecurity measure, where the attributes of the goods and hazard organism provide sufficient confidence that an inspection will be able to achieve the required level of detection efficacy;
- An audit, where the attributes of the goods, hazard organisms and function being audited provide sufficient confidence that an inspection will confirm that risk management has achieved the required level of efficacy;
- A biosecurity measure in a systems approach, where the other biosecurity measures are not able to provide sufficient efficacy alone or have significant levels of associated uncertainty.

In the case of inspection for audits, this is considered a function of assurance and is part of the implementation of the identified measures. Inspection as a biosecurity measure uses the direct comparison of required efficacy to manage risk versus actual efficacy of an inspection (maximum pest limit versus expected measure efficacy).However in practice it is not possible to precisely define either efficacy or pest limits.

The following chapters consider the ability of visual inspection to detect the individual hazards both prior to export and upon arrival in Bangladesh.

Inspection as a biosecurity measure in a systems approach is anticipated as being part of the production and post harvest management system. It could act either directly, as a top-up to the efficacy achieved by other measures in the system, or indirectly as a check to ensure an earlier measure was completed appropriately. In the latter case an appropriate inspection for the target organism may not be practical (the sample size may be too large) and an indirect sign of less-than-adequate efficacy may be used.

Examples of indirect indications of failed treatments include:

- Surviving non-target organisms that are more easily detected;
- Symptoms of infestation such as frass.

8.4 High-Temperature Forced-Air (HTFA) Treatment

8.4.1 Introduction

Heat treatments for quarantine pests have been used on a variety of fresh agricultural and horticultural commodities for more than 70 years. HTFA has primarily been used to kill eggs and larvae of certain fruit fly species found in the centers of fresh fruit prepared for export. It has subsequently been used for other invertebrate quarantine pests. These methods lost favor when fumigants such as ethylene dibromide (EDB) and methyl bromide (MB) became more convenient. EDB use was discontinued in the mid 1980s because of concerns with carcinogenicity and MB is being phased out having been identified as causing significant ozone depletion. This has necessitated the return of heat treatments and instigated further research into other alternatives.

8.4.2 Mode of Action

HTFA treatment uses forced hot air across the surface of the fruit to raise the core temperature to a specified level for a set duration. Heat transfer is by convection with relative humidity sometimes as low as 30% to avoid desiccation of the commodity. Ideally the dew point should be 2-3°C below the fruit surface temperature to maintain appropriate humidity. Unlike vapor heat treatment no condensation should form on the produce surface during treatment. Dry heat treatment is different again and should not be confused with HTFA as it has no added humidity and is usually operating at 80-100°C.

There is a ramping up time (sometimes of several hours) for the chamber temperature to reach the target temperature. The length of this time differs for a few reasons such as the size and number of fruit within the chamber, variation between chambers and different target temperatures.

8.4.3 Description of the HTFA Chamber

Air circulation in the HTFA chamber is unidirectional from the bottom of the stacks through the fruit to the top and is heated by hot water (50-60°C) pumped through a heat exchanger. Sensors regularly monitor and adjust relative humidity. If additional moisture is required clean water enters the system by two small misting nozzles and vaporizes into the circulating air. The chamber ceiling is insulated to avoid condensate forming and dripping onto fruit.

Condensate forming on walls leaves via floor drains that have a fitted water trap to prevent fruit fly access. Once treatment is complete the fruit in the chamber is hydro-cooled. Clean, filtered water is sprayed through jets fitted just above the top shelf of fruit. Probe sensors monitor the internal temperature of the commodity which provides the base data for the treatment determined by the computer. The computer runs specifically designed software for data acquisition, analysis and system control.

8.4.4 Treatment Efficacy Experiments

In some of the efficacy experiments mentioned below, the entire time for treatment is given, and in others the researchers refer only to the time it takes to kill the target pest, eg: this may be 20 minutes at the target temperature out of the several hours it takes to reach the target temperature. This causes some difficulty in comparing results. Other fruit species and plant material are considered here because either they are part of the founding research for testing *Citrus* fruit with HTFA or they provide data for certain pests and pathogens (eg: moths, mites, thrips, fungi) also associated with *Citrus*. Time/temperature treatments that are lethal to some target pests in specific fruits without compromising the quality and appearance of these fruits have been established (table 4). *Citrus* fruits can vary widely in their heat tolerance, even within the same variety. For instance; early, mid and late season grapefruit were treated with hot air at 46, 48 and 50°C for 3, 5 or 7 hours, showing early and late season grapefruit were more easily damaged than midseason fruit. 'Oroblanco' fruit suffers extensive damage at 47°C and some minor damage at 44°C which may be alleviated by rapid cooling. Valencia oranges can be heated at 44°C for 100min or 46°C for 60 min with no damage. Thus each treatment schedule should be specifically tested on the fruit that needs disinfesting to ensure that it will effectively meet quarantine requirement and not cause damage to the product.

8.4.5 Efficacy against Fruit Fly in Citrus

Marsh grapefruit have been treated with HTFA at 48 ± 0.3°C for ≥ 150 minutes, until the centre pulp reached ≥ 44°C and killed Caribbean fruit fly *Anastrepha suspensa* (Loew) eggs (not quantified) and 11,991 larvae. Hydrocooling of the fruit did not reduce the effectiveness of the heat treatment. 100% mortality of 113, 676 mature third stage instars of *Anastrepha suspensa* was achieved when Florida grown Golden Navel oranges were heated with 48 ± 0.3°C forced air until the centre pulp temperatures were ≥ 44°C.

"Dancy" tangerines at an air temperature of 45°C took a mean of 115 minutes to reach the same temperature at the fruit centre, "Valencia" oranges and "Rio Star" grapefruit at 46°C required a mean of 145 and 220 minutes respectively to reach 45°C at the fruit centre. It was found that holding the fruit centre temperature at 45°C for100 minutes would enable > 99.9968% mortality of Mexican fruit fly *Anastrepha ludens* (Loew).

For control of Mediterranean fruit fly *Ceratitis capitata* unwaxed Oroblanco fruit (triploid pummelo-grapefruit hybrid) can be heated to 44°C for 60 minutes with minor heat damage to the peel but no other quality loss. This killed the first instars, considered the most heat resistant form of *C. capitata* from mortality tests the researchers carried out. If conducted in 0.05% oxygen the temperature could be reduced to 43°C, with a treatment time of 30 minutes and still be effective, thus reducing the effect on the peel. This study was done in a CATTS (Controlled Atmosphere Temperature Treatment System) chamber and the researchers do not specify whether their final statement was based on atmosphere comparable with a standard HTFA chamber.

8.4.6 Efficacy against Fruit Fly in Papaya

Probit 9 is the probability of one individual surviving treatment from an estimated treated population of 30,000 at the 95% Confidence Level. Armstrong *et al.* (1989) tested eggs; first and third instar life stages of Mediterranean fruit fly *Ceratitis capitata*, melon fly *Bactrocera cucurbitae* and oriental fruit fly *Bactrocera dorsalis* in papaya under HTFA treatment. When the core temperature of the fruit reached 47.2°C there was one survivor each of *Ceratitis capitata*, *Bactrocera cucurbitae* and *Bactrocera dorsalis* from estimated treated populations of 328,071; 329,984 and 322,918 individuals respectively. This exceeded the probit 9 standard. This study used 4 air temperature stages to reach the target temperature of 47.2°C. Armstrong (1990) repeated the study using 50,000 eggs and 50,000 first instar larvae of *C. capitata* and *B. dorsalis* at one air temperature stage (to reach 47.2°C) reducing the overall time and achieving 100% mortality. He also determined that Pummelo, mango and atemoya tolerated the target temperature with no indication of external or internal damage. Complete mortality of 17,750 eggs of *Bactrocera melanotus* and *Bactrocera xanthodes* in papaya was achieved at 47.2°C (fruit centre temperature) for 20 minutes. This method was considered effective for disinfesting papaya of any potential *B. melanotus* and *B. xanthodes* fruit flies.

8.4.7 Other Pest Species and Commodities

Other species that have been killed by hot air treatment are light brown apple moth *Epiphyas postvittana*, longtailed mealybug *Pseudococcus longispinus*, greenhouse thrips *Heliothrips haemorrhoidalis* and *Thrips obscuratus*. Air temperatures between 48-50°C for about 4 hours (including a 2 hour warming up period) were required to kill 99% of fifth instar light brown apple moth and longtailed mealybug found on persimmons. Mixed life stages of the ite *Rhizoglyphus robini* on freesia corms suffered 100% mortality at 45°C for 24 hours hot air treatment. One thousand five hundred and thirty *Orthotydeus californicus* adults underwent hot air treatment at 40°C for 89 minutes achieving 99% mortality. It was taken 10 hrs at 45°C to achieve mortality of two-spotted mites in hot air, recognizing that these mites seemed quite heat tolerant and this may well be a factor of their long preheat warm up exposure. HTFA at 46°C for 5 hours delayed the development of green mould *Penicilium digitatum* on grapefruit. However, there is no evidence of HTFA being a suitable tool for disinfestation of fungi from produce.

8.4.8 Factors Affecting Treatment Efficacy

Both static and ramped pre-treatments can heat-condition the quarantine pest thereby having a significant effect on the efficacy of the heat treatment. The temperature experienced by insects inside fruit is effectively that of ramped heating. The location of the pest within the fruit, the thermal conductivity of the fruit, the heat transfer coefficient at the fruit-medium interface and the medium (air or water) temperature, all affect the potential for thermo tolerance and the time taken to mortality.

8.4.9 Effects of HTFA Treatment on Citrus Fruit

Most of the data available for *Citrus* fruit that has been treated with HTFA has come from research targeting *Anastrepha* species of fruit fly. Navel and other oranges, tangerines and grapefruit can be treated using HTFA by increasing the fruit centre temperature to 44°C within a minimum approach time of 90 minutes, and keeping it at 44°C or hotter for 100 minutes (Table 18). However, for treatment targeting *Ceratitis capitata, Bactrocera dorsalis* and *B. cucurbitae* fruit centers are required to reach 47.2°C by constant or increasing temperature for at least 4 hours. Of the *Citrus* species tested to date, grapefruit has shown the highest tolerance to the treatment and pummelo at 47.2°C tolerated HTFA with no external damage.

This suggests *Anastrepha* species die at the lower fruit core temperature (44°C for a determined time) whereas a higher temperature (47.2°C for 20 minutes) is required for mortality of *Bactrocera* species. The *Citrus* being treated will need to reach a core temperature of 47.2°C (thus an air temperature that is 2-3°C higher) and be held at that or slightly higher for 20 minutes, then cooled. This whole process will most likely take around 6 hours. It is uncertain all 7 species of *Citrus* considered in this risk analysis will tolerate this treatment without some damage to the fruit. The

USDA manual advises that users of this treatment should test the specific cultivar to determine how well it will tolerate the required heat treatment.

Lemons and limes do not appear to have been tested by HTFA treatment. Lemons are reasonably resistant to *Anastrepha suspensa*, but do host other fruit fly species such as *Ceratitis capitata* and *Bactrocera orientalis*. Both lemons and limes carry other potential hazard organisms such as scale, mites and mealybugs.

8.4.10 Conclusion

A number of potential hazard species have been tested, achieving 99-100% mortality using HTFA (a summary is shown in Table 18) without significant damage to the commodity.

A narrow margin exists between the high or low temperature that is needed to kill the pest and the tolerance of the infested commodity to the treatment. Therefore it is essential the exposure temperature and exposure time are determined and applied precisely (Sharp 1993). This is especially important for any untested organisms or commodities where this treatment has been proposed.

High-temperature forced-air is approved as a method of disinfestation for quarantine purposes of certain fruit fly in a number of commodities by APHIS-USDA, and MAF Biosecurity New Zealand accepts this method for fruit fly (*Bactrocera melanotus* and *B. xanthodes*) disinfestation in papaya from the Cook Islands and breadfruit from Samoa.

However, as a method for disinfestation of *Bactrocera* species in *Citrus* there is no supporting literature at this time to suggest that the fruit condition and appearance will not be significantly affected by HTFA. Most countries dealing with *Bactrocera* species in *Citrus* are using cold disinfestation treatments instead.

Table 18: Efficacy of HTFA treatment for certain potential hazard organisms on a variety of fresh fruit

Target quarantine pest species	Fruit	Forced air temp. (^{0}C)	Fruit core temp. (^{0}C)	Duration of treatment (Min.)	% ED
Anastrepha ludens (Loew) Mexican fruit fly	Dancy tangerine	Not given	45	100*	99.9971
	Rio Red grapefruit	Not given	46	100*	99.9968
	Valencia orange		46	100*	99.9970
Anastrepha suspense (Loew) Caribbean fruit fly	golden Navel orange	48 ± 0.3	≥ 44	105#	99.9986
	Marsh grapefruit	48 ± 0.3	44	≥ 150	not given
Bactrocera cucurbitae Coquillett - melon fly	Papaya	43-49 48-48.5	47.2 47.2	210-420# 210-420#	99.9985 99.9970
Bactrocera dorsalis Hendel - oriental fruit fly	Papaya	43-49 48-48.5	47.2 47.2	210-420# 210-420#	99.9985 99.9970
Bactrocera melanotus (Coquillett)	Waimanalo papaya	Not given	47.2	20*	99.9831
Bactrocera xanthodes (Broun) - Pacific fruit fly	Waimanalo papaya	Not given	47.2	20*	Assumed to be the same as above
Ceratitis capitata (Weidemann) - Medfly	Papaya	43-49 48-48.5	47.2 47.2	210-420# 210 ± 25#	99.9985 99.9970
Ceratitis capitata (Weidemann) - Medfly	Oroblanco	Not given	44	60*	not given

Target quarantine pest species	Fruit	Forced air temp. (^{0}C)	Fruit core temp. (^{0}C)	Duration of treatment (Min.)	% ED
Epiphyas postvittana Walker - light brown apple moth	Persimmon	48-50	Not applicable	240#	not given
Pseudococcus longispinus Targioni-Tozetti - long tailed mealybug	Persimmon	48-50	Not applicable	240#	not given

Note: ED means the estimated effect of this treatment on a population at a 95% CL and is expressed as xx.xxxx% (Couey and Chew, 1986)
*** refers to the lethal exposure time within the total time of treatment.**
 # refers to the total time of treatment.

8.5 Hot Water Immersion (HWI)

This treatment has mostly been used as a postharvest microbial disease control rather than insect control. However hot water is a more effective heat transfer medium that hot air and, when properly circulated through the load of fruit, quickly establishes a uniform temperature profile.

8.5.1 HWI for Microbial Disease Control

Phytophthora citrophthora on grapefruit was controlled by HWI at 48°C for 3 minutes and *Penicillium digitatum* on lemons by HWI at 52°C for 5-10 minutes. On oranges *Diplodia* sp., *Phomopsis* sp. and *Phytophthora* sp. were treated at 53°C for 5 minutes, although this resulted in poor degreening and only reduced incidence of decay by about 50%. Young infections of *Phytophthora palmivora* on papaya are difficult to recognise and frequently escape culling. An experiment they conducted showed *P. palmivora* inoculations of 24 hrs old are efficiently eradicated using HWI at 48°C for 20 minutes, but 30% of papayas with 48 hr old inoculations developed disease 3 days after the HWI. Although the pathogen was sensitive to the treatment it may have survived in deep-seated infections as the heat failed to penetrate the large fruit mass.

8.5.2 HWI for Invertebrate Control

Hot water immersion (HWI) has been suggested as a suitable method for disinfestation of mealybugs on limes. In the trial 7,200 limes were treated at 49°C for 20 minutes by hot water immersion, and 1,308 insects were killed with zero survivors providing an effective dose mortality of 99.7706% at a 95% confidence level. Included in the arthropods that were killed by this treatment were small numbers of Coleoptera, Hymenoptera, Lepidoptera, Thysanoptera and unidentified mites found externally or under the calyx.

Similar results have been found using this treatment on cut flowers for disinfestation of scale, aphids, thrips, ants and mealybugs. Aphids infesting red ginger flowers were destroyed after a HWI at 47°C for 5 minutes treated bird of paradise flowers by HWI for 10 minutes at 49°C obtaining 100% mortality (11,150 adult females, 22,622 nymphs, 14,077 crawlers and 54,506 eggs) of the magnolia white scale *Pseudaulacaspis cockerelli.* HWI at 49.5°C for 15 seconds and 20 seconds reduced the mean number of thrips per *Dendrobium* blossom by 88% and 95% respectively. The limiting factor in this case was phytotoxicity. It was concluded that for *Dendrobium* cultivars HWI could be used as part of a systems approach rather than a standalone disinfestation treatment.

HWI has been used on papaya for disinfestation of fruit flies. However this does not appear to have been fully tested in *Citrus* fruit. Therefore HWI should not be considered for use against internal hazard organisms in *Citrus* until there is evidence to support that an acceptable level of protection can be achieved

8.5.3 Conclusion

It is clear there are some limitations around the use of HWI as a standalone treatment. It is not yet determined suitable as a disinfestation treatment for internal hazard organisms in *Citrus* fruit. Although useful in the control of postharvest fungal diseases it appears to be less effective on deeper seated infections, which increases the level of residual risk. As the tolerance of *Citrus* (other than limes) to this treatment is uncertain it would be useful to have further research undertaken in this area.

8.6 Cold Disinfestation

Cold disinfestation has the advantage of being applied in two or three ways. The treatment can be carried out entirely in the exporting country; in transit; or in a combination of these options. Many tropical fruits are intolerant of cold treatment for the length of time required for disinfestation of the insects. Most *Citrus* fruit is compatible with cold disinfestation but grapefruit, lemon and lime show little tolerance for it. Most *Citrus* fruit from other countries exported to the USA undergoes cold disinfestations between 0°C-2.2°C for 11 up to 22 days depending on the species of fruit fly targeted (*B. tryoni, Anastrepha* spp., *C. capitata*).

Research on Eureka and Lisbon lemons showed *Bactrocera tryoni* and *Ceratitis capitata* were killed at 12 or 14 days respectively at 1°C ± 0.2°C. Mortality was 100% with no pupal development. Valencia and Navel oranges treated for 16 days at 1°C ± 0.5°C achieved 100% mortality of the most cold-tolerant life stages of *B. tryoni* and *C. capitata*. Cold disinfestation against *B. tryoni* and *C. capitata* showed that mandarins treated for 16 days at 1°C achieved probit 9 efficacy. This could also be achieved in 14 days at the same temperature or in 16 days at a slightly higher temperature.

Currently, Australian *Citrus* fruit for export receiving cold disinfestation against Mediterranean fruit fly *C. capitata* and the Queensland fruit fly *Bactrocera tryoni* undergoes 16 days at 1°C (oranges, mandarins and tangelos) or 14 days at 1°C (lemons). The Australian *Citrus* industry found that in order to cold disinfest *Citrus* at 1°C the thermostats needed to be set at 0.4°C in the cold rooms or refrigerated containers (reefers), and as the probe records can vary by ± 0.6°C fruit suffered damage when the temperature dropped below 0°C for any time. If temperatures could be elevated slightly, without compromising the quarantine efficacy there would be a bit more flexibility of treatment, with less damage to the fruit.

Results of large-scale export trials on 5 citrus cultivars (Navel and Valencia oranges, Murcott and Ellendale mandarins, and Lisbon lemons) at 2°C and 3°C against *Ceratitis capitata* and *Bactrocera tryoni* revealed that 2nd instar *C. capitata* and 1st instar *B. tryoni*, as these are the most cold-tolerant stages of both fruit fly species. The total number of fruit used in this trial is given for *C. capitata* (126,400) but no total number of fruit for *B. tryoni* is stated. For *C. capitata* each replicate trial consisted of 420 cartons each containing ~120 fruit (19kg), stacked on pallets as 10 cartons per layer, and 7 layers high (70 cartons/pallet), and 6 pallets per cold room. A similar procedure (not described) was used for testing against *B. tryoni*.

Treatment periods were selected based on consecutive 100% mortalities of the most tolerant life stage, for each species, as established in previous trials. For *C.capitata* this was 2°C for 18 days and 3°C for 20 days for oranges and mandarins, and 2°C for 16 days and 3°C for 18 days for lemons. For *B. tryoni* the oranges and mandarins received 16 days at 2°C and 3°C and lemons 14 days at both temperatures. Lemons appeared not as favorable to *B. tryoni* females as mandarins. The criterion used to assess the success of the treatment was the inability of 'surviving' larvae to produce apparently normal puparia.

All life stages of *B. tryoni* are killed in 12 days at 1°C no decrease in mortality with an increase in temperature from 1°C to 2°C and 3°C was found. In fact, 12 days at 2.8°C ± 1.1°C resulted in complete mortality of pre-adult life stages of the Oriental fruit fly *Bactrocera dorsalis* and the same result was achieved for melon fruit fly *B. cucurbitae* at 2.8°C ± 1.1°C for 10 days. It was concluded that cold disinfestation treatment for 16 days below 3°C provided 95% confidence of being effective against *C. capitata* and *B. tryoni* in oranges, mandarins and lemons.

Japan has accepted cold treatment of 3°C or less for 16-20 days for fruit fly disinfestation of *Citrus* exported from Australia. The AQIS advice to industry notice (No. 2007/34 Horticulture Japan Citrus Exports: 21 Sept 2007) gives the revised treatment schedule as below (Table 19):

Table 19: AQIS Advice to Industry Notice Cold Treatments for Citrus

Schedule	Fruit pulp temperature (^{0}C)	Exposure period (consecutive days)	Commodities
1	1^{0}C or below	16	Fresh Sweet Oranges, Imperials, Ellendales, Murcots and Minneolas of the Valencia or Washington Navel Varieties
2	1^{0}C or below	14	Fresh Lemons
3	2.1^{0}C or below	18	Fresh Sweet Oranges, Imperials, Ellendales, Murcots and Minneolas of the Valencia or Washington Navel Varieties
4	2.1^{0}C or below	16	Fresh Lemons
5	3.1^{0}C or below	20	Fresh Sweet Oranges, Imperials, Ellendales, Murcots and Minneolas of the Valencia or Washington Navel Varieties
6	3.1 ^{0}C or below	18	Fresh Lemons

Low temperature treatments and exposure period may vary with the transit time required for importing citrus fruits.

C. aurantiifolia is very susceptible to cold and *C. latifolia* is hardier in the orchard situation. Under refrigeration at 7°C, *C. aurantiifolia* suffers chilling injury and *C. latifolia* will remain in good condition for 6-8 weeks, although a temperature is not given for the latter. However, there seems to be no supporting literature that suggests Tahitian limes (*C. latifolia*) would tolerate cold disinfestation for fruit fly.

The IPPC Technical Panel for Phytosanitary Treatments (IPPC-TPPT) recently reviewed, approved and recommended the cold disinfestation treatments for *Citrus* of 2°C and 3°C (duration specific to fruit and fruit fly) for consideration of inclusion in the International Treatment Standard. The efficacies of these treatments against both *C. capitata* and *B. tryoni* are shown in Table 20.

Table 20: Efficacies of Cold Treatments for Some Citrus Fruits (DeLima *et al*. 2007)

***Citrus* species and cultivar**	**ED at 2ºC**	**ED at 3ºC**
Mediterranian Fruit Fly (*Ceratitis capitata* (Wiedemann)**)**		
Orange ‘Valencia’ (*Citrus sinensis*)	99.9979 (18 days)	99.9979 (20 days)
Orange ‘Navel’ (*Citrus sinensis*)	99.9982 (18 days)	99.9980 (20 days)
Orange ‘Washington Navel’, ‘Salustiana’ and ‘Lue Gim Gong’ (*Citrus sinensis*)	99.9917 (21 days)	--
Lemon ‘Lisbon’ (*Citrus limon*)	99.9977 (16 days)	99.9975 (18 days)
Tangor ‘Ellendale’ and ‘Murcott’ (*Citrus reticulata* and *Citrus sinensis* x *C. reticulata*)	99.9972 (18 days)	99.9972 (20 days)
Clementinas Group’ (*Citrus reticulata,* Clemenule) ‘Nova’ (*C. reticulata* x Tangelo)	99.9918 (23 days)	--

'Orlando' (*Citrus reticulata* x *C. paradisi)*		
Grapefruit (*Citrus paradisi*) 99.9917 (19 days) 99.9916 (23 days)	99.9917 (19 days)	99.9916 (23 days)
Queensland Fruit Fly (*Bactrocera tryoni* (Froggatt)**)**		
Orange 'Valencia' (*Citrus sinensis*)	99.9960 (16 days)	99.9976 (16 days)
Orange 'Navel' (*Citrus sinensis*)	99.9973 (16 days)	99.9973 (16 days)
Lemon 'Lisbon' (*Citrus limon*)	99.9935 (14 days)	99.9928 (14 days)
Tangor 'Ellendale' and 'Murcott' (*Citrus reticulata* and *Citrus sinensis* x *C. reticulata*)	99.9968 (16 days)	99.9968 (16 days)

8.6.1 Conclusion

This treatment is in wide use for *Citrus* fruit. Although this treatment has tested mortality of *B. tryoni*, it is thought, given *B. tryoni* is considered one of the more cold tolerant of the *Bactrocera* fruit flies that this treatment would be suitable against *B. kirki* and *B*. *xanthodes.* Cold disinfestation will be suitable for oranges, mandarins, tangelos, lemons and grapefruit within strictly defined temperature regimes. However, there are no data available for Pummelo, and limes will not tolerate this treatment.

8.7 Fumigation

Methyl bromide is being phased out of use as a biosecurity treatment and is known to be phytotoxic to *Citrus*. Alternative fumigants for fruit fly disinfestation of *Citrus* were investigated by Australian researchers. Phosphine fumigation had potential for disinfesting *Citrus* of fruit fly. Using *Bactrocera tryoni* larvae in Washington navel oranges 99.998% mortality was achieved with exposure of more than 48,000 larvae over 48 hours at 23 or 25°C to phosphine concentrations of 1.67g m^{-3}, topping up to ~ 0.7 g m^{-3} after the first 24 hours. No adverse effects on the oranges were observed. Grapefruit have also been fumigated at concentrations sufficient to kill *Anastrepha suspensa* (Caribbean fruit fly) without causing injury to the commodity.

8.7.1 Conclusion

Phosphine is approved for use on particular perishables in certain countries and appears to be a promising option. Further research of this could prove useful. However the USDA treatment manual still uses methyl bromide for disinfesting *Citrus*.

8.8 Assessment of Residual Risk

Residual risk can be described as the risk remaining after measures have been implemented.

Assuming:

- The measures have been implemented in a manner that ensures they reduce the level of risk posed by the hazard(s) to a degree anticipated by the risk analysis; and
- The level of risk posed by the hazard(s) was determined accurately in the risk assessment.

The remaining risk while being acceptable may still result in what could be interpreted as failures in risk management. There are a range of risk management measures, or combinations of measures which will reduce the risk associated with this pathway by varying amounts. Whatever options are chosen it is advisable to monitor whether the residual risk is the expected level. Residual risk information in this case would be interception data from the *Citrus* consignments coming into Bangladesh from India, Bhutan, China, Pakistan, Egypt, South Africa, USA and Australia.

8.9 Assumptions and Uncertainties

The major uncertainties encountered in this risk analysis are identified here. The assumptions made to take account of them are explicitly identified where relevant in the text.

8.9.1 Hazard Biology and Identification

The biology of insects that have been reared in the laboratory for several generations is often different to wild counterparts established in field conditions (Mangan and Hallman, 1998). Aspects such as life cycle, preovipositional period, fecundity and flight ability, as well as cold or heat tolerance can be influenced by the highly controlled laboratory environment. Laboratory reared insects may differ in their responses to environmental stress and exhibit tolerances that are exaggerated or reduced when compared with wild relatives. For example longevity and fecundity of adult *Aphis gossypii* in a greenhouse was longer and higher than those in a growth chamber with similar conditions (Kim and Kim, 2004).

If a pest species occurs in Bangladesh often its full host range or behaviour in the colonized environment remains patchy. It is difficult to predict how a species will behave in a new environment, particularly if it has not become established as a pest elsewhere outside its natural range. Therefore there will be considerable uncertainty around the likelihood of an organism colonizing new hosts or the consequences of its establishment and spread on the natural environment. Where indigenous plants are discussed as potential hosts this is extrapolated from the host range (at genus and family level) overseas and is not intended as a definitive list.

Where there is uncertainty about the identity of an organism, e.g. *Prays citri* vs *P. nephelomima*, the more serious pest is considered in the RA. The conclusions may need to be revisited if evidence to the contrary becomes available.

There is uncertainty around the efficacy of risk management measures for many of the hazards identified in this Risk Analysis. In some cases efficacy data for similar species has had to be used.

8.9.2 Assumption Regarding Transit Time of Fruit on the Air Pathway

An assumption is made around the time the fruit takes to get from the field in India/ Bhutan / China / Pakistan / USA / Australia/ South Africa / Egypt to Bangladesh ready for wholesale if it is transported by air-carrier. It is assumed that the harvesting, treatment, packing and transit of *Citrus* fruit from the above countries, inspection and release in Bangladesh will take a minimum of 3 days, and on average will take 5 days.

8.9.3 Assumption and Uncertainty around Disposal of Infested Fruit

It is not known what proportion of imported *Citrus* will be consumed or discarded. It is assumed that a proportion of *Citrus* that is infested or damaged will be disposed of in a manner that exposes any potential hazard organisms on that fruit to suitable hosts. Disposal would include discarding fruit or peel on urban or rural roadsides, in bush reserves, in open rubbish bins in public places, and on open composts in domestic areas.

8.9.4 Assumption and Uncertainty around Risk Management Measures

A lot of uncertainty exists around the efficacy of risk management measures. Interception data is one way of estimating efficacy, as records of live and dead organisms indicate the success of a treatment and the thresholds for growth and development of each individual organism. A sample audit is required to monitor efficacy. Currently this is 600 units of fruit/vegetable product per consignment. The assumption is that this monitoring will adequately record type and number of organisms associated with each fresh produce commodity.

This approach makes the following assumptions, that:

- The consignment is homogeneous (fruit are harvested inspected and packaged in similar conditions, and have received similar treatments before arrival into Bangladesh). Heterogeneous or non-randomly distributed consignments would require a higher sampling rate to achieve the same confidence levels. Level of sampling depends on the degree of heterogeneity;
- The samples are chosen randomly from the consignment;
- The inspector is 100 percent likely to detect the pest if it is present in the sample. Because of uncertain distribution of pests within the consignment some pests will not be detected if they are present outside the 600 unit sample. Some pests are difficult to detect because of their small size and behaviors;
- It is acceptable that the sampling system is based on a level (percentage) of contamination rather than a level of surviving individuals;
- Because for lines of less than 600 units, 100 percent inspection is required, it is therefore acceptable that the effective level of confidence gained by the sampling method significantly increases as the consignment size moves below 10,000. This is because a sample of around 590 provides 95 percent confidence that a contamination level of 1 in 200 (0.5 percent) will be detected in consignments larger than about 25,000 individuals.

Interception records can rarely be used quantitatively because of limitations in the identification and recording processes.

There is a paucity of information on the efficacy of the available risk mitigation options in managing the hazards associated with *Citrus*. In the absence of efficacy data, assumptions are made on the basis of data for similar species or similar treatments.

8.9.5 Assumption around Citrus spp. Grown in Bangladesh

Discussion with the main growers (David Austen, Alan Booth & John Prince pers. Comm. June-July 2007) suggests fewer than 15 citrus trees reported to fruit are grown in Bangladesh. There are likely to be less than 40 trees in total cultivated here. Appropriate conditions for the growth and development of successfully fruiting trees include high temperatures in summer and constant moisture for the roots (David Austen pers. comm. July 2007). These conditions are met in a small number of areas in Northland and Bay of Plenty. Only one variety (Brewster 3) sets fruit unassisted and with any regularity.

It is assumed from the small number of isolated specimens, their slow growth in New Zealand and restricted ability to grow mature fruit set seed that they would present a minimal risk of providing host material to potential pests and pathogens imported on litchi from Taiwan. Should more trees be planted in future or cultivated for commercial purposes this assumption will need to be reviewed.

9.0 Potential Hazard Organisms: Risk Analyses

Fruit Fly

9.1 *Ceratitis capitata* (Mediterranean Fruit Fly)

9.1.1 Hazard Identification

Common name: Mediterranean fruit fly
Scientific name: *Ceratitis capitata* (Wiedemann) (Diptera: Tephritidae)
Synonyms : *Ceratitis citriperda* MacLea, *Ceratitis hispanica* Breme, *Pardalaspis asparagi* Bezzi, *Tephritis capitata* Wiedemann
Bangladesh status: Not known to be present in Bangladesh.

C. capitata is a highly invasive species. It has a high dispersive ability, a very large host range and a tolerance of both natural and cultivated habitats over a comparatively wide temperature range. It has a high economic impact, affecting production, control costs and market access. It has successfully established in many parts of the world, often as a result of multiple introductions (Malacrida *et al*., 2007). Frequent incursions into North America require expensive eradication treatments and many countries maintain extensive monitoring networks.

9.1.2 Biology

The eggs of *C. capitata* are laid below the skin of the host fruit. They hatch within 2-4 days (up to 16-18 days in cool weather) and the larvae feed for another 6-11 days (at 13-28°C). Pupariation is in the soil under the host plant, the adults emerge after 6-11 days (24-26°C); longer in cool conditions), and after adult emergence, ovarian development at 25^0C takes 5 days. The thermal constant for development from egg to adult is 26^0C. Adult C. capitata live for up to 2 months (field-caged), but this may well be an underestimate of their lifespan because wild-caught-adults brought into the laboratory had a lifespan longer than reference adults that had never been in the field. Mating success of *C. capitata* males can be improved by exposing them to the odor of orange or ginger root oil. Male *C. capitata* with access to a high-protein diet may also exhibit higher sexual performance, but this effect may vary according to fly genotype, experimental setting or environmental conditions.

9.1.3 Hosts

C. capitata is a highly polyphagous species and its pattern of host relationships from region to region appears to relate largely to what fruits are available. *Coffea spp*. are especially heavily attacked, although the attack on coffee does not impact on this crop as only the fleshy part of the fruit, which is discarded, is utilized by the larvae. However, the quality may be affected and in many areas coffee crops appear to act as an important reservoir from which other crops may be attacked. In some areas wild hosts are of importance, for example, box thorn, Lycium europaeum, is an important overwintering host in North Africa and 51 wild host species were recorded in Kenya. Citrus hosts are Citrus aurantiifolia (lime) Citrus aurantium (sour orange), Citrus limetta (sweet lemon tree), Citrus limon (lemon), Citrus limonia (mandarin lime), Citrus maxima (pummelo), Citrus medica (citron), Citrus nobilis (tangor), Citrus reticulata (mandarin), Citrus paradisi (tangelo), Citrus sinensis (sweet orange).

9.1.4 Distribution

Africa: Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Congo, Congo Democratic Republic, Cote d'Ivoire, Egypt, Ethiopia, Gabon, Ghana, Guinea, Kenya, Liberia, Libya, Madagascar, Malawi, Mali, Mauritious, Morocco, Mozambique, Niger, Nigeria, Reunion, Sao Tome & Principe, Senegal, Seychelles, Sierra Leone, South Africa, St. Helena, Sudan, Tanzania, Togo, Tunisia, Uganda, Zimbabwe; **Asia:** Cyprus, Israel, Jordan, Lebanon, Saudi Arabia, Syria, Turkey, Yemen; **Australia:** Western Australia; Hawaii, **Central American and Caribbean:** Costa Rica, El Salvador, Guatemala, Honduras, Jamaica, Netherlands Antilles, Nicaragua, Panama, Puerto Rico; **Europe:** Albania, Azores, Balearic Islands, Canary Islands, Corsica, Croatia, France, Greece, Italy, Maderia Islands, Portugal, southern Russia, Sardinia, Sicily, Slovenia, Spain, Yugoslavia; **South American:** Argentina, Brazil, Columbia, Ecuador, Paraguay, Peru, Uruguay, Venezuela.

Ceratitis capitata originated in sub-Saharan Africa. *C. capitata* is widespread in Africa and is endemic to most sub-Saharan countries. It was recorded from western Zambia and Namibia. The lack of records or reports of 'restricted distributions' in many African countries is likely to reflect the lack of observations rather than absence. The spread to Europe, Egypt, the Middle East, the Malagasy subregion, Australia and the Americas is likely to be a result of accidental transportation during trade. *C. capitata* was also recorded from the Mazandaran Province of Iran, where it was first detected in 1977 and also from the Comoros.

The first records from the Amazon area of Brazil were in 1996 for Rondonia and in 1997 for Para. It has been recorded intermittently in the Ukraine between 1937 and 1966, in California since 1975, in Florida since 1929 and in Texas since 1966. It has been argued that, despite numerous eradication campaigns, *C. capitata* is now established and widespread in California as small, barely detectable populations. In Chile it was present from 1963 to 1995. In New South Wales, Australia, it was first recorded in 1898 and had disappeared by 1948. In Queensland, Australia it was formerly present in the southeast and first recorded in 1909. It disappeared during the 1930s. Occasional outbreaks occur in South Australia. In Victoria, Australia it was first recorded in 1909 and had disappeared by the 1940s. It has been eradicated in New Zealand, but an outbreak occurred in 1996.

9.1.5 Hazard Identification Conclusion

C. capitata is an internationally recognized pest on a wide range of host plants. Many of its known hosts are common horticultural and garden species grown throughout Bangladesh. It also has potential to impact some native species. It is likely to have spread through international trade and should be able to establish and cause unwanted consequences in Bangladesh. With its high fecundity and mobility it is considered a potential hazard on fresh citrus fruits from Egypt, Middle East, South Africa, Hawaii, South America, European countries and Australia.

9.1.6 Risk Assessment

9.1.6.1 Entry Assessment

The major risk is from the import of fruit containing larvae, either as part of cargo, or through the smuggling of fruit in airline passenger baggage or mail. Private individuals who successfully smuggle fruit are likely to discard it when they discover that it is rotten. *C. capitata* eggs will hatch within 2-4 days of oviposition. Eggs laid inside *Citrus* fruits just prior to harvest are most likely to enter Bangladesh as larvae, given the time from harvest in South Africa, Egypt and Hawaii to arrival in Bangladesh would be 10-15 days. Since the egg to pupation period of *C. capitata* is 8-15 days. Therefore eggs laid in a Citrus fruit just prior to harvest and larvae feeding in fruit would be expected to survive given that transport time is likely to be no more than 15 days. The fly pupates in soil and the adults require a protein source to reproduce. The shipping pathway is temporally long reducing the likelihood of entry of adult and pupal life stages into Bangladesh. Air travel is much shorter and all life stages could potentially survive and enter the country.

9.1.6.2 Exposure Assessment

Citrus fruit are imported in Bangladesh from India, Bhutan, China, Pakistan, Egypt, South Africa, USA and Australia. A number of the host species used by *Bactrocera* and many other potential hosts are grown in this region, providing food and oviposition sites all year round. *Citrus* fruit will be distributed more widely after arrival so this increases exposure to host material. Waste fruit discarded onto open domestic compost increases the likelihood of exposure to local hosts and the spread of individuals. Longevity of adults, the overwintering strategy and their acclimation ability increase the likelihood of invading *Bactrocera* spp. mating and subsequently egg laying. Fallen fruits can also serve as major breeding sites and create a reservoir population. The likelihood of exposure is considered to be high. It is likely that exposure will be higher when waste fruit is discarded in a domestic compost heap and suitable hosts are grown in the same area.

9.1.6.3 Establishment Assessment

In undisturbed areas, *C. capitata* primarily occurs in woodland but it has successfully adapted to cultivated and urban areas. Its wide host range suggests an ability to utilize almost any type of fleshy fruit for larval development. It overwinters as adults and adults can spend prolonged periods at temperatures above 30°C or below 5°C. Acclimation during late larval stage also aids adult survival at low temperatures. No pupal survival was observed below 12°C or above 34°C, and optimal survival temperatures were 20-27°C. *C. capitata* Is multivoltine, polyphagous, high mobility and abundant plant hosts the likelihood of establishing of *C. capitata* in Bangladesh is considered to be high.

It is highly likely *C. capitata* that would be exposed to suitable hosts in Bangladesh and climatic conditions would facilitate its establishment in all over Bangladesh. Such factors are considered non-negligible.

9.1.7 Consequence Assessment

9.1.7.1 Economic Impact

C. capitata is an important pest in Africa and has spread to almost every other continent to become the single most important pest species in its family. It is highly polyphagous and causes damage to a very wide range of unrelated fruit crops. In Mediterranean countries, it is particularly damaging to citrus and peach. It may also transmit fruit-rotting fungi.

Fruit fly infestation of fruit causes early maturation and subsequent early drop thus significantly reducing harvestable crops. Damage to fruit crops is frequently high and may reach 100%. In Central America, losses to coffee crops were estimated at 5-15% and the berries matured earlier and fell to the ground with reduced quality. As in areas where the fly is endemic, in outbreak conditions the economic impacts include reduced production, increased control costs and lost markets. The domestic market would be adversely affected by costs for control and reduced yields. The economic consequences due to entry and /or establishment are considered to be high.

9.1.7.2 Environmental Impact

No impact of *C. capitata* on the natural environment or on other species has been observed, although the decline in populations of *Ceratitis catoirii* on Mauritius and Réunion may be due in part to competition from *C. capitata* (Duyck et al., 2006). However fruit flies are not usually considered to be pests in natural ecosystems. The environmental consequences of establishment are uncertain but non negligible.

9.1.7.3 Human Health Impact

Sela et al. (2005) showed that the Mediterranean fruit fly *Ceratitis capitata* is a potential vector of human pathogens (eg: *Escherichia coli*) to fruits. It must feed protein for egg development and it gains from faecal material. Thus *C. capitata* transmits human pathogens from faeces to intact fruit.

9.1.8 Risk estimation

The likelihood of entry, exposure and establishment *Ceratitis capitata* is high. If they were to enter and /or establish then the consequences would be high. The risk estimates for *Ceratitis capitata* is non negligible therefore these organisms are classified as hazards in citrus fruits and risk management measures can be justified.

9.1.9 Risk Management

9.1.9.1 Options

There are a number of points on the import pathway at which effective measures could be applied to reduce the likelihood of live life stages being intercepted at the border, surveillance detection or the establishment of *C. capitata* to an acceptable level. Pest management systems in the orchards, screening measures and visual inspection should be viewed as complementary options that need to be implemented in conjunction with the chosen disinfestation treatment to reduce pest numbers in fruit for export.

9.1.9.1.1 Field Sanitation

Fruit fly infestation may be reduced by implementation of field sanitation such as removal of infested fruits, ripe or decaying fruits and use of protein bait insecticide. This will assist in reducing the likelihood of entry of fruit fly but will not be sufficient as a single measure to mitigate the risk.

9.1.9.1.2 Post Harvest Culling, Washing, Waxing and Visual Inspection

The post harvest washing of fruit followed by visual inspection should be seen as a supplementary measure to be implemented in conjunction with the chosen disinfestation treatment to reduce pest numbers in fruit for export. *Citrus* fruit harvested for export to Bangladesh should be free from any scabbing, holes, cracks or damage to the skin, free from any abnormal discoloration and pests or pathogens. Fruit fly oviposition sites become raised, or turn brown after a few days or the rind around the oviopsition site may turn yellow, therefore attacked fruits should be easy to identify by visual inspection unless very recent. Fruit showing any sign of damage or infestation should be discarded.

Washing and waxing of fruit adds to the quarantine security but is insufficient on its own therefore should be used in conjunction with an approved fruit fly disinfestation treatment such as HTFA or Cold Disinfestation. Waxing is beneficial to the fruit if the treatment is cold disinfestation or cool storage.

9.1.9.1.3 High Temperature Forced Air (HTFA)

For *Citrus* except lemons and limes: high temperature forced air treatment raising the internal temperature of the commodity from ambient temperature to 47.2°C for a minimum of 20 minutes with the total treatment time being at least 4 hours or longer.

9.1.9.1.4 Cold Disinfestation

This treatment is in wide use for the disinfestation of fruit fly from *Citrus* fruit.
0°C or below for 13 days or
1°C + or – 0.6°C for 16 days

9.1.9.1.5 Visual Inspection at the Border

Visual inspection of the consignment for oviposition punctures should reveal old puncture sites but it may be difficult to detect a new puncture in very recently infested fruit. The efficacy of detecting fruit fly infested fruit can be lower than for some other insects. Emerging larvae or adults on the fruit surface may be detected on arrival in Bangladesh. This will assist in reducing the likelihood of entry of fruit fly but will not be sufficient as a single measure to mitigate the risk.

9.1.9.2 Recommended Management Options

Pest management systems in the orchards, screening measures and pre export visual inspection should be implemented in conjunction with the recommended disinfestations treatment.
a) Cold disinfestations treatment: 0-1ºC or below for 13 days. or
b) HTFA treatment: 47.2°C for of 20 minutes.
c) Visual inspection will be undertaken in Bangladesh after the consignment has arrived.

Fruit Fly

9.2 *Bactrocera invadens* (Asian Fruit Fly)

9.2.1 Hazard Identification

Common name: Asian fruit fly

Scientific name: *Bactrocera invadens* Drew, Tsuruta & White (Diptera: Tephritidae)

Bangladesh status: Not known to be present in Bangladesh.

B. invadens is an Asian species belonging to the Oriental fruit fly, *Bactrocera dorsalis,* species complex. Its known distribution in Asia is limited to areas of the Indian subcontinent and adjacent. Due to its recent description it might have been confused with other members of the *B. dorsalis* complex and the native range may be larger. The species invaded the African continent around 2003 and spread very fast throughout the continent. It is now established in several countries of tropical Africa as well as on the Comoros.

9.2.2 Biology

Development of immatures (in laboratory conditions of 28 ± 1°C; 50 ± 8% RH; photoperiod L12:D12) lasts 25 days: egg incubation lasts 1.2 days; larval development lasts 11.1 days; and puparia to adult development lasts 12.4 days. Average net fecundity and net fertility were 794.6 eggs and 608.1 eggs, respectively. Average daily oviposition was 18.2 eggs. Life expectancy at pupal eclosion is 75.1 days for females and 86.4 days for males. This suggests that there are multiple generations per year. Mean generation time is 31 days.

9.2.3 Hosts

A new fruit fly species, morphologically very similar to *B. dorsalis,* has been reported spreading rapidly in central Africa. This new pest is attacking mangoes, citrus and other tropical fruits. It was recently described and called *Bactrocera invadens* (Drew *et al*., 2005). *B. invadens* appears to be highly polyphagous and may be expected to have as broad a host range as *Bactrocera dorsalis*. It is particularly injurious to mango (*Mangifera indica*) and guava (*Psidium guajava*). *Citrus* spp., *Citrus aurantium* (sour orange), *Citrus limon* (lemon), *Citrus reticulata* (mandarin), *Citrus sinensis* (orange), papaya (*Carica papaya*), tomato (*Lycopersicon esculentum*), banana (*Musa* spp.), *Annona* spp. and some other wild African hosts (e.g. *Strychnos* spp.). Studies carried out in Kenya on the host range of this fruit fly have shown that it could attack a wide range of fruit crops (in particular mango, banana and citrus).

9.2.4 Distribution

In 2003, an unknown *Bactrocera* species was found in Kenya. Following the discovery of this species in Kenya in 2003, RAI Drew (Brisbane, Australia) was examining specimens collected in Sri Lanka in 1993 by K Tsuruta (Yokohama, Japan) during his survey of that island. This species had previously been overlooked as unusual variants of several other species. However, their discovery confirms that the native range of *B. invadens* includes Sri Lanka, where it is not known to have any status as a pest. Taxonomic expertise showed that it could not be a native species of Africa, but that it proved to be a member of the *Bactrocera dorsalis* complex; an Asian species complex that comprises several pest species (Drew and Hancock, 1994). Identical specimens were collected earlier during a survey in Sri Lanka in 1993 and initially classified as aberrant forms of *B. dorsalis*. Distribution of *B. invadens* includes Africa and Asia.

Africa: Angola, Benin (first found 2004-06), Burkina Faso, Cameroon (2004-07), Chad, Congo, Comoros, Côte d'Ivoire, Democratic Republic of Congo, Equatorial Guinea, Ethiopia, Gabon, Gambia, Ghana (2005-01), Guinea, Guinea-Bissau, Kenya (2003-02), Liberia, Malia, Mauritania, Mozambique (2007), Niger, Nigeria (2005-01), Senegal (2004-10), Sierra Leone, Sudan (2004-05), Tanzania (2003-12), Togo (2004-10), Uganda (2004-07), Zambia. Its first place of discovery (i.e. Kenya) should not be assumed to be its point of entry into Africa, as it may have been overlooked in some areas. **Asia:** Bhutan, India, Sri Lanka.

9.2.5 Hazard Identification Conclusion

B. invadens was not considered to be a pest species in its native range, although it could have been confused with other members of the *Bactrocera dorsalis* complex. In Africa, where the species is invasive, it is considered to have a high economic impact. The percentage of fruits infested with *B. invadens* can be very high. Many of its known hosts including citrus are grown all over the Bangladesh. Eggs and larvae of *B. invadens* are associated with infested fruits and it is likely to have spread through international trade of citrus fruits and should be able to establish and may cause unwanted consequences in Bangladesh. It is considered a potential hazard on fresh citrus fruits imported from India, Bhutan, Sri Lanka, South Africa and other African countries.

Fruit Fly

9.3 *Bactrocera papayae* (Papaya Fruit Fly)

9.3.1 Hazard Identification

Common name: Papaya fruit fly

Scientific name: *Bactrocera papayae* Drew & Hancock (Diptera: Tephritidae)

Bangladesh status: Not known to be present in Bangladesh (EPPO 2013).

B. papayae is a highly invasive species. It has a high dispersive ability, a very large host range and a tolerance of both forest and non-forest habitats. It has a high economic impact, affecting production, control costs and market access. Following introduction into Irian Jaya [Papua Barat], eastern Indonesia, it spread rapidly throughout mainland Papua New Guinea within 10 years of detection. It established successfully in mainland Queensland and spread over a relatively large area before being detected and eradicated.

9.3.2 Biology

Few specific details on the reproductive biology of *B. papayae* are available. The eggs of related species are laid below the skin of the host fruit. These hatch within a day (or up to 20 days in cool conditions) and the larvae feed for another 6 to 35 days, depending on the season. Pupation is in the soil under the host plant for 10 to 12 days, but may be delayed for up to 90 days under cool conditions. The adults occur throughout the year and begin mating after approximately 8 to 12 days, and may live 1 to 3 months depending on temperature (up to 12 months in cool conditions). In *B. papayae*, mating begins within the first week after eclosion and continues for at least 60 days after that. Adult flight and the transport of infected fruit are the major means of movement and dispersal to previously uninfested areas. Many *Bactrocera* spp. can fly 50 to 100 km.

9.3.3 Hosts

In Malaysia this species is a pest of papaya (*Carica papaya*) and it also caused heavy attack on mango (*Mangifera indica*) and ripe (not green) banana (*Musa paradisiaca*). At least 51 plant families are recorded as hosts. *Terminalia catappa*, (alamond), *Psidium guajava* (guava), *Syzygium samarangense* (water apple), *Ziziphus mauritiana* (jujube), *Syzygium jambos* (rose apple), *Carissa carandas* (caronda), *Momordica charantia* (bitter gourd), and *Averrhoa carambola* (caramola) were found to be favored hosts in southern Thailand and Peninsular Malaysia, and papaya and ripe banana are also important. Mango was the main host recorded during the Queensland outbreak. Its citrus hosts include *Citrus aurantiifolia* (lime), *Citrus limon* (lemon), *Citrus maxima* (pummelo), *Citrus reticulata* (mandarin), *Citrus sinensis* (sweet orange) and *Citrus paradisi* (grapefruit).

9.3.4 Distribution

B. papayae is endemic to Malaysia, the southern (peninsular) area of Thailand and throughout western Indonesia. It has been accidentally introduced into Irian Jaya (eastern Indonesia) and from there has spread to Papua New Guinea. It is present in Singapore, Brunei Darussalam (CABI, 2013).

9.3.5 Hazard Identification Conclusion

B. papayae is one of the most serious of fruit fly pests in the Asian region. It has a very wide host range, including many cultivated crops. Most of its hosts are cultivated all over the Bangladesh. International trade of citrus fruits facilitates dispersion of eggs and larvae and will be able to establish in Bangladesh. It is considered a potential hazard on fresh citrus fruits imported from Papua New Guinea, Indonesia, Malaysia and Thailand.

Fruit Fly

9.4 *Bractrocera tryoni* (Queensland Fruit Fly)

9.4.1 Hazard Identification

Common name: Queensland fruit fly

Scientific name: *Bactrocera tryoni* (Froggatt) [Diptera: Tephritidae]

Synonyms: *Chaetodacus tryoni* (Froggatt), *Dacus ferrugineus tryoni* (Froggatt), *Dacus tryoni* (Froggatt), *Strumeta tryoni* (Froggatt), *Tephritis tryoni* Froggatt.

Bangladesh status: Not known to be present in Bangladesh.

B. tryoni, the Queensland fruit fly, is the most costly horticultural pest in Australia and has invaded several countries in the surrounding region (White and Elson-Harris, 1994). It has the potential to spread too many places around the world because of its wide climatic and host range and a tendency to be carried by human travelers at the larval stage inside infested fruit. *B. tryoni* is a very serious pest of a wide variety of fruits throughout its range. Damage levels can be anything up to 100% of unprotected fruit.

9.4.2 Biology

Eggs are laid below the skin of the host fruit. These hatch within 1-3 days and the larvae feed for 10-31 days. Pupariation is in the soil under the host plant and adults emerge after 1-2 weeks (longer in cool conditions) and adults occur throughout the year. *B. tryoni* would be unable to survive the winter in the EPPO region, except in the south. The adults are best able to survive low temperatures, *Bactrocera* spp. generally having a normal torpor threshold of 7°C, dropping as low as 2°C in winter. Climatic factors limit its geographical distribution and abundance.

9.4.3 Hosts

B. tryoni has a very wide host range on both cultivated and wild species (in 25 families). As shown by Fitt (1986), adults of *B. tryoni* exhibit no particular preference in the species of fruits on which they will lay. The main hosts are in practice mostly tree fruits: *Annona*, *Averrhoa carambola*, avocados (*Persea americana*), *Citrus*, *Fortunella*, guavas (*Psidium guajava*), *Malus*, mangoes (*Mangifera indica*), passion fruits (*Passiflora edulis*), papaya (*Carica papaya*), peaches (*Prunus persica*), plums (*Prunus domestica*) and *Pyrus*. However, vegetables such as tomatoes (*Lycopersicon esculentum*) are also infested. Many tree fruit crops of the EPPO region are potential hosts. Citrus hosts include *Citrus aurantiifolia* (lime), *Citrus aurantium* (sour orange), *Citrus jambhiri* (rough lemon), *Citrus limetta* (sweet lemon tree), *Citrus limon* (lemon), *Citrus maxima* (pummelo), *Citrus medica* (citron), *Citrus reticulata* (mandarin), *Citrus sinensis* (orange), *Citrus paradisi* (grapefruit)

9.4.4 Distribution

B. tryoni is found throughout the eastern half of Queensland, eastern New South Wales, and the extreme east of Victoria. In 1989 it became established in the Perth area of Western Australia and it was declared eradicated by 1991. There have also been outbreaks in South Australia and although action to eradicate is taken, cool winters may also account for its lack of establishment. A few males have been trapped in Papua New Guinea but it is unlikely to be established there. It is also adventive in French Polynesia and New Caledonia and has twice been adventive in Easter Island, but eradicated.

9.4.5 Hazard Identification Conclusion

B. tryoni is the most serious insect pest of fruit and vegetable crops in Australia, and it infests all commercial fruit crops. Most of its hosts are cultivated in Bangladesh. Introduction of eggs and larvae associated with citrus fruits from Australia will facilitate its establishment in Bangladesh. It is considered a potential hazard for the purpose of this risk analysis

9.4.6 Risk assessment for B. invadens, B. papayae and B. tryoni

9.4.6.1 Entry Assessment

Bactrocera eggs will hatch within one to two days of oviposition. Eggs laid inside Citrus fruits just prior to harvest are most likely to enter Bangladesh as eggs or larvae, given the time from harvest to arrival in Bangladesh would be 24- 48 hours. Dacine (subfamily of the Tephritidae to which the genus *Bactrocera* belongs) females do not discriminate against fruits that already contain eggs or larvae, nor do they deposit a pheromone to deter oviposition by subsequent females, so it can be assumed any number of larvae could be present in any single fruit entering the country. For instance, approximately 750 *B. xanthodes* larvae were found in a single breadfruit from Niue indicating several females had oviposited in the one fruit. Since the average egg to pupation period is ten days, there is a higher likelihood of larvae entering in fruit arriving by air than arriving by sea. As pupation occurs in the soil it is considered unlikely pupae would enter with Citrus fruit. Given the duration of each life stage of three species the likelihood of entry of eggs and larvae is considered to be medium.

The shipping pathway is temporally long reducing the likelihood of entry of adult and pupal life stages into Bangladesh. The likelihood of entry of larvae on the shipping pathway and all life stages on the air pathway/road pathway which is temporally shorter is high and therefore nonnegligible.

9.4.6.2 Exposure Assessment

Citrus fruit are most likely to import in Bangladesh from India, Bhutan, China, Pakistan, Egypt, South Africa, USA and Australia. A number of the host species used by *Bactrocera* and many other potential hosts are grown in this region, providing food and oviposition sites all year round. The main host crops in the area are *Capsicum annuum* (bell pepper), *Persea americana* (avocado), various Citrus fruits, *Citrullus lanatus* (watermelon), *Cucumis melo* (rockmelon), *Lycopersicon esculentum* (tomato) and a commonly grown fruiting ornamental *Psidium cattleianum.* Citrus fruit will be distributed more widely after arrival so this increases exposure to host material. Waste fruit discarded onto open domestic compost increases the likelihood of exposure to local hosts and the spread of individuals. Longevity of adults, the overwintering strategy and their acclimation ability increase the likelihood of invading *Bactrocera* spp. mating and subsequently egg lying. The likelihood of exposure is considered to be high.

It is likely that exposure will be higher when waste fruit is discarded in a domestic compost heap and suitable hosts are grown in the same area.

9.4.6.3 Establishment Assessment

Most dacine flies overwinter as adults. Adults can spend prolonged periods at temperatures above 30°C or below 5°C. Acclimation during late larval stage also aids adult survival at low temperatures. Melon fly pupae were subjected to varying temperatures below 15°C for 2-6 days tolerance to low temperatures was greatly increased. Both species of fruit fly are multivoltine, polyphagous and assumed to be highly mobile. Abundant plant hosts, the likelihood of *B. invadens, B. papayae* and *B. tryoni* establishing in Bangladesh is considered to be high. It is highly likely that *Bactrocera* spp. would be exposed to suitable hosts in Bangladesh and climatic conditions would facilitate its establishment in all over Bangladesh. Such factors are considered non-negligible.

9.4.7 Consequence Assessment

9.4.7.1 Economic Impact

B. invadens was not considered to be a pest species in its native range, although it could have been confused with other members of the *Bactrocera dorsalis* complex and its actual impact underestimated. In Africa, where the species is invasive, it is considered to have a high economic impact. The percentage of fruits infested with *B. invadens* can be very high. *B. papayae* is one of the most serious of fruit fly pests in the Asian region. As in areas where the fly is endemic, in outbreak conditions economic impacts include reduced production, increased control costs and lost markets. The percentage of produce lost by *B. tryoni* has been estimated to be 10-50% in tropical Asia and Oceania and higher levels can occur in other parts of the world if control measures are not in place. Various statutory authorities have estimated economic losses in Australia due to *B. tryoni* to be between $28.5 million and $100 million per annum. *Bactrocera* spp. infestation of fruit causes early maturation and subsequent early drop thus significantly reducing harvestable crops. The economic consequences due to entry and /or establishment are considered to be high.

9.4.7.2 Environmental Impact

Fruit flies are not usually considered to be pests in natural ecosystems. The environmental consequences of establishment are uncertain but non negligible. It has been shown that invasive fruit fly species can compete with native fruit flies or with earlier introduced fruit flies, for the same host resources. Invasive *Bactrocera* species display more K-selected traits than native polyphagous pest and K-selected fruit fly species appeared to be better invaders. This, combined with the highly polyphagous nature of *B. invadens*, could lead to native species becoming outcompeted and reduced to particular, suboptimal niches. In the long term, this could have an impact on fruit fly biodiversity in a given region.

9.4.7.3 Human Health Impact

Sela *et al*. (2005) showed that the Mediterranean fruit fly *Ceratitis capitata* is a potential vector of human pathogens (eg: *Escherichia coli*) to fruits. Although there seems to be no evidence that *Bactrocera* spp. are directly or indirectly of human health significance, it is possible that they may play a similar role as vectors of human pathogens. Based on current information the impacts on human health are considered to be negligible.

9.4.8 Risk Estimation

The likelihood of entry, exposure and establishment of *B. invadens, B. papayae* and *B. tryoni in* Bangladesh is high. If they were to enter and /or establish then the consequences would be high. The risk estimate for *B. invadens, B. papayae* and *B. tryoni is* non negligible therefore these organisms are classified as hazards in this commodity and risk management measures can be justified

9.4.9 Risk Management

9.4.9.1 Options

There are a number of points on the import pathway at which effective measures could be applied to reduce the likelihood of live life stages being intercepted at the border, surveillance detection or the establishment of *Bactrocera* spp. to an acceptable level. Pest management systems in the orchards, screening measures and visual inspection should be viewed as complementary options that need to be implemented in conjunction with the chosen disinfestation treatment to reduce pest numbers in fruit for export.

9.4.6.1.1 Field Sanitation

Fruit fly infestation may be reduced by implementation of field sanitation such as removal of infested fruits, ripe or decaying fruits and use of protein bait insecticide. This will assist in reducing the likelihood of entry of fruit fly but will not be sufficient as a single measure to mitigate the risk.

9.4.6.1.2 Post Harvest Culling, Washing, Waxing and Visual Inspection

The post harvest washing of fruit followed by visual inspection should be seen as a supplementary measure to be implemented in conjunction with the chosen disinfestation treatment to reduce pest numbers in fruit for export. *Citrus* fruit harvested for export to Bangladesh should be free from any scabbing, holes, cracks or damage to the skin, free from any abnormal discoloration and pests or pathogens. Fruit fly oviposition sites become raised, or turn brown after a few days or the rind around the oviopsition site may turn yellow, therefore attacked fruits should be easy to identify by visual inspection unless very recent. Fruit showing any sign of damage or infestation should be discarded.

Washing and waxing of fruit adds to the quarantine security but is insufficient on its own therefore should be used in conjunction with an approved fruit fly disinfestation treatment such as HTFA or Cold Disinfestation. Waxing is beneficial to the fruit if the treatment is cold disinfestation or cool storage.

9.4.6.1.3 High Temperature Forced Air (HTFA)

For *Citrus* except lemons and limes: high temperature forced air treatment raising the internal temperature of the commodity from ambient temperature to 47.2°C for a minimum of 20 minutes with the total treatment time being at least 4 hours or longer.

9.4.6.1.4 Cold Disinfestation

This treatment is in wide use for the disinfestation of fruit fly from Citrus fruit.
0°C or below for 13 days or
1°C + or – 0.6°C for 16 days

9.4.6.1.5 Visual inspection at the border

Visual inspection of the consignment for oviposition punctures should reveal old puncture sites but it may be difficult to detect a new puncture in very recently infested fruit. The efficacy of detecting fruit fly infested fruit can be lower than for some other insects. Emerging larvae or adults on the fruit surface may be detected on arrival in Bangladesh. This will assist in reducing the likelihood of entry of fruit fly but will not be sufficient as a single measure to mitigate the risk.

9.4.9.2 Recommended Management Options

Pest management systems in the orchards, screening measures and pre export visual inspection should be implemented in conjunction with the recommended disinfestations treatment.

a) Cold disinfestations treatment: 0-1ºC or below for 13 days. or

b) HTFA treatment: 47.2°C for of 20 minutes.

c) Visual inspection will be undertaken in Bangladesh after the consignment has arrived.

Aphid

9.5 *Toxoptera citricida* (Brown Citrus Aphid)

9.5.1 Hazard Identification

Common name: Brown Citrus Aphid (BrCA)
Scientific name: *Toxoptera citricida* Kirkaldy [Homoptera: Aphididae]
Synonyms: *Aphis citricidus*
Bangladesh status: Not known to be present in Bangladesh.

9.5.2 Biology

Biology studies conducted under field conditions showed that the BrCA development time was 8--21 days, and there were about 30 generations per year in southern Rhodesia. Like other aphids, BrCA normally does not reproduce sexual adults, except under temperate conditions in Japan. Host plants significantly affected development, survival longevity and reproduction of BrCA. Immature survival at 25 ± 1° C on sour orange, *C. aurantium* L.; grapefruit, *C. paradisi* Macfadyen; key lime, *C. aurantifolia* Swing; calamondin, X *Citrofortunella microcarpa* (Bunge) Wijnands; rough lemon, *Citrus jambhiri* Lush.; orange jassamine, *Murraya paniculata* (L.) Jack; box orange, *Severinia buxifolia* (Poir) Tenore; lime berry, *Triphasia trifolia* (Burm. f.) P. Wilson was 93.5, 93.3, 88.3, 86.5, 82.0, 62.8, 53.1, and 41.6%, respectively. Developmental times for the immature stages among populations on rough lemon, sour orange, grapefruit, and key lime were 5.9-6.2 days. Longer development periods (6.5--7.2 days) occurred on box orange, calamondin, lime berry, and orange jassamine. The average number of nymphs reproduced per female was 58.8, 43.0, 42.5, 34.1, 32.7, 17.7, 20.8 and 23.0 on sour orange, grapefruit; rough lemon, key lime, calamondin, box orange, lime berry, and orange jassamine, respectively. Female adults lived an average of 22.1, 19.5, 18.0, 17.5, 22.8, 16.3, 22.6, and 14.6 days on these same hosts. The intrinsic rate of natural increase (rm) for BrCA on grapefruit was highest. Jackknife estimates of rm varied from 0.381 on grapefruit to 0.183 on lime berry. The mean population generation time on these hosts ranged from 9.7 to 12.2 days. BrCA reared on *C. aurantium* at 25.1° C had a much lower net reproductive rate (36.8) and longer mean generation time (11.3 days) than those reared on *C. unshiu*.

The environmental factors, especially temperature, have a great effect on the biology and life history of BrCA. The age-specific fecundity and net reproductive rate of apterae were higher at at 20° and 25° C. The intrinsic rate of increase for BrCA was highest at 27° C., although the maximum fecundity and net reproductive rate of individual adults were at 21.5° C. The development, survivorship, and reproduction of BrCA were evaluated at 8 constant temperatures (8, 10, 15, 20, 25, 28, 30 and 32° C). The developmental periods of immature stages ranged from 63.1 days at 8° C to 5.5 days at 30° C. The lower developmental threshold for the immature BrCA was estimated at 6.27° C. The upper temperature threshold of 31.17° C for development of nymphs was determined from a nonlinear biophysical model. The survivorship percentage of immature stages varied from 81 to 97% within the temperature range of 8-30° C. However, survivorship was reduced to 29% at 32° C. The average longevity of adult females ranged from 60.0 days at 10° C to 6.5 days at 32° C. The average number of progeny per female was 52.5 at 20° C and 7.5 at 32° C. The largest rm (0.3765) occurred at 28° C. Populations reared at 10 and 32° C had the smallest rm values of 0.0588 and 0.0960, respectively. The mean generation time of the population ranged from 51 days at 10° C to 8 days at 32° C. The optimal range of temperature for BrCA population growth was 20--30° C.

9.5.2.1 Toxoptera Citricida as a Vector

Brown citrus aphids are known to efficiently transmit *Citrus tristeza virus* (CTV). Citrus propagated on sour orange rootstock are particularly susceptible to the virus. Citrus tristeza virus (CTV) is transmitted semi-persistently by *Aphis gossypii* Glover, *A. spiraecola* Patch, *A. craccivora* Koch, *Dactynotus jacae* L., *Toxoptera aurantii* Boyer de Fonscolombe, and *T. citricida*. BrCA is the most efficient vector of CTV followed by *A. gossypii*. The relative single aphid transmission efficiencies by these two aphids from side by side tests were 16.0 and 1.4%.

Current isolates of CTV only affect trees on susceptible root stocks such as sour orange; no resistant root stock is known for CTV. CTV can cause major economic losses. A tree infected with CTV typically dies within 1-5 years. CTV exists as a complex of many strains which cause diverse symptoms. CTV strains fit into one or more of the following broad categories: mild strains (causing no discernable effect on commercial citrus); decline on sour orange rootstock strains (cause decline and death of trees on sour orange rootstock); seedling yellows strains (cause dwarfing and chlorosis in grapefruit and sour orange); and stem pitting strains. The stem pitting strains may produce stem pitting on either sweet orange cultivars and/or grapefruit cultivars.
CTV is semipersistently transmitted by citrus aphids. Aphids acquire virus from an infected trees with feeding times as short as 5-10 min; transmission efficiency increases with feeding times up to 24 h. There is no latent period and the virus does not multiply or circulate in the aphid. The time required to inoculate a plant is the same as for acquisition. The aphid is capable of spreading the virus for 24-48 hours without reacquisition.

9.5.3 Hosts

The host range of the BrCA is largely restricted to the Genus *Citrus*, although there are many reports of it colonizing other rutaceous plants. The majority of its other hosts are woody shrubs, although some are perennial vines and annual herbs. It was also reported from cotton in Rhodesia and Taiwan, India, Australia and Africa. The record from white yam, *Dioscorea rotundata*, is from Togo and that for *Passiflora* sp. from Kenya.

Most non-rutaceous plants are not normally suitable hosts for the BrCA and it should be noted that collections from these plants do not imply they are suitable for development and reproduction of the aphid. These may be colonized occasionally by variant individuals when suitable citrus foliage is unavailable, or alates may be collected that are resting rather than feeding. It has also been recorded on soybean, *Glycine max*, but this work examined only transmission of soybean mosaic virus by BrCA.

9.5.4 Distribution

The origin of BrCA is thought to be in Southeast Asia and has been reported in the Pacific region including China, Taiwan, India, Japan, Laos, the Philippines, Viet Nam, Thailand, Nepal, Indonesia, Malaysia, Sri Lanka, Hawaii, Fiji, Mauritius, Reunion, Samoa, Tonga, Australia and New Zealand. Brown citrus aphid has also been recorded in Africa including Cameroon, Congo, Ethiopia, Ghana, Kenya, Morocco, Mozambique, Somalia, South Africa, Tanzania, Tunisia, Uganda, Zaire, and Zimbabwe. BrCA is found in the western hemisphere: Argentina, Belize, Brazil, Bolivia, Chile, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, El Salvador, Florida in the USA, Guadeloupe, Guyana, Haiti, Jamaica, Martinique, Nicaragua, Peru, Puerto Rico, St. Lucia, Surinam, Trinidad, Uruguay, and Venezuela. By the summer of 1997, BrCA was widely distributed throughout southern central and coastal regions of Florida.

9.5.5 Hazard Identification Conclusion

T. cirticida is much more likely to be introduced on plants for planting and associated transportation materials. It is more strongly attracted to yellow than are many other aphids and it may therefore be transported on yellow packaging or aircraft parts. So, *T. cirticida* is not considered to be a potential hazard for importation of citrus fruits. However, plant parts like leaf or peduncle with fruits and yellow packaging material will be strictly prohibited.

Psyllid

9.6 *Trioza erytreae* (African Citrus Psyllid)

9.6.1 Hazard Identification

Common name: African citrus psyllid
Scientific name: *Trioza erytreae* (Del Guercio) [Homoptera: Triozidae]
Synonyms: *Spanioza erytreae* Del Guercio, *Trioza merwei* Pettey

Bangladesh status: Not known to be present in Bangladesh.

9.6.2 Biology

T. erytreae has temperature sensitivity similar to that of the African form of citrus greening bacterium. It is very sensitive to extremes of hot, dry weather (the eggs and first instar nymphs being particularly vulnerable). It is favored in cool, moist areas over 500-600 m, where citrus growth flushes tend to be prolonged. Sex ratios fluctuate in the field, but females always predominate. There is a pre-oviposition period of 3-7 days, but this is considerably extended in the absence of young foliage; longevity is also prolonged under such conditions. Mating occurs 2 to 4 times a day and eggs may be laid immediately. Eggs are supplied with a sharp point which is driven through the leaf epidermis and is thought to be responsible for maintaining a favorable internal water relationship. Females remain fertile for 11-16 days in the absence of males, and maximum egg production occurs towards the middle of their life span, which normally lasts 17-50 days; up to 2000 eggs may be laid per female. There is an incubation period of 6-15 days and nymphal development (five instars) takes 17-43 days, both periods being inversely related to mean temperature and directly related to nutritional value to the leaves. The temperature threshold for nymphal development is, apparently, around 10-12°C. There are no diapauses of *T. erytreae*.

Trioza erytrea transmits the causal agent of the African form of citrus huanglongbing (greening) disease, *Liberibacter africanum,* a very destructive disease of citrus plants. It has been shown experimentally that *T. erytreae* is also able to transmit the Asian form, *Liberibacter asiaticum* In Mauritius and Reunion, where both forms occur, *T. erytreae* probably transmits both. Fifth- or sixthinstar nymphs, as well as the adults derived from these nymphs, are capable of transmitting *L. africanum* to citrus.

9.6.3 Hosts

T. erytreae is confined to Rutaceae, occurring on wild hosts (*Clausena anisata*, *Vespris undulata*) as well as on *Citrus*, especially lemons (*C. limon*) and limes (*C. aurantiifolia*). Within the EPPO region the host species are generally confined to countries surrounding the Mediterranean. *Citrus jambhiri* (rough lemon) *Citrus maxima* (pummelo), *Citrus nobilis* (tangor) and *Citrus sinensis* (navel orange) are also attacked by *T. erytreae* (CABI, 2013).

9.6.4 Pest Distribution

The distribution of *T. erytreae* is wider than that of citrus greening bacterium, the major pathogen which it transmits, since it occurs in Cameroon, Congo, Malawi, Rwanda, St. Helena, Sudan, Tanzania, Uganda and Zambia where the bacterium has not been recorded. *T. erytreae* is found in Portugal (Madeira only; isolated outbreaks first found in 1994), Saudi Arabia, Yemen, Cameroon, Comoros, Ethiopia, Kenya, Madagascar, Malawi, Mauritius, Réunion, Rwanda, South Africa, St. Helena, Sudan, Swaziland, Tanzania, Uganda, Zaire, Zambia, Zimbabwe.

9.6.5 Hazard Identification Conclusion

T. erytreae is only likely to spread locally by natural dispersal, up to distances of 1.5 km. Citrus material (budwood, grafted trees, and rootstock seedlings) from infected areas can carry eggs and/or nymphs over longer distances. International movement on citrus fruits is extremely unlikely. Therefore, *T. erytreae* is not considered to be a potential hazard for importation of citrus fruits. However, importation of plants for planting and cut branches of citrus from countries where *Liberibacter africanum* and its vector occur should be strictly prohibited.

Scale

9.7 *Unaspis citri* (Citrus Snow Scale)

9.7.1 Hazard Identification

Common name: Citrus snow scale
Scientific name: *Unaspis citri* (Comstock) [Homoptera: Diaspididae]
Synonyms: *Chionaspis citri* Comstock, *Prontaspis citri* (Comstock), *Dinaspis veitchi* Green & Laing
Bangladesh status: Not known to be present in Bangladesh.

9.7.2 Biology

U. citri is sexually reproductive and produces several overlapping generations a year (up to 9). The active first instars are most abundant during late spring, summer and autumn, and populations tend to peak in numbers in late autumn. The life cycle takes 10 to 12 weeks to complete during the summer but longer during cooler weather. Each female can produce up to 169 first instars (over a period of 146 days); the average number of offspring per female is about 80. For a short period after hatching, the first instars are attracted to light and move upwards towards the apical twigs or on to the fruit, especially if leaf fall has occurred. Once a feeding site has been selected the females and immature males become sessile.

Laboratory studies of the population dynamics of *U. citri* showed the net reproductive rate, intrinsic rate of increase and finite rate of increase was higher on orange than on lemon. The longevity of female scales on orange was approximately 13 weeks compared to 17 weeks on lemon (Fern ndez & García, 1988a). Population studies in Colombia have shown that at any given time, 86.5 to 95.5%

of *U. citri* are not feeding and that 43.9 to 79.3% of first instars are male which cease to feed after the second moult (Mosquera, 1979).

9.7.3 Hosts

U. citri is polyphagous, attacking plant species belonging to 12 genera in 9 families. The main hosts of economic importance are *Citrus* spp., especially oranges (*C. sinensis*) but the insect has also been recorded on a wide range of other crops, mostly fruit crops and ornamentals, including *Annona muricata*, bananas (*Musa paradisiaca*), *Capsicum*, coconuts (*Cocos nucifera*), guavas (*Psidium guajava*), *Hibiscus*, jackfruits (*Artocarpus heterophyllus*), kumquats (*Fortunella*), pineapples (*Ananas comosus*), *Poncirus trifoliata* and *Tillandsia usneoides*.

9.7.4 Pest Distribution

U. citri originated in Asia and has spread widely in tropical and subtropical regions.

EPPO region: A closely related species, the arrowhead scale (*Unaspis yanonensis* (Kuwana)), also a pest of citrus, has recently been introduced into France and possibly into Italy. Specimens of *U. citri* were collected in Portugal (Azores) in the 1920s, but there have been no records since; there is no suggestion that the pest is established there now. There has recently been an isolated record in Malta.
Asia: China (Guangdong, Hubei), Hong Kong, Indonesia (Java), Malaysia (Peninsular), Singapore, Viet Nam.

Africa: Benin, Cameroon, Congo, Côte d'Ivoire, Gabon, Guinea, Mauritius, Niger, Nigeria, Senegal, Sierra Leone, Togo, Zaire.

North America: Bermuda, Mexico, USA (California, Florida, Georgia, Louisiana).

Central America and Caribbean: Antigua and Barbuda, Barbados, British Virgin Islands, Cuba, Dominica, Dominican Republic, El Salvador, Grenada, Guadeloupe, Haiti, Honduras, Jamaica, Montserrat, Panama, Puerto Rico, St. Kitts and Nevis, St. Lucia, St. Vincent and Grenadines, Trinidad and Tobago, United States Virgin Islands.

South America: Argentina, Bolivia, Brazil (Rio Grande do Sul, Rio de Janeiro, São Paulo), Chile, Colombia, Ecuador, Guyana, Paraguay, Peru, Uruguay, Venezuela.

Oceania: Australia (New South Wales, Queensland, South Australia, Victoria), Cook Islands, Fiji, Kiribati, New Caledonia, New Zealand, Niue, Papua New Guinea, Samoa, Solomon Islands (Stapley, 1976), Tonga, Vanuatu, Wallis and Futuna.

9.7.5 Hazard Identification Conclusion

U. citri is a polyphagous pest and widely distributed in tropical and subtropical regions. It was recorded from China, USA, Brazil, and Australia. It is readily carried on consignments of plant material and fruits. Its hosts are widely distributed in all over the Bangladesh. *U. citri* is therefore considered a potential hazard in this risk analysis.

Scale

9.8 *Icerya purchasi* (Cottony Cushion Scale)

9.8.1 Hazard Identification

Common name: Cottony cushion scale
Scientific name: Icerya purchasi Maskell [Homoptera: Margarodidae]
Synonyms: *Pericerya purchasi* (Maskell)
Bangladesh status: Not known to be present in Bangladesh.

9.8.2 Biology

I. purchasi have four ('female') or five (male) developmental stages. As with all scale insects, the females do not produce wings and look similar to the immature stages. The males possess a single pair of dusky wings. However the 'females' are actually hermaphrodites with fertilization occurring between the eggs and the sperm of the same individual. Sexually functional males are occasionally produced from unfertilized eggs, but mating is not necessary for reproduction. The adult females produce 500 to 2000 bright-red, oblong eggs over a period of 2 to 3 months. The number of eggs produced depends on the body size, condition of the host and climatic conditions into the protective ovisac. After the crawlers emerge they settle nearby, mostly along branches and leaf veins. Shortly after settling they begin to secrete white wax, first in isolated plates and later as a total cover. Unlike the females of most scale insects (except Pseudococcidae, the mealybugs), *I. purchasi* moves about throughout its life, preferring the inside of trees over their periphery. There are three to four annual generations.

Males are rare, usually appearing during very hot weather. Although they mate with the females, it is not clear whether they are functional. The scale may easily be reared in a greenhouse on seedlings of citrus.

9.8.3 Hosts

I. purchasi lives on a wide variety of hosts, especially woody plants. Cottony-cushion scale may develop on many perennial shrubs and trees, being a pest mostly of citrus, occasionally of roses.

9.8.4 Pest Distribution

I. purchasi is native to Australia; it was accidentally introduced to California in about 1868 and devastated the citrus industry there until a natural enemy from Australia was introduced in 1888. This was the first ever example of successful classical biological control. The pest also reached New Zealand and South Africa at about the same time, and has subsequently spread widely through most of the tropical and subtropical countries of the world. *I. purchasi* is widespread throughout the tropical and warmer temperate regions. **Asia:** China, India, Indonesia, Iran, Iraq, Israel, Japan, Korea, Jordan, Malaysia, Pakistan, Saudia Arabia, Syria, Thailand, Turkey, Singapore, Sri Lanka, Vietnam, Yemen. **Africa:** Algeria, Cape Verde, Egypt, Ethiopia, Kenya, Libya, Madagascar, Morocco, South Africa, Senegal, Somalia, Sudan, Uganda, Tunisia, Zambia, Zimbabwe. **North America:** Bermuda**,** Mexico**,** USA. **Central America and Caribbean:** Antigua and Barbuda, Bahamas, Barbados, Dominican Republic, Haiti, Trinidad and Tobago, Saint Lucia. **South America:** Argentina, Brazil, Bolivia, Chile, Colombia, Paraguay, Uruguay, Venezuela. **Europe:** Albania, Bulgaria, Cyprus, Greece, Hungary, Italy, Malta, Portugal, Madeira, Romania. **Oceania:** Australia, Fiji, New Zealand.

9.8.5 Hazard Identification Conclusion

I. purchase is a polyphagous pest of tropical and warmer temperate regions. It was recorded from India, China, Pakistan, Egypt, South Africa, USA, and Brazil. Adults, eggs, nymph are associated with fruits. Its major citrus hosts are found all over the Bangladesh. So, it is considered as a potential host in this risk analysis.

9.8.6 Risk Assessment

9.8.6.1 Entry Assessment

Eggs, crawlers and adult *U. citri* and *I. purchase* on fruit would survive the transit time to Bangladesh from India, China, Pakistan, Thailand, Egypt, South Africa, Brazil and USA. Therefore it is considered the likelihood of entry for all the scale species is considered to be high**.**

9.8.6.2 Exposure Assessment

The requisites for exposure of scale infested citrus fruit to suitable hosts will be the lifestage of the scale, the environmental conditions and the proximity to potential hosts. A recently mated female or parthenogenetic scale about to lay or already laying eggs could survive in warm, dry or slightly humid conditions allowing the eggs to hatch. Newly hatched crawlers have the greater likelihood of exposure, but are also susceptible to desiccation. Although they actively disperse only over very short distances, scale insects may disperse over several kilometers by wind. In the urban and rural environments near the point of arrival in Bangladesh there will be suitable hosts for the scale species considered in this risk analysis.

Infested fruit or peel may be discarded on the roadside, in reserves or open composts. However crawlers are likely to suffer high mortality, therefore the likelihood of exposure is considered to be low but non negligible.

9.8.6.3 Establishment Assessment

The scale insects considered in this risk analysis have a subtropical and tropical range. Those that are also found in temperature regions are usually found in greenhouses or under glass. Thus *U. citri* and *I. purchase* could survive wide range of climatic factors. Therefore the likelihood of establishment for these two scale insects is considered to vary from moderate to high.

9.8.7 Consequence Assessment

9.8.7.1 Economic Impact

U. citri is one of the principal pests of *Citrus* spp. in many of the citrus-growing regions of the world, especially in the tropics. It infests the trunk, branches and small shoots causing serious damage to orchards due to leaf drop and rapid dieback. Relatively low numbers of scales can cause damage.
Damage to the plant by *I. purchasi* is mostly caused by sap depletion; the shoots dry up and die, and defoliation occurs. In addition, the copious quantities of honeydew produced by the scales coat the leaves, blocking the stomata and impeding gas exchange. Such fouling frequently results in the growth of sooty moulds over the leaf surfaces, which blocks light from the mesophyll, so reducing photosynthesis. *I. purchasi* is a particular pest of citrus, Acacia spp., Casuarina spp. and Pittosporum spp., but it can damage many types of fruit and forest trees, and ornamental shrubs and trees. After its introduction into California, USA, in the late nineteenth century, it was recorded devastating citrus orchards, killing even large trees. By 1887, the problem on citrus had increased to such serious proportions that the entire citrus industry of California was threatened with destruction. Serious damage to citrus orchards by *I. purchasi* was also recorded in many other countries when the cottony cushion scale first arrived but with successful biological control this insect has become relatively unimportant in fruit orchards today.

9.8.7.2 Environmental Impact

Establishment of *I. purchasi* in the Galapagos Islands has caused concern because the pest has attacked a wide range of plants, including some of the endemic flora, and could endanger the native flora and the fauna dependant on it. Therefore the likelihood of unwanted environmental consequences is considered to be high.

9.8.7.3 Human Health Impact

Scale insects are not known to directly impact on human health. However honeydew excreting species, *I. purchase* can indirectly affect people by attracting nuisance species such as wasps and ants, whose stings and bites can cause severe reactions in people allergic to them.

9.8.8 Risk Estimation

The likelihood of scale insects entering the country is high, the likelihood of exposure is low and the likelihood of establishment varies from low to high depending on the species. If they were to establish then the consequences would be high. The risk estimation for *U. citri* and *I. purchasi* insects considered in this risk analysis is non negligible. Therefore these organisms are classified as hazards in this commodity and risk management measures can be justified.

9.8.9 Risk Management

9.8.9.1 Options

There are a number of points on the import pathway where effective measures could be applied to reduce the likelihood of scale insects arriving in New Zealand.

9.8.9.1.1 Post Harvest Culling, Washing, Waxing and Visual Inspection

Citrus fruit harvested for export to Bangladesh should be free from any scabbing, holes, cracks or damage to the skin, free from any abnormal discoloration and pests or pathogens. Damaged or infested fruit should be discarded. Visual inspection may detect sessile adults; crawlers under calyxes are unlikely to be seen.

Washing is unlikely to remove adult scale insects as they are usually firmly fixed by their mouthparts, requiring active brushing to dislodge them. It was noted that the stylets remain imbedded in the fruit and sap oozed from the wound encouraging pathogen entry.

Surfactants in the washing water have been shown to increase efficacy of washing. Waxing may assist in repelling or killing scale insects. However it is considered that these measures will not be sufficient on their own, and should be supplemented by another treatment

9.8.9.1.2 High Temperature Forced Air

There are no specific efficacy data for the disinfestation of scale insects on *Citrus* by HTFA. Hansen *et al.* (1992) found vapor heat treatment of tropical cut flowers at 46.6°C for 1 hour or 45°C for 2 hours killed nymphs and adults of soft and armoured scale insects. High temperature forced air treatment raising the core temperature of the commodity from ambient temperature to 47.2°C for 20 minutes with the total treatment time being at least 4 hours or longer would kill scale insects, with a low level of survivors.

9.8.9.1.3 Hot Water Immersion

Gould and McGuire (2000) found mealybugs on limes were killed after a hot water immersion at 49°C for 20 minutes. This treatment was considered a suitable method of disinfestation. The tolerance of *Citrus* other than limes for this treatment is uncertain. Mealybugs have a waxy coating similar to that of scale insects so it is assumed measures for mealybugs may be effective for scale insects. However the degree of residual risk is uncertain.

9.8.9.1.4 Cold Disinfestation

Cold treatment is not an efficacious treatment for scale insects. Diaspidids were survived 20-66 days at 4°C.

9.8.9.1.5 Visual Inspection at the Border

The crawler stages of scale insects are small and can seek shelter under the fruit calyx therefore may escape detection by visual inspection of the consignment on arrival in Bangladesh. The adult, sessile scale insects may be more visible but may not be detected if they are in low densities.

9.8.9.2 Recommended Management Practice

Pest management systems in the orchards, screening measures and pre export visual inspection should be implemented in conjunction with the recommended disinfestations treatment.

a) Vapor heat treatment: ≥ 46.5 ºC for 1 hour Or HTFA treatment: 47.2°C for of 20 minutes.
b) Visual inspection will be undertaken in Bangladesh after the consignment has arrived.

Thrips

9.9 *Scirtothrips citri* (California Citrus Thrips)

9.9.1 Hazard Identification

Common name: California citrus thrips
Scientific name: *Scirtothrips citri* (Moulton) [Thysanoptera: Thripidae]
Synonyms: *Euthrips citri* Moulton
Bangladesh status: Not known to be present in Bangladesh.

9.9.2 Biology

The life history and biology of *S. citri* are essentially similar to those of *S. aurantii*. The eggs (0.2 mm) are oviposited under the cuticle of new leaves, stems, and fruit. One female may lay as many as 250 eggs. They hatch is 6 to 8 days during warm weather. Those laid in the fall pass the winter and hatch in March (first generation) about the time new foliage growth commences. However, in the Yuma area, it is not uncommon to find citrus thrips throughout the year during warm periods. There are two active nymphal stages (first and second instars) requiring 4 to 14 days for development. First instar larvae feed actively on tender leaves and fruit, especially under the sepals of young fruit. The third and fourth instars are pupation stages and do not feed. They complete development on the ground in litter beneath the tree or in the crevices of the tree. The third instar is the prepseudopupal stage and the fourth instar is known as the pseudopupal stage. A single generation may be completed in a period of 15 days. In Yuma, there may be as many as 10 to 12 generations per year, while in Maricopa County they will usually complete 8 to 10 generations per year.

9.9.3 Hosts

All citrus species and their hybrids are the primary hosts, this species has been taken from 53 different plant species; not all of these are likely to be breeding host plants and many, like *Citrus*, are not native Californian plants. Other crops on which it has been found include cotton (*Gossypium hirsutum*), dates (*Phoenix dactylifera*), grapevine (*Vitis vinifera*) lucerne (*Medicago sativa*) and pecans (*Carya illinoensis*), and also ornamentals such as *Magnolia* and *Rosa*. The native host plant is possibly one or more species of *Quercus*, or more likely *Rhus laurina*.

Feeding of young leaves results in leaf distortion and silvering on leaf surface. These leaves will appear distorted and thickened with gray streaks usually parallel to the midvein. Extensive feeding on small leaves and leaf buds can result in significant defoliation and limb “buggy whipping”.

9.9.4 Pest Distribution

S. citri is native to the western United States and Mexico. It is known only from the southern parts of North America. Mexico (northern), USA (Arizona, California, Florida).

9.9.5 Hazard Identification Conclusion

So only seedlings or cuttings with young growing leaf buds are liable to carry these pests. Only young fruits are attacked, so the risk of these thrips being carried on harvested fruits is small.

Thrips

9.10 *Scirtothrips aurantii* (South African Citrus Thrips)

9.10.1 Hazard Identification

Common name: South African citrus thrips
Scientific name: *Scirtothrips aurantii* Faure [Thysanoptera: Thripidae]
Synonyms: *Scirtothrips acaciae* Moulton
Bangladesh status: Not known to be present in Bangladesh.

9.10.2 Biology

All stages feed on epidermal or even palisade, cells of young leaves, and on the apex of young fruit often concealed under the calyx. They do not feed on mature leaves. In *S. aurantii*, the eggs are bean-shaped, minute (less than 0.2 mm) and eggs are inserted into young tissues. Females are capable of laying up to 250 eggs. There are two nymphal (feeding) stages, followed by two pupal (non-feeding) stages. Pupation occurs on the ground amongst leaf litter; pupae occur rarely beneath the calyx of fruits. Breeding is almost continuous, although development is slow in winter, and the life history can be completed in less than 30 days. Breeding is continuous, so there are many generations possible annually.

9.10.3 Hosts

Although usually considered to be associated with *Citrus*, especially orange (*C. sinensis*), in Southern Africa, lemon (*Citrus limon*) *S. aurantii* has been found on more than 50 plant species in a wide range of different plant families, and is sometimes a pest of mangoes (*Mangifera indica*), when these are grown close to citrus trees in South Africa, tea (*Camellia sinensis*) and banana (*Musa paradisiaca*). Its native hosts are probably *Acacia* and *Combretum* trees, but it has also been taken on a range of crops that are not only botanically unrelated but differ widely in form, including *Arachis*, *Asparagus*, *Gossypium*, *Musa*, *Ricinus* and *Vitis*.

On Citrus, *S. aurantii* causes silvering of the leaf surface, linear thickenings of the leaf lamina, brown frass markings on the leaves and fruits, grey to black markings on fruits often forming a ring around the apex, and ultimately fruit distortion and early senescence of leaves. If flushes of young leaves are severely attacked later in the season, then the crop of the following season may be reduced. On mangoes, *S. aurantii* causes lesions on the fruit, leaf malformation and stunting of new growth. It causes fruit spotting on bananas.

9.10.4 Pest Distribution

S. aurantii is native to Africa, and the only records considered to be valid (supported by voucher specimens in an available collection) from outside this continent are from Yemen. It is found in Yemen, Angola, Cape Verde, Egypt, Ethiopia, Ghana, Kenya, Malawi, Mauritius, Nigeria, Réunion, South Africa, Sudan, Swaziland, Tanzania, Uganda, Zimbabwe and Australia

9.10.5 Hazard Identification Conclusion

The potential of *Scirtothrips* spp. for natural spread is relatively limited. In international trade, *S. aurantii* could be carried on plants for planting, but in fact interceptions are relatively rare. Unlike many Thysanoptera, *Scirtothrips* spp. seem to require access to soft green tissues, except when pupating in leaf litter and soil. Only seedlings or cuttings with young growing leaf buds are liable to carry these pests. The youngest fruits are attacked, so the risk of these thrips being carried on harvested fruits is small. There is no direct evidence that *S. aurantii* has been dispersed beyond its natural range by human activity.

9.10.6 Risk Assessment for S. citri and S. aurantii

9.10.6.1 Entry Assessment

Scirtothrips spp. seems to require access to soft green tissues, except when pupating in leaf litter and soil. So only seedlings or cuttings with young growing leaf buds are liable to carry these pests. Only young fruits are attacked, so the risk of these thrips being carried on harvested fruits is small. There is no direct evidence that *S. citri* has been dispersed beyond its natural range by human activity. The likelihood of entry for *S. citri* and *S. aurantii* is considered to be low.

9.10.6.2 Exposure Assessment

Given the polyphagous nature of both thrips species there will be potential hosts near any of the likely places of fruit disposal. Urban and rural areas will have most of the common hosts for both species such as cucurbits, *Citrus*, *Musa* and capsicums. Thrips are weak fliers but can be blown long distances by wind. The likelihood of exposure for both species is considered to be high.

9.10.6.3 Establishment Assessment

S. citri and *S. aurantii* have tropical and sub-tropical distribution. The climate of Bangladesh is favorable for both species. The likelihood of establishment for both species is considered to be high.

9.10.7 Consequence Assessment

9.10.7.1 Economic Impact

Scirtothrips spp. is known as pests of various crops in different parts of the tropics, but most of them have restricted geographic ranges and tropical host plants. They are associated with plants that grow in warm, dry conditions and are usually more abundant on terminal shoots rather than within the canopy of a tree. On fruit, *S. citri* punctures epidermal cells, leaving scabby, grayish or silvery scars on the rind. Second instar nymphs do the most damage because they feed mainly under the sepals of young fruit. *S. aurantii* is the primary cause of banana fruit-spotting in Yemen. It is also recorded as the most important thrips species on mangoes in South Africa. *S. citri* is of greatest importance on navel oranges in the San Joaquin Valley, California, and also on lemons in desert and coastal areas in California. In South Africa and Zimbabwe, *S. aurantii* causes reduction in citrus yields through serious damage to young leaves, and reduces the proportion of export quality fruits. It is a most serious pest at low altitudes. The economic consequences of establishment are considered to be high.

9.10.7.2 Environmental Impact

S. citri and *S. aurantii* are polyphagous and have found on more than 50 different plant plants. Feeding of young leaves results in leaf distortion and silvering on leaf surface. These leaves will appear distorted and thickened with gray streaks usually parallel to the midvein. Extensive feeding on small leaves and leaf buds can result in significant defoliation and limb “buggy whipping”.

9.10.7.3 Human Health and Social Impact

Thrips can cause thysanoptera dermatitis by biting through human skin and sucking the epidermal lymph. The lesions formed are small, pink and itchy, often mistaken for mosquito bites. Thysanoptera dermatitis is not harmful and will resolve in a few days by itself.

Establishment of *S. citri* and *S. aurantii would* have adverse affects on amenity plantings and home gardens due to damage, cost and difficulty of control. Although it is uncertain the degree of impact this would have it is considered to be non negligible.

9.10.8 Risk Estimation

The likelihood of *S. citri* and *S. aurantii* entering the country is low, being exposed to suitable hosts and establishing is high. The consequences of establishment are high. The risk estimation for *S. citri* and *S. aurantii* is non negligible therefore these organisms are classified as hazards in this commodity and risk management measures can be justified.

9.10.9 Risk Management for S. citri and S. aurantii

9.10.9.1 Options

There are a number of points on the import pathway where effective measures could be applied to reduce the likelihood of *S. citri* and *S. aurantii* arriving in Bangladesh.

9.10.9.1.1 Post Harvest Culling, Washing, Waxing and Visual Inspection

The post-harvest washing of fruit followed by visual inspection is a supplementary measure to be implemented in conjunction with the chosen disinfestation treatment to reduce pest numbers in fruit for export. *Citrus* fruit harvested for export to Bangladesh should be free from any scabbing, holes, cracks or damage to the skin, free from any abnormal discoloration and pests or pathogens. Thrips damage should be visible and damaged fruit discarded.

Both thrips species are very small as adults and larvae and whilst they only occur on the surface of the fruit, they may shelter under the fruit calyx escaping detection by visual inspection. Washing may dislodge some thrips but it may not be effective in removing any sheltering under the calyx. Waxing is more likely to repel or kill some thrips remaining on the fruit.

9.10.9.1.2 High Temperature Forced Air

There are no specific efficacy data for the disinfestation of thrips on *Citrus* fruits by HTFA. Cowley *et al*. (1992) conducted mortality tests using dry heat with 55-60% RH (HTFA) at 47°C for 10 minutes on the thrips *Heliothrips haemorrhoidalis* (adults). From the 30 individuals tested at that temperature there were no survivors. This means the ED = 90.0000%, which is the estimated effect of this treatment on a population of *Heliothrips haemorrhoidalis* at 95%CL (Couey and Chew 1986). This research was to assess the feasibility of disinfesting persimmons of this species. It could be anticipated that the treatment for *Citrus* would be similarly efficacious. For *Citrus* except lemons and limes: high temperature forced air treatment raising the internal temperature of the commodity from ambient temperature to 47.2°C for a minimum of 20 minutes with the total treatment time being at least 4 hours or longer.

*(**NB**. This is an approved treatment by the USDA-PPQ; however they note that of all Citrus tested to date, grapefruit has shown the highest tolerance for this treatment and specific cultivars should be tested to determine their tolerance to HTFA at this time/temperature regime.)*

9.10.9.1.3 Hot Water Immersion

Gould and McGuire (2000) found that all the insects infesting the limes they tested were killed after a hot water immersion at 49°C for 20 minutes. The tolerance of *Citrus* other than limes for this treatment is uncertain. *Thrips obscurata* on stone fruit has been successfully treated by hot water dip at 50°C for 2 minutes or 48°C for 3 minutes. Using naturally infested fruit at 50°C for 2 minutes, 99.8% of adults, 100% of larvae and 99.65% of eggs were killed (McLaren *et al.* 1997).

9.10.9.1.4 Cold Disinfestation

There are no efficacy data for disinfestation of *Citrus* for thrips by this treatment. *T. palmi* has been reported overwintering in unheated glasshouses at sub-zero temperatures (Nagai and Tsumuki

1990). Therefore cold disinfestation would not be a sufficiently effective measure because there would be uncertainty as to the level of residual risk after such a treatment.

9.10.9.1.5 Visual Inspection at the Border

Both species of thrips are particularly small and detection larvae and adults by visual inspection of the consignment on arrival in Bangladesh would be difficult especially if the thrips are in low densities and can seek shelter under the fruit calyx.

9.10.9.2 Recommended Management Options

Pest management systems in the orchards, screening damage fruits should be implemented in conjunction with the recommended disinfestations treatment.

a) Hot water immersion: 50°C for 2 minutes. Or
b) HTFA treatment: 47.2°C for of 20 minutes.
c) Visual inspection at the border in Bangladesh.

Moth

9.11 *Eudocima fullonia* Clerck (Fruit Piercing Moth)

9.11.1 Hazard Identification

Common name: Fruit piercing moth / Fruit sucking moth
Scientific name: *Eudocima fullonia* Clerck
Synonyms: *Othreis fullonia, Othreis fullonica, Ophideres fullonia, Ophideres fullonica*
Bangladesh status: Not known to be present in Bangladesh

9.11.2 Biology

Larvae are between 4mm (newly hatched) and 60mm (mature) in length, with variable coloration. The adult is large and robust, with a wingspan of 80-100mm and body approximately 50mm long. Eggs are laid in batches of up to 100 (when moth populations are low) or several hundred (when moth populations are high) on the undersides of the host plant leaves (often *Erythrina* spp.), though sometimes on bark or other nearby plants. At about 25°C eggs will hatch in 3 days. There are 5 larval instars, the total duration of which is about 13- 22 days. Pupation occurs in a silk cocoon woven between leaves and lasts 16-18 days. After emergence the female usually feeds, mates then commences egg laying. She may lay up to 750 eggs in her lifetime. Females live 27-30 days and males 26-28 days and both sexes continue feeding throughout their lifetime. Being nocturnal the moths feed and mate at night, and shelter during the day in dense, undisturbed foliage.

Adults can fly substantial distances. In New Caledonia they regularly move between the mountains and coastal plains and in Australia are thought to migrate over long distances such as from northern Queensland to the southeastern parts of the state.

9.11.3 Hosts

The adult of this species is a serious pest of ripening fruits, associated directly with *Citrus* fruit upon which it feeds. The adult host plants are different to larval host plants. In the Pacific larvae develop almost exclusively on plants in the genus *Erythrina* with the exception of the creeper *Stephania forsteri* (Menispermaceae). Elsewhere the Menispermaceae are favored, particularly plants of *Tinospora, Tiliacora, Triclisia* and *Stephania* genera. Unlike most Lepidoptera it is the adult, not the larval stage that is responsible for damage to crops. Feeding occurs at night. The adult's mouthparts are about 2.5cm long and designed to pierce thick fruit skins giving access to the juice. The entry site allows bacterial and fungal infections to take hold.

E. fullonia are known to attack more than 40 different types of fruit including *Actinidia chinensis* (kiwifruit), *Anacardium occidentale* (cashew nut), *Ananas comosus* (pineapple), *Annona muricata* (soursop), *Annona squamosa* (sugarapple), *Artocarpus altilis* (breadfruit), *Artocarpus heterophyllus* (jackfruit),*Averrhoa carambola* (carambola), *Capsicum annuum* (bell pepper), *Carica papaya* (papaw), *Casimiroa edulis* (white sapote), *Chrysophyllum cainito* (caimito), *Citrus limon* (lemon), *Citrus maxima* (pummelo), *Citrus x paradisi* (grapefruit), *Citrus reticulata* (mandarin), *Citrus sinensis* (navel orange), *Cocculus hirsutus*, *Coffea arabica* (arabica coffee), *Cucumis melo* (melon), *Dimocarpus longan* (longan tree), *Diospyros kaki* (persimmon), *Eichhornia* (waterhyacinth), *Erythrina subumbrans* (December tree), *Erythrina variegata* (Indian coral tree), *Eugenia dombeyi* (brazil cherry), *Ficus carica* (fig), *Litchi chinensis* (lichi), *Lycopersicon esculentum* (tomato), *Mangifera indica* (mango), *Malus sylvestris* (crab-apple tree), *Muntingia calabura* (Jamaica cherry), *Musa* (banana), *Nephelium lappaceum* (rambutan), *Opuntia* (Pricklypear), *Pachygone ovata*, *Passiflora edulis* (passionfruit), *Passiflora quadrangularis* (giant granadilla), *Pometia pinnata* (fijian longan), *Psidium cattleianum* (strawberry guava), *Psidium guajava* (guava), *Prunus americana* (apricot), *Prunus domestica* (plum), *Prunus persica* (peach), *Punica granatum* (pomegranate), *Salvinia molesta* (kariba weed), *Sandoricum koetjape* (santol), *Solanum melongena* (aubergine), *Syzygium malaccense* (malay-apple), *Tinospora cordifolia*, *Tinospora sinensis*, *Vitis vinifera* (grapevine).

9.11.4 Pest Distribution

E. fullonia is native to the Indo-Malay region and is widespread throughout Asia (India, Thailand), Africa (Cameroon, DRCongo, Eritrea, Ethiopia, Gambia, Kenya, Madagascar, Malawi, Mozambique, Nigeria, Rwanda, Somalia, South Africa, Tanzania, Uganda, Zambia, Zimbabwe), tropical America and some areas of Europe. In the South Pacific it is present in Australia, American Samoa, Belau, Cook Islands, Federated States of Micronesia, Fiji, French Polynesia, Guam, New Caledonia, Niue, Northern Mariana Islands, Papua New Guinea, Samoa, Solomon Islands, Tonga, Vanuatu, Wallis and Futuna. *E. fullonia* is an occasional vagrant in New Zealand- recorded under its synonym *Othreis fullonia* thought to be blown in from Australia on the prevailing westerly winds.

9.11.5 Hazard Identification Conclusion

The larvae and pupae are associated with specific non-citrus plants and it is unlikely that any lifestage of *E. fullonia* will be found on fresh *Citrus* fruit coming from India, Thailand, South Africa and Australia. Fruit piercing moth is not considered to be a potential hazard in this risk analysis.

Beetle

9.12 *Anoplophora chinensis* (White-Spotted Longicorn Beetle)

9.12.1 Hazard identification

Common name: White-spotted longicorn beetle
Scientific name: *Anoplophora chinensis* (Forster) [Coleoptera: Cerambycidae]
Synonyms: *Cerambyx farinosus* Houttuyn, *Cerambyx chinensis* Forster, *Cerambyx punctator*Olivier, *Melanauster chinensis* Thomson, *Anoplophora chinensis* Bates, *Anoplophora chinensis* Breuning, *Anoplophora malasiaca* (Thomson).
Bangladesh status: Not known to be present in Bangladesh.

9.12.2 Biology

In tropical and subtropical regions, there is a single generation per year, but the life cycle occasionally takes two years depending on climatic and feeding conditions. The adults live about a month between May and August. They feed on leaves, petioles and young bark of various trees.

Egg deposition begins a week after copulation. The eggs, about 70 per female, are laid one by one under the bark of the trunk, from just above the soil surface to 60 cm higher. The feeding larva tunnels in the branches and trunk just under the bark and later enters the woody tissues of the lowest portions of the trunk and roots. Pupation takes place in the wood, often in the upper part of the feeding area.

9.12.3 Hosts

A. chinensis is polyphagous on woody hosts, having been recorded on at least 68 species of host trees belonging to 19 families. These include *Alnus*, *Casuarina*, *Citrus*, *Litchi*, *Melia*, *Morus* and *Salix*. *A. chinensis* behaves similarly, being recorded for example on *Acer*, *Citrus*, *Cryptomeria japonica*, *Malus*, *Populus* and *Salix*. Probably, the host ranges of the two species practically coincide. *Ficus*, *Hibiscus*, *Mallotus*, *Platanus*, *Pyrus* and *Rosa* are mentioned as hosts of either species. Citrus hosts of *A. chinensis* include *Citrus aurantiifolia* (lime), *Citrus aurantium* (sour orange), Citrus *deliciosa* (mediterranean mandarin), *Citrus limonia* (mandarin lime), Citrus maxima (pummelo), Citrus *nobilis* (tangor), Citrus reticulata (mandarin), Citrus *sinensis* (orange)**.**

9.12.4 Pest Distribution

Asia: China (subtropical areas, including Fujian, Jiangsu), Hong Kong, Japan, Korea Republic, Malaysia, Myanmar, Viet Nam. **North America**: USA (Hawaii; interceptions on mainland) Europe: Denmark, Italy, Rumania (Badeanu *et al*., 2009).

9.12.5 Hazard Identification Conclusion

This beetle feeds on foliage and wood both during the adult and larval stages, so it is unlikely to be associated with citrus fruit. Moreover, it is not transmitted with citrus fruits. For these reasons, *A. chinensis* is not considered potential hazards in this risk analysis.

Ant

9.13 *Solenopsis xyloni* (Southern Fire Ant)

9.13.1 Hazard Identification

Common name: Southern fire ant, Californian fire ant, cotton-ant

Scientific name: *Solenopsis xyloni* McCook [Hymenoptera: Formicidae]
Synonyms: *Solenopsis geminata* subsp. *maniosa* Wheeler, *Solenopsis geminate* r. *pylades* Forel, *Solenopsis pylades* Forel

Bangladesh status: Not known to be present in Bangladesh.

9.13.2 Biology

Mating flights are the primary means of ant colony propagation. Colonies generally contain a few large workers (major workers), many medium-sized workers (media workers), and a majority of small workers (minor workers). The three types of workers are all sterile females and serve to perform tasks necessary to maintain the colony. The queen (or queens) is the single producer of eggs. Eggs are white in color, occur in underground nest, only seen when mound is disturbed. Occur in underground nest, only seen when mound is disturbed. They have four larval stages, larvae are white, grub-like and fourth instar larvae are the only stage capable of ingesting solid food. The diet of foraging workers consists of dead animals, including insects, earthworms, and vertebrates. Workers also collect honeydew and store seeds. Larvae are fed only a liquid diet until they reach the third instar. When the larvae reach the fourth instar, they are able to digest solid foods. Worker ants will bring solid food rich in protein and deposit it in a depression in front of the mouth of the larvae. The larvae will secrete digestive enzymes that break down the solid food and regurgitate it back to worker ants.

9.13.3 Hosts

All Citrus species and their hybrids.

9.13.4 Pest Distribution

S. xyloni is native to the southern United States and Mexico. *Solenopsis xyloni* is found across the southern United States from the Carolinas and Georgia, through lowland Tennessee, south central Kansas and southern Nevada to the Pacific coast of California. In Mexico, it seems to be limited to dry subtropical areas. In the southeastern U.S., *Solenopsis xyloni* has been largely eliminated from areas within the current range of the imported fire ant species, *Solenopsis invicta* and *Solenopsis richteri*. There is no evidence that *Solenopsis xyloni* ever inhabited any portion of Florida, and it is very rare or absent right along the Gulf Coast.

9.13.5 Hazard Identification Conclusion

Southern fire ants usually swarm in late spring or summer. In California this occurs on warm evenings when temperatures are about 30^{o}C. It is not established outside its native range and no interceptions of this species occur in Bangladesh. Moreover it is not found in India and Myanmar. So *S. xyloni* is not considered as potential hazard in this risk analysis.

Wasp

9.14 *Bruchophagus fellis* (Citrus Gall Wasp)

9.14.1 Hazard Identification

Common name: Citrus gall wasp
Scientific name: *Bruchophagus fellis* (Girault) [Hymenoptera: Eurytomidae]
Synonyms: *Eurytoma fellis* Girault
Bangladesh status: Not known to be present in Bangladesh.

9.14.2 Biology

The adult wasp is small, shiny-black and 2.5mm long. Larvae are 2mm long, thickset, white and have no legs. This is the only wasp that directly attacks citrus. The larval development in the young twig can produce distinctive woody galls typically up to 250mm long and 25mm thick containing hundreds of larvae. More recently galls of up to 500mm containing thousands of larvae have been reported by O'Neill (2013).

Adults emerge from infested galls in most areas from mid-September until early November. Upon emergence, the adult wasps mate immediately and females begin to lay eggs soon afterwards as both sexes live for approximately one week. The female wasp lays eggs between the bark and wood of young twigs leaving scar-like flecks on the bark. Egg laying continues throughout October and finishes by mid-November. Adult wasps live for 5–14 days, they lay about 100 eggs under the fresh young green bark of the spring flush.

Eggs hatch in 2 to 4 weeks, and are all hatched by early December. The young larvae burrow into the bark, and a flask-like sheath of soft host tissue develops around each larva. By late December, woody tissue begins to form around the sheath of soft tissue; the twig swells and begins to develop the characteristic gall. Heavily infested trees can be covered with galls, resulting in very little leaf or fruit production, and severe dieback. Pupation occurs about a month before emergence. During this time the larvae ceases feeding, voids its waste material and begins to differentiate into the adult form.

Spread by the adult is only local. The wasps are weak fliers and usually do not leave the tree from which they have emerged. However, there is probably some wind-borne transport of the adults. The most important means of spread to new localities is by the movement of infested young trees. This risk would be greatest with young trees from home gardens. Heavily galled twigs have been carried away as curiosities by people who do not appreciate the danger of infesting new areas.

9.14.3 Hosts

Finger lime (*Microcitrus australasica*) is the native host for citrus gall wasp. All citrus varieties can be attacked but there are differences in susceptibility. Rough lemon and Troyer citrange rootstocks are very susceptible while grapefruit is the most susceptible cultivated variety. Lemons and oranges can be seriously affected with mandarins being the least susceptible. Lemons (*C. limon*) and oranges (*C. sinensis*) can be seriously affected, and mandarins (*C. reticulata*) are the least susceptible.

9.14.4 Distribution

Citrus gall wasp has traditionally been a pest of citrus trees in the growing regions of Queensland and northern and central coastal New South Wales (NSW), but can also be found in the central inland citrus growing regions of NSW. In the past decade it has been found in isolated pockets in the southern growing regions of the Sunraysia and riverland areas and more recently has been identified in backyard trees in the city of Griffith. It is also found in Victoria (VIAC 2013)and South Australia (Lamb 2011).

9.14.5 Hazard Identification Conclusion

Citrus gall wasp is a serious pest of citrus that can reduce leaf production and subsequently lower fruit yield. Citrus gall wasp does not directly affect fruit. The spread of citrus gall wasp is thought to have occurred mainly through the distribution of infected nursery trees. So it is unlikely to be associated with citrus fruit and is not considered as potential hazard in risk analysis.

Mite

9.15 *Eotetranychus lewisi* (Lewis Spider Mite)

9.15.1 Hazard Identification

Common name: Lewis spider mite
Scientific name: *Eotetranychus lewisi* (McGregor) [Acarina: Tetranychidae]
Synonyms: *Tetranychus lewisi* McGregor
Bangladesh status: Not known to be present in Bangladesh.

9.15.2 Biology

As in all the tetranychid species, the life cycle of *E. lewisi* comprises five stages: egg, larva, protonymph, deutonymph and adult. On citrus, the eggs are laid in depressions on the surface of the fruit and the mites feed on the developing fruit and do not usually damage the leaves.
The lower development temperature threshold of *E. lewisi* from egg to adult lies at 8.3 or 9.0 °C based on estimations using the Lactin and linear model, respectively. The upper development threshold lies at 28.2 °C according to the same authors. Deutonymphs are the most cold-tolerant stage with estimated thresholds at 2.5 or 3.4 °C according to the Lactin and linear model, respectively. The most heat-tolerant stage is the protonymph, with an upper development threshold

at 31.5 °C. Development from egg to adult on poinsettia leaves takes 19 days at 16 °C and decreases linearly with temperature to a minimum of eight days at 26 °C. At 26 °C, egg hatching took an average of 2.5 days, while the larval, protonymphal and deutonymphal stages lasted for 1.8, 1.4 and 2.3 days, respectively.

When *E. lewisi* was reared on tender lemon leaves at temperatures ranging from 17 to 23 °C, the period between egg deposition and female emergence was twelve days. The average duration of stages was six days for egg incubation, two days for the larval stage, two days for the protonymph and another two days for the deutonymph. The development of males was two days shorter than that of females. The life cycle from egg to adult on citrus in California (USA) averages 12 days for the male and 14.5 days for the female.

9.15.3 Hosts

E. lewisi has been reported from 69 herbaceous and woody plant species belonging to 26 different families. The list of potential hosts includes cultivated species, such as castor oil plant (*Ricinus communis*), poinsettia (*Euphorbia pulcherrima*), strawberry (*Fragaria ananassa*), cotton (*Gossypium hirsutum*), orange (*Citrus sinesnis*), fig (*Ficus carica*), lemon (*C. limon*), papaya (*Carica papaya*), olive (*Olea europaea*), peach (*Prunus persica*), and vine (*Vitis vinifera*). Wild hosts include weeds, such as nightshade (*Solanum eleagnifolium*), and several tree species including acacias (*Acacia* spp.), pines (*Pinus ponderosa*) and aspens (*Populus tremuloides*).

It should be noted, however, that the report of a species as a host of *E. lewisi* does not necessarily mean that the mite can complete its life cycle on the species or it can cause economic damage. Therefore, there is uncertainty regarding the exact host status of many species where it was found.

9.15.4 Distribution

Country of origin is not known, possibly Central America where it occurs on native *Euphorbia* spp. The Lewis spider mite has been reported from 17 countries in Africa, North and South America, Asia and Europe. It was found in South Africa, Mexico, USA (southwestern states, California, Washington, Michigan, and Massachusetts), Costa Rica, El Salvador, Honduras, Nicaragua, Brazil, Portugal (Madeira), Denmark, Poland, and Taiwan. *E. lewisi* occurs on native *Euphorbia* species—including on poinsettia (*Euphorbia pulcherrima*)—in the tropical area of Central America, which has been suggested as the native host and habitat of the mite.

9.15.5 Hazard Identification Conclusion

Populations of *E. lewisi* can increase rapidly in numbers and spread gradually from original source plants. It is a polyphagous species and several potential host (citrus) plants are widely distributed in Bangladesh. It is associated with fruits. Citrus fruits are imported in Bangladesh from South Africa, USA and Brazil where *E. lewisi* present. It is considered as potential hazards for citrus fruits in Bangladesh.

9.15.6 Risk Assessment

9.15.6.1 Entry Assessment

Mites are small and can shelter under the calyx of *Citrus* fruit. Adult *E. lewisi* can live up to about 19 days so would easily survive the time from harvest in South Africa, to distribution in Bangladesh. Mites have frequently been intercepted on *Citrus* fruit at the Bangladesh border. Although *E. lewisi* is reported to be associated with *Citrus* fruit this is not its preferred host. Therefore the likelihood of *E. lewisi* entering Bangladesh on fresh *Citrus* fruit is medium.

9.15.6.2 Exposure Assessment

E. lewisi has multiple ways to disperse (natural active and passive, animal/human assisted) all of which occur in the Bangladesh. The most likely route for exposure will be by peel or poor quality fruit discarded on compost or into the environment. *E. lewisi* is a polyphagous species and several potential host plants are widely distributed in Bangladesh. This species is mobile and may crawl onto other hosts, or climb a plant to be carried by the wind. As citrus fruits are grown most of the districts in Bangladesh the likelihood of exposure is considered to be high.

9.15.6.3 Establishment Assessment

Populations of *E. lewisi* can increase rapidly in numbers and spread gradually from original source plants. Many of its host plants are available in Bangladesh. Several of the host plants on which *E. lewisi* has been reported are economically important crops, and some are particularly widely distributed in Bangladesh and cultivated in open fields (e.g. citrus). Environmental conditions are also suitable for the establishment of the pest in Bangladesh. Therefore the likelihood of establishment is considered to be high.

9.15.7 Consequence Assessment

9.15.7.1 Economic Impact

On most plants, *E. lewisi* feeds on the underside of the leaves, preferring the regions close to the main veins. *E. lewisi* populations increase most rapidly on *Euphorbia marginata*, poinsettias and *Ricinus communis* (all Euphorbiaceae) under glass. If not controlled, the resulting leaf discoloration and leaf drop ruin the sale value of the plants. On *Citrus*, mites feed mostly on the fruit causing stippling of the rind, heavy infestations produce silvering on lemons and silvering or russetting on oranges.

Damage, in the form of chlorosis, can be caused to the leaves, twigs and fruit of host plants. On most of leaf drop is also common, as mites suck the plant sap causing wilting, drying and eventually dropping of the leaf. Growth, flowering and fruit yield is also adversely affected by mite damage to host plants. Infestations would affect agricultural, forestry, horticultural and nursery sectors. Conditions in Bangladesh are not optimal for development of heavy infestations. Therefore the economic consequences of establishment are considered to be medium.

9.15.7.2 Environmental Impact

As it is a polyphagous species it is likely to find a number of native Bangladesh species palatable. Heavy damage may cause loss of species from the environment.

9.15.7.3 Human Health and Social Impact

There are numerous reports of respiratory allergy due to exposure to mites like *T. urticae* in particular in horticulture and farm workers. No evidence appears to exist to indicate that similar impacts on human health are caused by *E. lewisi*.

9.15.8 Risk Estimation

The likelihood of entry of *E. lewisi* is medium, exposure is high and establishment is medium. The consequences of establishment are medium. The risk estimate for *E. lewisi* is non negligible therefore this organism is classified as a hazard in this commodity and risk managemnet measures can be justified.

9.15.9 Risk Management

9.15.9.1 Options

There are a number of points on the import pathway where effective measures could be applied to reduce the likelihood of *E. lewisi* arriving in Bangladesh.

9.15.9.1.1 Post Harvest Culling, Washing, Waxing and Visual Inspection

The post harvest washing of fruit followed by visual inspection is a supplementary measure to be implemented in conjunction with the chosen disinfestation treatment to reduce pest numbers in fruit for export. Mite damage, especially when extensive is detectable and the fruit should be discarded. Although the mite is very small, visual inspection may detect it, as it is a bright carmine red colour. However, red-green color blind individuals may be less effective in detecting these mites on green fruit, and the mite is able to shelter under the fruit calyx thus escaping detection.

Washing may remove some mites from the fruit surfaces, but may not remove those under the calyx. Surfactants may assist in removing mites from under the calyx. Waxing is more likely to repel or kill some mites remaining on the fruit. However there are no efficacy data specific to mites with regard to waxing therefore residual risk is uncertain.

9.15.9.1.2 High Temperature Forced Air

There are no specific efficacy data for the disinfestation of mites from *Citrus* fruit by HTFA. Waddell *et al.* (1993) found it took 10.9 hours at 45°C to achieve 99% mortality of *Tetranychus urticae* (a particularly difficult mite to kill as it is very hardy) using “hot air”, although the method they employed is not comparable to HTFA. HTFA treatment takes about 4-6 hours to get the air temperature a degree or two higher than the required (47.2°C) core temperature of the fruit for fruit fly disinfestation, therefore HTFA at 47.2°C for 20 minutes is likely to kill *E. lewisi* on the fruit surface with a low likelihood of survivors.

For *Citrus* except lemons and limes: high temperature forced air treatment raising the internal temperature of the commodity from ambient temperature to 47.2°C for a minimum of 20 minutes with the total treatment time being at least 4 hours or longer.

9.15.9.1.3 Hot Water Immersion

Hot water immersion for 20 minutes at 49°C killed all arthropods on limes, including mites found externally and under the calyx. It is likely HWI at 49°C for 20 minutes will be effective against *E. lewisi*.

9.15.9.1.4 Cold Disinfestation

There are no efficacy data for disinfestation of mites by cold treatment. Given that it seems this mite may be able to tolerate low temperatures for an extended period of time this treatment may not be suitable.

9.15.9.1.5 Visual Inspection at the Border

The life stages of *E. lewisi* are very small (the adults are about 0.5 mm). Although the adult is brightly colored, because adults and nymphs can seek shelter under the calyx they may be difficult to detect by visual inspection of the consignment on arrival in Bangladesh.

9.15.9.2 Recommended Management Options

Pest management systems in the orchards, screening damage fruits should be implemented in conjunction with the recommended disinfestations treatment.

a) Hot water immersion: 49°C for 20 minutes. Or
b) HTFA treatment: 47.2°C for of 20 minutes.
c) Visual inspection at the border in Bangladesh.

Fungus

9.16 *Guignardia citricarpa*

9.16.1 Hazard Identification

Disease: Black spot of citrus
Pathogen: *Guignardia citricarpa* Kiely
Anamorph: *Phyllosticta citricarpa* (McAlpine) Van der Aa (macroconidial state)
Synonyms: *Phoma citricarpa* McAlpine
Phyllostictina citricarpa (McAlpine) Petrak
Taxonomic position: Fungi: Ascomycetes: Dothideales
Common names: Black spot, hard spot, shot-hole, freckle spot, virulent spot, speckled blotch of citrus (English)
Bangladesh Status: Not present in Bangladesh

9.16.2 Biology

Citrus Black spot (CBS) caused by *Phyllosticta* state occurs on fruit lesions, leaf lesions, dead twigs, fruit stalks and in abundance on leaves on the orchard floor. The teleomorph state, *Guignardia citricarpa* usually appears on fallen leaves before ascocarps develop; the role of the microconidia is unclear. Ascocarps occur throughout the year on leaf litter lying on the orchard floor.

Cultures of *G. citricarpa* grow well on agar media; the optimal temperature for growth has been reported to be 24-27°C and optimum growth in liquid basal synthetic medium has been reported to be at 27°C. Maximum germination, nearly 80%, has been obtained using 0.3% citric acid solution and incubating conidia for 4 days at 25°C in a damp chamber. Germination of macroconidia in tap water has been reported in South Africa. Longevity of macroconidia differs from country to country. In Australia, freshly exuded mature macroconidia have been reported to lose their ability to germinate 1 month after they were produced but in South Africa macroconidia have been reported to retain their germinative capacity up to 5 months. Macroconidia on germination enter both unwounded and wounded fruits, and through abrasions caused by hail or insect damage. In field trials carried out in Australia, young fruits inoculated with conidial suspensions after petal fall in October produced black spot disease after nearly 1 year. In South Africa, young citrus fruits inoculated with high concentrations of macroconidia near mid-November showed speckled blotch lesions by the end of January the following year. The role of macroconidia in spreading the black spot disease is considered to be of minor importance when compared with airborne ascospores which are regarded as the primary source of inoculum.

The disease spreads in orchards by infection coming from macroconidia and ascospores. It takes several years from the time the first symptoms are noticed until the disease reaches epidemic proportions in South Africa. Macroconidia are water-borne and require droplets of water for their emergence and dispersal and pycnidia have no special release mechanism for expelling conidia into the atmosphere. Macroconidia are washed down or rain-splashed from dead twigs and old fruit stalks to infect susceptible fruits in Zimbabwe. Ascospores are forcibly ejected vertically up to 1 cm and carried by wind and water. Dew, rain and high temperature promote the release of ascospores from ascocarps developed on leaf litter from the floor of orchards during May to October in Taiwan, from November to June in South Africa, and throughout the year in Australia.

In Australia, ascospores take more than 24 h to germinate at 25°C and 4 days to reach 98% germination, whereas in South Africa peak germination approaching 100% has been observed in 24h. Ascospores on germination produce appressoria with infection pegs that penetrate the cuticle. The infection pegs produce at their tips, between the cuticle and the upper epidermal cells, knots of fungal tissue which are considered to establish latent infection. Flowers and fruits are susceptible to infection from anthesis until approximately 16 weeks later. Infection is usually followed by a long period of latency which may last 12-36 months in Australia and about 3-12 months after anthesis for fruit infection in South Africa. Latent infections on green leave provide ascospore inoculum, whenever such leaves fall, over a period of 1 to approximately 3 years. The presence of *G. citricarpa* mycelium in healthy green citrus leaves in commercial nurseries has been demonstrated and mycelium in latent infections has been reported to survive 18 days in wilted air-dried citrus leaves and then to produce fructifications when such leaves were moistened and incubated at 30°C.

The existence in Australia of a primary and secondary infection cycle and their relationships has been demonstrated by Kiely. Primary latent infection of young fruits gives rise to pycnidia with macroconidia after 12-15 months, and at maturity they develop black spot lesions, which in turn initiate a secondary infection cycle. In South Africa, the seasonal cycle of the pathogen, the climatic conditions and the cycle of citrus fruit and leaves are regarded as the three primary components affecting a black spot epidemic. The leaf litter on the floor of the orchard acts as the reservoir for ascocarps which develop within 50-180 days but maturation depends on intermittent wetting and drying of leaves and prevailing temperature. Heavy dew alone has been reported to be sufficient for maturation and release of ascospores in New South Wales, but in South Africa irrigation and dew have been reported to have little or no noticeable effect on ascocarp development or ascospore release. Cool, dry weather has been reported to prolong ascocarp maturation up to 6 months under South African conditions. Rainfall pattern has been reported to influence the release of the primary inoculum (ascospores) into the atmosphere; 3 mm of rain is considered sufficient for the release of large numbers of ascospores but continuous heavy showers are reported to affect ascospore discharge adversely and reduce ascospore load in the air.

9.16.3 Hosts

The principal hosts are *Citrus* species: *C. limonia*, *C. nobilis*, *C. poonensis*, *C. tankan*, grapefruits (*C. paradisi*), lemons (*C. limon*), limes (*C. aurantifolia*), mandarins (*C. reticulata*), oranges (*C. sinensis*). Sour oranges (*C. aurantium*) are not susceptible.

Non-citrus hosts reported to harbor *G. citricarpa* include almonds (*Prunus dulcis)*, avocados (*Persea americana*), *Eucalyptus* spp., guavas (*Psidium guajava*, *P. montanum*), mangoes (*Mangifera indica*), passionfruits (*Passiflora edulis*), Rubus spp. and a variety of ornamentals such as *Caesalpinia pulcherrima*, *Callistemon citrinus*, *Camellia japonica*, *Dendrobium speciosum*, holly (*Ilex aquifolium*), *Magnolia* sp., *Smilax* sp. Other recorded hosts are cardamoms (*Elettaria cardamomum*), *Cola nitida*, *Dioscorea pentaphylla*, *Eucalyptus deglupta* and sugarcane (*Saccharum officinarum*).

The non-citrus host list is controversial and doubtful for two main reasons: 1) adequate cross inoculation details are lacking and 2) on *Camellia*, *Dioscorea*, *Ilex*, *Persea*, *Psidium*, *Mangifera* and s*milax*, species have been described under the names *Guignardia camelliae* (Cooke) Butler, *G. dioscoreae* A.K. Pande, *G. philoprina* (Berk. & M.A. Curtis) Van der Aa, *G. perseae* Punithalingam, *G. psidii* B.A. Ullasa & R.D. Rawal, *G. mangiferae* A.J. Roy and *G. smilacis* A.J. Roy, respectively.

9.16.4 Geographical Distribution

Citrus black spot is found in Argentina, Australia, Brazil, China, United States (Florida), Indonesia, Japan, Kenya, Mozambique, Nigeria, Philippines, Sicily, Spain, South Africa Taiwan, Uruguay, Venezuela, and Zimbabwe. No reports have been made from Mediterranean countries.

9.16.5 Hazard Identification Conclusion

Considering the facts that:

- *Guignardia citricarpa* is not known to be present in Bangladesh;
- is present in Brazil, China, and South Africa;
- and can be carried on *Citrus* fruit;

Guignardia citricarpa is considered to be a potential hazard organism in this risk analysis.

9.16.6 Risk Assessment of Black spot (*Guignardia citricarpa)*

9.16.6.1 Entry Assessment

Three potential pathways that *G. citricarpa* may enter through importation of propagative material, importation of leaves as contaminants, and the importation of fruit. Propagative materials of citrus area not imported to Bangladesh so there is no likelihood to enter this organism through this pathway. Leaves are not normally allowed to be present with the consignment but may be associated as contaminant of fruits and hence there is midium possibility of entering through leaves. The possibility of entering this pathogen through infected fruit is high. There might the initial infection in fruit or the disease may be symptomless which might be escaping the inspection. Therefore, the probability of entry through infected fruit is high.

9.16.6.2 Exposure Assessment

The peel or poor quality or damaged fruits in Bangladesh discarded on compost or anywhere into the environment. Citrus market in Bangladesh has extended to everywhere even in the remote rural areas. Citrus plants are grown almost in every vallage, if not commercial in the homestead. Besides the non-citrus host like guava and mangos are also grown everywhere. Therefore the likelihood of exposure is high.

9.16.6.3 Establishment Assessment

CBS occurs in tropical and subtropical regions with abundant rainfall in the summer. Actors such as rainfall and temperature, the amount of available inoculum, and the susceptibility of the fruit influence the survival, sporulation, and dispersal of the pathogen. Rainfall is positively correlated with disease development during susceptible periods and disease development is negatively correlated with rainfall after petal fall. For ascospores a minimum of 15-38 hours of wetness is required for production and germination, while pycnidiospore germination and appressorium formation require a minimum of 12 hours of wetness. Ascostroma formation is optimal at temperatures between 21-28°C and ceases below 7^0C and above 35^0C. In the field, the release of ascospores is more closely correlated to leaf wetness than temperature. For pycnidiospores, appressorium formation may occur between 10-40^oC, with appressorium formation at the extreme temperatures requiring a longer wetness period. All *Citrus* spp. are susceptible to CBS, fruit are susceptible to infection for four to five months after fruit set, while leaves are susceptible up to 10 months of age. Considering the environmental requirement for the establishment of this disease and availability of host plant it is likely that this disease could be established under Bangladesh condition and the probability is medium.

9.16.7 Consequence Assessment

9.16.7.1 Economic Impact

CBS may affect the leaves, twigs, and fruit of host plants but its effects are most marked on the fruit. Unappealing lesions typically develop as fruit reach maturity or postharvest. Virulent spot lesions develop on either fruit reaching maturity or fully mature fruit and are typically irregular in shape. Symptomatic fruit that are still attached to the tree fall readily. Some yield losses due to fruit drop may occur in years favorable for disease development. Control of CBS in the field is costly as several prophylactic applications of fungicide are typically required throughout the growing season. Large economic losses have been recorded in groves not treated with prophylactic sprays to control CBS. In South Africa in 1946, up to 90% of unprotected fruit were commonly deemed unsuitable for export. The unappealing lesions that develop postharvest render the fruits unacceptable and unmarketable for export and also low price in the domestic market. Based on the above information there is a high likelihood that the introduction of G*. citricarpa* and subsequent CBS development in Bangladesh would lead to direct negative impacts on citrus industry in Bangladesh.

9.16.7.2 Environmental Impact

There is no information on the direct impact of CBS on environment. However, the indirect negative impact on environment is that once the disease established it needs heavy sprays of chemicals to control the disease which leads to polluted environment and negative impact on human health.

9.16.8 Risk Estimation

The likelihood of entry and exposure of CBS in Bangladesh is high and medium probability for establishment. This would bring negative economic and environmental impact. The risk estimate for CBS is non negligible therefore this organism is classified as a hazard in this commodity and risk managemnet measures can be justified.

9.16.9 Risk Management

Current disease management strategies employed to control and treat CBS disease in the field and packing house appear to be generally effective and encourages growers to employ CBS disease management programs but there is no universal program or guarantee that such programs are undertaken. If CBS disease management programs are undertaken, the pest risk potential rating will be lowered further. Disease management programs and commercial harvesting and packing practices reduce the prevalence of G. citricarpa infected or CBS affected fruit in commercial shipments of fruit thus further lowering the overall risk.

Fungus

9.17 *Pseudocercospora angolensis*

9.17.1 Hazard Identification

Disease name: Pesudocersospora spot
Name of pathogen: *Pseudocercospora angolensis* (T. de Carvalho & O. Mendes) Crous & U. Braun
Synonyms: Cercospora angolensis T. de Carvalho & O. Mendes 1953
Phaeoramularia angolensis (T. de Carvalho & O. Mendes) P.M. Kirk 1986
Pseudophaeoramularia angolensis (T. de Carvalho & O. Mendes) U. Braun 1999
Taxinomic position: Fungi
Phylum: Ascomycota
Subphylum: Pezizomycotina
Class: Dothideomycetes

Subclass: Dothideomycetidae
Order: Capnodiales
Family: Mycosphaerellaceae
Genus: *Pseudocercospora*
Species: *Pseudocercospora angolensis*
Common name: Leaf and fruit spot of citrus
Bangladesh Status: Not present in Bangladesh

9.17.2 Biology

This disease has been reported from some African countries and Yemen. It is widespread in Angola. Regarding biology of the fungus or field epidemiology limited studies have been carried out in western Africa. Prolonged wet weather conditions followed by dry spells are favorable for the rapid development of the disease. The optimum temperature for the pathogen is 22-26^{0}C. Disease incidence varies with the amount of rainfall. The fungus preferred tropical rainforest climate, tropical monsoon climate, tropical wet and dry savanna climate for disease development. However, it can tolerate steppe climate and also desert climate.

The pathogen produces symptoms as spots or lesions on leaves, fruits and stem. On older leaves non-sporulating lesions may be present at the onset of rainy season, when the new disease-free leaves are formed. Sporulation on the lesions on older leaves begins after 3-5 weeks from where the spores are dispersed by wind or rain splash to new young leaves where the symptoms appear 2-3 weeks. The old lesions appear to be the source of inoculum when conditions favor infection.

9.17.3 Hosts

All species of cultivated *Citrus* appear to be susceptible, although the lime (*Citrus latifolia*) and smooth lemon (*Citrus limon*) are often reported to be relatively resistant. Of the other members of the Rutaceae in Africa, *Citropsis tanakae* is known to be infected.

9.17.4 Geographical Distribution

Pseudocercospora spots of citrus has been reported from some African countries namely, Angola (wide spread), Burundi, Cameroon, Central African Republic, Comoros, Congo, Congo Democratic Republic, Côte d'Ivoire, Ethiopia, Gabon, Gambia, Ghana, Guinea, Kenya, Mozambique, Nigeria, Rwanda, Sierra Leone, Tanzania, Togo, Uganda, Zambia, Zimbabwe and from one Asian country namely Yemen.

9.17.5 Hazard Identification Conclusion

Considering the facts that:

- *Pseudocercospora angolensis* is not known to be present in Bangladesh;
- is present in some African countries and Yemen;
- and can be carried on *Citrus* fruit;

Pseudocercospora angolensis is considered to be a potential hazard organism in this risk analysis.

9.17.6 Risk Assessment of Pseudocercospora spot of citrus *(P. angolensis)*

9.17.6.1 Entry Assessment

Three potential pathways that *P. angolensis* may enter as spore and/or mycelium into Bangladesh are through propagative material, importation of leaves as contaminants, and the importation of fruits. Propagative materials of citrus are generally not imported to Bangladesh but if imported for research or for varietal improvement purpose then the likelihood of entry of this organism through this pathway is low. Leaves are not normally allowed to be present with the consignment but may be associated as contaminant of fruits and hence there is midium possibility of entering through leaves. The possibility of entering this pathogen through infected fruit is high. There might the initial infection in fruit or the disease may be symptomless which might be escaping the inspection. Therefore, the probability of entry through infected fruit is high.

9.17.6.2 Exposure Assessment

The peel or poor quality or damaged fruits in Bangladesh discarded on compost or anywhere into the environment. Citrus market in Bangladesh has extended to everywhere even in the remote rural areas. Citrus plants are grown almost in every village, if not commercial in the homestead. The asexual spores of the fungus can be dispersed to long distance by wind. Therefore, the likelihood of exposure of citrus plant to this fungus is high.

9.17.6.3 Establishment Assessment

Pseudocercospora spot of citrus occurs in tropical regions with abundant rainfall in the summer. Factors such as rainfall and temperature, the amount of available inoculum, and the susceptibility of the fruit influence the survival, sporulation, and dispersal of the pathogen. Sporulation on the infected plant parts starts after 3-4 weeks of the onset of rainfall. At this time new leaves are developed and the spores are dispersed by wind to long distance. As all the cultivated citrus are susceptible to this pathogen there is every possibility of carried the inoculums to the new leaves and cause infection where the symptom appear 2-3 weeks later. The disease also occurs on the fruits and stems. The optimum temperature for disease development is 22-26^{0}C. Considering the environmental requirement for the establishment of this disease and availability of host plant it is likely that this disease could be established under Bangladesh condition and the probability is medium.

9.17.7 Consequence Assessment

9.17.7.1 Economic Impact

Pseudocercospora spot of citrus may affect the leaves, twigs, and fruit of host plants but its effects are most marked on the fruit. The most devastating effect of the disease is the premature fall of young fruits and leaves. The development of even a few fruit lesions renders the fruit unmarketable. A yield loss of 50-100% is not uncommon in most disease-affected areas. The loss of leaves and desiccation of shoots can have a significant debilitating effect on the tree, which will affect subsequent fruit yields. In some areas, farmers have abandoned citrus plantings or replaced them with other crops. Based on the above information there is a high likelihood that the introduction of *P. angolensis* and subsequent disease development in Bangladesh would lead to direct negative impacts on citrus industry in Bangladesh.

9.17.7.2 Environmental Impact

There is no information on the direct impact of Pseudocercospora on environment. However, the indirect negative impact on environment is that once the disease established it needs heavy sprays of chemicals to control the disease which leads to polluted environment and negative impact on human health.

9.17.7.3 Social impact

The pathogen reproduces asexually and produces abundant spores and spread mainly by wind. Therefore, it has the potentiality to spread the disease rapidly and causes upto 50 to 100% yield loss. Due to its high reproductive potential, high mobility and host damage it may cause negative impact on livelihood of citrus farmers.

9.17.8 Risk Estimation

The likelihood of entry and exposure of *P. angolensis* in Bangladesh is high and medium probability for establishment. This would bring negative economic and environmental impact. The risk estimate for *P. angolensis* is non negligible therefore this organism is classified as a hazard in this commodity and risk managemnet measures can be justified.

9.17.9 Risk Management

Prevention of the transport of infected trees and fruit from contaminated areas is an important measure for inhibiting the spread of the pathogen.

9.17.9.1 Cultural Control and Sanitary Measures

The following disease management methods have been recommended:

- Collection and destruction by burying and/or burning of all fallen fruit and leaves in affected orchards. This may drastically reduce the inoculum pressure in the field.
- Planting of windbreaks around the citrus orchards to minimize the impact of wind, which is the primary dispersal agent for spores.
- Judicious pruning of shoots, particularly those that have died back, to allow light penetration into and free aeration within the tree canopy, thus making the environment in the phyllosphere less conducive to disease development, i.e. shorter leaf-wetness period, lower RH, moderate temperatures.

9.17.9.2 Chemical Control

The most effective fungicides tested on fruit and leaf spot of citrus in Cameroon were copper oxide and benomyl. Treatments with benomyl, alternated with copper-based fungicides, may be applied at 2-week intervals beginning a week after the onset of rains recommend spraying after rainfall, rather than on a fixed schedule. Of the newer triazole fungicides, fluzilazole provided the best control of disease in the field. A mixture of benomyl and chlorothalonil applied at 15-day intervals was most effective in controlling the disease on the leaves of sweet orange in Ethiopia, compared to a mixture of benomyl and copper hydroxide or any of the fungicides alone.

Fungus

9.18 *Phoma tracheiphila*

9.18.1 Hazard Identification

Disease name: Mal secco disease
Name of Pathogen: *Phoma tracheiphila* (Petri) Kantschaveli & Gikashvili
Synonyms: *Bakerophoma tracheiphila* (Petri) Ciferri
Taxonomic position: Fungi: Ascomycetes (probable anamorph)
Common names: Mal secco (Italian)
Bangladesh Status: Not present in Bangladesh

9.18.2 Biology

The fungus produced conidia in pycnidia found on withered twigs and from hyphae growing on exposed wood or debris, including branches, leaves, and fruits. Most probably the pathogen can also be transmitted to other trees through contaminated pruning tools. Twigs and leaves lying on the soil may be a source of inoculum for infection through wounded roots. Inoculum enters through wounds via both conidia and mycelium. Cultivation practices, wind, frost and hail that cause injuries to different organs favor infection by *P. tracheiphila*. Inoculum could be provided both by conidia produced from pycnidia present on withered twigs, and by conidia produced from phialides borne on free hyphae on exposed woody surfaces of the tree or on debris. Inoculum is believed to be water-borne. The inoculum can be dispersed by wind and rain under natural conditions.

Although the optimum temperature for pathogen growth is about 25°C, optimum temperature for symptom expression and xylem colonization is 20 to 22°C. The optimum temperature for growth of the pathogen and for symptom expression is 20-25°C, whereas the maximum temperature for mycelial growth is 30°C. Infection occurs between 14 and 28°C, whereas at temperatures above 28°C symptoms are not expressed. A unique characteristic of this fungus is its ability to produce a-sexual spores called phialoconidia. These are spores formed on the mycelium in the plant xylem released into the transpiration flow. When a spore reaches a location where it can germinate it forms new hyphae causing disease. Prunings containing affected twigs or branches can be a source of inoculum for several weeks. The fungus can survive within infected twigs in the soil for more than 4 months.

9.18.3 Hosts

Mal secco is most prevalent and severe on lemon (*Citrus* x *limon*), lime (*Citrus* x *aurantiifolia*), citron (*Citrus medica*) and bergamont *(Citrus* x *bergamia*). However, all citrus species are susceptible to *Phoma tracheiphila* by artificial inoculation under laboratory conditions.

9.18.4 Geographical Distribution

EPPO region: Mediterranean and Black Sea areas including Albania, Algeria, Cyprus, Greece (including Crete and Aegean Islands), Israel, Italy (including Sardinia and Sicily), Lebanon, Russia (Caucasus), Syria, Tunisia, Turkey. **Asia**: Cyprus, Georgia, Iraq, Israel, Lebanon, Syria, Turkey, Yemen. **Africa**: Algeria, Tunisia.

9.18.5 Hazard Identification Conclusion

Considering the facts that:

- *Phoma tracheiphila* is not known to be present in Bangladesh;
- is present in Middle East from where citrus fruits are imported to Bangladesh;
- and can be carried on *Citrus* fruits, twigs and leaves;

Phoma tracheiphila is considered to be a potential hazard organism in this risk analysis.

9.18.6 Risk Assessment of Mal secco *(Phoma tracheiphila)*

Similar to black spot disease and therefore this organism is classified as a hazard in this commodity and risk managemnet measures can be justified.

9.18.7 Risk Management

Current disease management strategies employed to control and treat mal secco disease in the field and packing house appear to be generally effective and encourages growers to employ mal secco disease management programs but there is no universal program or guarantee that such programs are undertaken. If CBS disease management programs are undertaken, the pest risk potential rating will be lowered further. Disease management programs and commercial harvesting and packing practices reduce the prevalence of *P. tracheiphila* infected fruit in commercial shipments of fruit thus further lowering the overall risk.

Bacterium

9.19 *Candidatus Liberibacter africanus*

9.19.1 Hazard Identification

Disease: Huanglongbing/Citrus Greening
Pathogen: *Candidatus Liberibacter africanus*
Taxonomic position: Bacteria: Gracilicutes
Common names: Greening (Africa), leaf mottling (Philippines), decline (India), vein phloem degeneration (Indonesia) (English); Huang long bin (yellow shoot), likubin (decline) (Chinese) Greening (French), Enverdecimiento (Spanish)
Bangladesh Status: Not present in Bangladesh

9.19.2 Biology

The bacteria are non-culturable. In South Africa, Kenya, Ethiopia, Madagascar and Yemen, huanglongbing occurs only in cool climatic conditions, at elevations above 600-1000 m. The psyllid vector is *Trioza erytreae*. In contrast, in the Indian Subcontinent, Asia and Saudi Arabia, the disease also occurs at low elevations with a hot climate. The psyllid vector is *Diaphorina citri*. These observations, confirmed by experiments under phytotron conditions, suggest that there are two forms of huanglongbing: the African heat-sensitive form caused by Liberibacter africanus, and the Asian heat-tolerant form caused by L. asiaticus. That these temperature effects are due to the respective liberibacters has been demonstrated in Catharanthus roseus: in plants infected by L. africanus, the disease is heat sensitive (no symptoms above 25-30 °C), while in L. asiaticus-infected plants, the disease is heat tolerant (symptoms also above 30 °C). The distinction between heat-tolerant and heat-sensitive forms of huanglongbing was the first indication that different strains of the agent occur, and that African strains are quite different from Asian strains. These early observations are now easily understood on the basis of two recognized Liberibacter species: L. africanus and L. asiaticus. No data are available on the climatic conditions necessary for the survival of L. americanus; however, it does occur in the same areas as L. asiaticus, suggesting similar climatic requirements. It has also been demonstrated that the asian psyllid *Diaphorina citri* is equally efficient in transmitting both asiaticus and africanus strains.

9.19.3 Hosts

Citrus greening bacterium infects citrus generally. The bacterium may persist and multiply in most *Citrus* spp. but most severe symptoms are found on oranges (*C. sinensis*), mandarins (*C. reticulata*) and tangelos (*C. reticulata* x *C. paradisi*). Somewhat less severe symptoms are found on lemons (*C. limon*), grapefruits (*C. paradisi*), *C. limonia*, *C. limettioides*, rough lemons (*C. jambhiri*), kumquats (*Fortunella* spp.) and citrons (*C. medica*) (McClean & Schwarz, 1970). Symptoms are even weaker on limes (*C. aurantiifolia*) and pummelos (*C. grandis*).

9.19.4 Geographical Distribution

Asia: Saudi Arabia, Yemen.

Africa: Burundi, Cameroon, Central African Republic, Comoros, Ethiopia, Kenya, Madagascar, Malawi, Mauritius, Réunion, Rwanda, Somalia, South Africa, Swaziland, Tanzania, Zimbabwe.

Americas: Mexico, USA (California, Florida), Belize, Dominican Republic, French West Indies, Guadeloupe, Honduras, Martinique, Puerto Rico, Argentina, Brazil.

Oceania: Papua New Guinea

9.19.5 Hazard Identification Conclusion

Considering the facts that:

- the strain Candidatus *Liberibacter africanus*, causing Greening disease of citrus is not present in Bangladesh;
- It is present in Brazil, South Africa and Middle East from where citrus fruits are imported to Bangladesh;
- and can be carried to Bangladesh along with citrus plants and plant parts as well as the eggs and /or nymphs of the vector insect along with the plants and plant parts but it is unlikely to carry with the fruits;

Candidatus *Liberibacter africanus* is identified as the potential hazard organism in this risk analysis.

Bacterium

9.20 *Spiroplasma citri*

9.20.1 Hazard Identification

Disease: Stubborn
Pathogen: *Spiroplasma citri* Saglio *et al.*
Taxonomic position: Bacteria: Tenericutes: Mollicutes
Common names: Stubborn, little leaf (English) Stubborn (French)
Bangladesh Status: Not present in Bangladesh

9.20.2 Biology

Spiroplasma citri infects the phloem sieve tubes of its hosts. The pathogen persists in affected trees as they decline. It is in practice an obligate parasite, surviving in citrus or in a variety of other host plants, with no saprophytic phase. It is naturally transmitted by leafhoppers: *Circulifer tenellus*, *Scaphytopius nitridus* and *S. acutus delongi* in California (USA) *Neoaliturus haematoceps* and *C. tenellus* in the Mediterranean area. None of these vectors have a particular preference for citrus as a host; they may therefore acquire *S. citri* from other hosts. *S. citri* multiplies in its insect vectors, which become infective some 10-20 days after acquisition feeding. The insects can remain infective throughout their lives (which may be shortened by the infection), but there is no transovarial transmission. Other Homoptera may acquire the spiroplasm, but not transmit it. It remains possible that other species may act as vectors in the Mediterranean area.

In North America, the distribution of *S. citri* follows rather closely that of *C. tenellus* (primarily a sugar beet insect). In the Mediterranean area, one or other vector is present practically wherever citrus is grown, so that availability of vectors does not appear to be a limiting factor in the spread of stubborn disease to new areas. For further information on vectors, see also Golino & Oldfield (1990).

The spiroplasm develops best in citrus under hot conditions (28-32°C) and may not give rise to conspicuous symptoms at lower temperatures. Damage due to stubborn in Syria, by comparison with Corsica (France). Annual plants experimentally infected are rapidly killed at temperatures over 30°C, but may again not show symptoms at lower temperatures.

Spiroplasma citri from areas where citrus does not occur can be experimentally vector-transmitted to citrus, while the pathogen from citrus can be experimentally transmitted to horseradish. Thus, there is no indication at present of special races or strains attacking citrus.

9.20.3 Hosts

Susceptible *Citrus* spp. including the major commercial species in the Mediterranean area: grapefruits (*C. paradisi*), lemons (*C. limon*), mandarins (*C. reticulata*), oranges (*C. sinensis*) and sour oranges (*C. aurantium*). Other citrus hosts are *C. grandis*, *C. limettioides*, *C. limonia*, *C. madurensis*, rough lemons (*C. jambhiri*), satsumas (*C. unshiu*), and tangelos (*C. paradisi* x *reticulata*) (Calavan, 1980). Other rutaceous hosts include *Fortunella* spp. and interspecific rootstock hybrids like citranges (*C. sinensis* x *Poncirus trifoliata*). Some forms are symptomlessly infected, including *P. trifoliata*. Many other cultivated or wild plants, particularly Amaranthaceae, Chenopodiaceae, Brassicaceae and Plantaginaceae, have been found to be naturally infected in south-western USA. *S. citri* causes a specific disease (brittle root) of horseradish (*Armoracia rusticana*) in eastern USA. *Catharanthus roseus*, a host for many phytoplasms, has been found naturally infected in Mediterranean countries; there are probably many other hosts there.

9.20.4 Geographical Distribution

EPPO region: Algeria, Cyprus, Egypt, France (Corsica only), Greece, Israel, Italy (few records; at least Sardinia, Sicily), Lebanon, Libya, Morocco, Spain, Syria, Tunisia, Turkey.
Asia: Cyprus, Iran, Iraq, Israel, Jordan, Lebanon, Pakistan, Saudi Arabia, Syria, Turkey, Yemen.
Africa: Algeria, Egypt, Libya, Morocco, Tunisia.
North America: Mexico, USA (Arizona, California, Illinois, Maryland).
South America: All the following 'records' from South America are based on suspicious symptoms only and should be considered as unconfirmed: Argentina (Tucumán), Brazil (São Paulo), Peru, Suriname, Venezuela.
Oceania: New Zealand (isolated reports).
EU: Present.

9.20.5 Hazard Identification Conclusion

Considering the facts that:

- the bacteria *Spiroplasma citri*, causing Stubborn disease of citrus is not present in Bangladesh;
- It is present in Brazil, Middle East and Pakistan from where citrus fruits are imported to Bangladesh;
- and can be carried to Bangladesh along with citrus plants and plant parts as well as the eggs and /or nymphs of the vector insect along with the plants and plant parts but it is unlikely to carry with the fruits;

Spiroplasma citri is identified as the potential hazard organism in this risk analysis.

Virus

9.21 *Citrus Leprosis Virus C*

9.21.1 Hazard Identification

Disease: Leprosis
Pathogen: Citrus Leprosis Virus C (CiLV-C)
Taxonomic position: Domain: Virus, Genus: Cilevirus, Species: Citrus leprosis virus C
Common names: Leprosis of citrus, CiLV-C (English acronym)
Vector: Mites (*Brevipalpus phoenicis*)
Bangladesh Status: Not present in Bangladesh

9.21.2 Biology

Citrus leprosis is always associated with infestation by a false spider mite of the genus Brevipalpus. Brevipalpus is associated with citrus leprosis in Florida, USA. It also demonstrated that *Brevialpus obovatus* collected from *Bidens pilosa* was able to induce citrus leprosis symptoms and that *B. californicus* was the reported vector of leprosis in Florida, USA. However, those symptoms, unusually, were only observed a long time after mite infestation. This led to speculation about possible mite contamination during the transmission tests.

The same mite species was found associated with citrus leprosis in Argentina and Brazil. B. phoenicis were found to transmit the disease under experimental conditions and that natural infestation of orchards by this mite was associated with the incidence of citrus leprosis. The larvae were reported as more efficient vectors than adults and nymphs but there is contradiction regarding this report,
The mites are parthenogenetic (females producing females) with males rarely found. *B.* ***lewisi*** occurs in California citrus and has never been incriminated with vectoring leprosis. *B.* chilensis has been reported on citrus in Chile. Reproduction of Brevipalpus mites is by parthenogenesis, i.e., female lay eggs that will lead to genetically similar females. Populations of mites from different hosts present a high degree of polymorphism in fragments of DNA amplified by PCR and they possess different capacities of colonization on different host plant species.

The disease is characterized by lesions in leaves, twigs and fruits which do not become systemic. Its aetiology has been controversial, since the cause has been considered to be either a toxin produced by the mite, or localized infection with a virus transmitted by the mite. Several pieces of experimental evidence support viral aetiology: only mites which have access to lesions cause leprosis; tip grafting of infected shoots results in spread from the graft to the receptor tissue; lesions can be experimentally reproduced by mechanical transmission from citrus to citrus and from citrus to several herbaceous; and unenveloped or enveloped rhabdovirus-like particles have been consistently found in cells from citrus leprosis lesions of citrus fruit, leaf or stem. The same type of particle was found in both inoculum tissue and in the lesions produced by mechanical transmission. Indirect evidence is that the mite vectors occur in many parts of the world where leprosis has never been recorded.

Large numbers of particles similar to CiLV occur within the bodies of viruliferous mites. When originating from eggs, Brevipalpus mites do not have particles present within their bodies nor do they transmit virus. This indicates that the virus is not transovarially transmitted. Mites that acquire the virus have the ability to transmit for their lifetime, even if only feeding on non-virus hosts plants and after successive moults. All this information, suggests that the virus is of the circulative type, not only accumulating, but also multiplying inside the body of the mite vector.

9.21.3 Host

Citrus species, especially sweet oranges (**Citrus sinensis**) are naturally infected by CiLV. Lemons (C. limon)**,** mandarins (C. reticulata, C. reshni, C.deliciosa)**,** grapefruits (*C. paradisi*) and hybrids (for example, Murcott) are much less susceptible under natural conditions. No other plant species is known to serve as a natural host for the agent causing citrus leprosis.

9.21.4 Geographical Distribution

Citrus leprosis virus (CiLV-C) is a quarantine pest and economically important disease, reported only on the American continent. Countries from where the disease is reported are Brazil, Maxico, Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Panama, Argentina, Bolivia, Colombia, Paraguay, Peru, Uruguay and Venezuela.

9.21.5 Hazard Identification Conclusion

Considering the facts that:

- Citrus leprosis virus is not known to be present in Bangladesh;
- is wide spread in Brazil from where citrus fruits are imported to Bangladesh;
- and can be carried on *Citrus* fruits, twigs and leaves;

Citrus leprosis virus is considered to be a potential hazard organism in this risk analysis.

Virus

9.22 *Indian ringspot virus*

9.22.1 Hazard Identification

Disease: Indian citrus ringspot disease
Pathogen: Indian ringspot virus (ICRSV)
Taxonomic position: Family: *Flexiviridae;* Genus: *Mandarivirus*
Vector: Mites (***Brevipalpus phoenicis***)
Bangladesh Status: Not present in Bangladesh

9.22.2 Biology

The only known source of infection is infected citrus plants. The virus is transmitted by grafting, but is not seed-borne or soilborne and has no known vector. It has, however, been detected in pollen. The virus may have been present in the original Kinnow mandarin mother plants and has been widely spread by grafting and propagation. Kinnow trees are symptomless in warm weather and appear to offer good material for propagation.

9.22.3 Host

Under natural condition no resistant or tolerant citrus varieties have yet been identified. The commonly grown Kinnow mandarin and Mosambi sweet orange are highly susceptible, and the virus has also been detected in King mandarin, Willow leaf mandarin (the parents of Kinnow), the sweet oranges, Pineapple and Satgudi, sour orange, Nagpur orange, Rangpur lime, Kagzi lime and Kagzi kalan (*C. aurantifolia* (Christen) Swingle and Karna khatta (*C. karna* Raf.). Rough lemon and Malta sweet orange were also easily infected by graft-inoculation.

9.22.4 Geographical Distribution

Indian citrus ringspot disease is only known to occur in Andhra Pradesh, Haryana, Indian Punjab, Karnataka, Maharashtra and Uttar Pradesh of India

9.22.5 Hazard Identification Conclusion

Considering the facts that:

- Indian citrus ringspot disease is not known to be present in Bangladesh;
- is wide spread in some provinces in India from where citrus fruits are imported to Bangladesh;
- and can be carried on *Citrus* fruits, buds, twigs and leaves;

Indian citrus ringspot disease is considered to be a potential hazard organism in this risk analysis.

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