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IMPORT RISK ANALYSIS (IRA) OF CARNATIONS (*Dianthus caryophyllus* L.)

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ABSTRACT

Export of carnation cut flowers earns a considerable amount of foreign exchange to Sri Lanka but the growers depend on the imported nursery stocks for its production. Small rooted plants are imported into the country and sent directly to the growing sites. The entry conditions stipulating the safeguards against unwanted pests of carnation were formulated in 1982. For any updating, pests of quarantine concern must be determined after a risk analysis based on scientific justifications and according to International Standards on Phytosanitary Measures (ISPM). A survey on current pest problems of carnation in Sri Lanka indicated the presence of several important pests such as *Alternaria dianthi*, *Botryotinia fuckeliana*, *Fusarium avenaceum*, *Fusarium dianthi*, *Tetranychus urticae*, and *Uromyces caryophylli*. One hundred and twenty-five pests that can infest carnation plants were considered for the import risk analysis (IRA). The pathway was taken for initiation because imported rooted plantlets could introduce carnation pests into Sri Lanka. The widespread presence in Sri Lanka of a pest makes it a non-quarantine pest. The analysis considered criteria on possibilities of entry and the establishment and spread of pests. Special attention was given to pests that can cause considerable damage not only to carnations but also to our economically important crops in the carnation growing Nuwara Eliya region. The analysis revealed that six bacteria (*Burkholderia caryophylli*, *Pectobacterium chrysanthemi*, *Pectobacterium rhapontici*, *Pseudomonas marginalis* pv. *marginalis*, *Rhizobium rhizogenes*, and *Rhodococcus fascians*), five fungi (*Alternaria dianthicola*, *Corticium stevensii*, *Phialophora cinerescens*, *Phymatotrichopsis omnivora*, and *Verticillium dahliae*), four insects/mites (*Cacoecimorpha pronubana*, *Epichoristodes acerbella*, *Hercinothrips femoralis*, and *Phytonemus pallidus*), four nematodes (*Criconemella curvata*, *Ditylenchus dipsaci*, *Heterodera schachtii*, and *Heterodera trifolii*) and eight viruses (Arabis mosaic nepovirus, carnation 1 alphacryptovirus, carnation etched ring caulimovirus, carnation latent carlavirus, carnation mottle carmovirus, carnation necrotic fleck closterovirus, carnation ringspot dianthovirus, and carnation vein mottle potyvirus) require plant quarantine attention during the importation of rooted plantlets of carnations.

KEYWORDS: Carnation nursery stocks, Import risk analysis, IRA, Pest risk analysis, PRA, Quarantine pests.

INRODUCTION

Risk analysis is one of the pre-requisites for implementation of phytosanitary measures (Anon, 1998). Such scientific justification cannot be then considered as barriers for trade. Yet, for international acceptance, the analytical procedures must follow international standards adopted by the International Plant Protection Convention (IPPC). Depending on the perceived risk, safeguards could be recommended to minimize the introduction and spread of plant pests during the transboundary movement of commodities. Even though Sri Lanka has signed multilateral agreements

(Anon, 1998; 1999a) esp. the agreement on Sanitary and Phytosanitary Measures under World Trade Organization (WTO/SPS Agreement) and International Plant Protection Convention (IPPC), no attempts were seriously taken to fulfill the obligations for carrying out pest risk analysis (PRA). Since plant quarantine service is required to do such studies, a simple procedure for determining pests of quarantine significance during the importation of carnation nursery stocks is presented.

In Sri Lanka, carnation (*Dianthus caryophyllus* L.) is the most important export cut flower (Dhanasekera, 1998), which is grown inside net houses under protected environmental conditions. Carnation cultivation is entirely based on imported planting materials, especially rooted cuttings (Table 1) because no attempts have been made to mass-produce carnation nursery stocks in Sri Lanka. Furthermore, the cultivators preferred to get new germplasm material in large quantities.

Table 1. Quantity of carnation nursery stocks imported to Sri Lanka during 2001-2004.

Year	*No. of plants imported*
2001	437,900
2002	985,600
2003	995,800
2004*	501,350

* From January to August

The phytosanitary requirements for the import of carnation nursery stocks require that they be free from the following:

Bacteria: *Corynebacterium fascians, Erwinia chrysanthemi, Xanthomonas oryzae*;

Fungi: *Fusarium* spp., *Phytophthora nicotianae, Pellicularia koleroga, Phialophora* spp., *Phytophthora omnivorum, Pythium ultimum, Uromyces* spp. and *Ustilago violacea*;

Insects: *Cacoecimorpha pronubana, Liriomyza trifolii, Phytomyza syngenesiae, Spodoptera exigua, Spodoptera littoralis.*

Nematodes: *Heterodera trifolii.*

Virus: Aster Yellows, Beet Curly Top Virus, Carnation Etched Ring Virus, Carnation Latent Disease, Carnation Mosaic Virus, Carnation Necrotic Fleck Virus, Carnation Ringspot Virus, Carnation Streak Virus, Carnation Yellows and Clover Big Vein Virus, and other virus, virus like and phytoplasma diseases.

These entry conditions have been in operation since 1982. The basis for selecting these pests was not reported and the names of certain pests have been changed with time (CAB International, 2002). This study was undertaken to update the phytosanitary requirements because, except for a brief report (De Silva, 1985) no such attempts have been made before in Sri Lanka.

MATERIALS AND METHODS

Sample Collection

Up country wet zone was selected to collect samples to identify the pests of carnation in Sri Lanka. The nurseries where carnations were cultivated were inspected to collect information on pest status. Samples from each field were collected purposively. Diseased plants and plant parts such as leaves, stems, flowers, and plants with roots were collected from each nursery. They were put in separately labeled poly-bags and brought to the laboratory for identification of pests.

Culturing

Plant parts sampled and brought to the laboratory were dissected. The areas showing disease symptoms were surface sterilized and cultured on potato dextrose agar (PDA) medium. The cultures were maintained at 25°C until the growth of fungal and bacterial colonies were visible.

Pest risk analysis

WTO/SPS requires that the phytosanitary measures be based on international standards, if IPPC has developed such standards. Hence, for this study, a simple procedure was adopted based on International Standards for Phytosanitary Measures (ISPM) Nos. 2 and 11 (IPPC, 1996a ; 2003).

According to the ISPMs, PRA or IRA has several steps: 1. Initiation 2. Risk assessment 3. Risk management. At each stage, several criteria will be considered for selecting the potential quarantine pests. A list of pests of carnation was made from the data obtained from the Crop Protection Compendium (CAB International, 2002) from the Crop Knowledge Master (2004) and from text books (Baily, 1982, Farr *et al.*, 1995, Brunt *et al.*, 1996, and Horst, 1996). Information given in these sources was used throughout this study and, if at any stage, there is no relevant information available (information gaps) indicating the limit of our knowledge on the pest, the risk analysis could not be continued. Pathway was considered for initiation of pest risk analysis (PRA) because the outcome of this study may lead to a revision of the entry conditions for carnation nursery stocks. For risk assessment,

presence/absence in Sri Lanka, entry potential, establishment and spread potential, and economic impact of the pests were considered. Thereafter, availability of pest management options was considered. Nuwara Eliya region, where carnations are grown was selected as the PRA area, where vegetables and tea are also extensively cultivated.

RESULTS AND DISCUSSION

Survey of pests

The survey revealed the presence of following pests in the PRA area:

Fungi: *Alternaria dianthi*, *Cladosporium* sp., *Fusarium avenaceum*, *Fusarium oxysporium* pv. *dianthi* and *Uromyces dianthi*;

Mites: *Tetranychus urticae*;

Insects: *Agrotis segetum*, *Aphis* sp., *Chrysodeixis eriosoma*, *Coccus hesperidum*, *Liriomyza* sp., *Myzus persicae* and *Spodoptera exigua*.

Insect and mite damage was more severe in cultivations where pest management practices were at a low level. Some of the carnation cultivations were nearly abandoned. One detected caterpillar could not be identified.

Import Risk Analysis (IRA)

Stage 1: Initiation

There were 125 pests infesting carnations (Table 2), which were studied for this import risk analysis (IRA).

Stage 2: Risk assessment

The possibility of each pest coming with the rooted cuttings of carnation was considered to select those having the entry potential (Table 2). Hence, any pest infesting vegetative parts, leaves, stems, roots can arrive at the PRA area via the selected pathway. On the other hand, those pests affecting only seeds, inflorescences, flowers and/or pods cannot enter with nursery stocks.

Table 2. Occurrence of carnation pests in Sri Lanka and their potential for entry into PRA area by rooted carnation cuttings.

Pest	*Presence/ Absence in Sri Lanka*	*Affected plant parts*	*Potential of entry*	*Potential quarantine pest*
BACTERIA:				
Burkholderia andropogonis	Ab	Leaves	Yes	Yes
Burkholderia caryophylli	Ab	Stem	Yes	Yes
Erwinia chrysanthemi	Pr.	Vegetative parts	Yes	No
Erwinia chrysanthemi pv. *chrysanthemi*	Ab	Whole plant	Yes	Yes
Erwinia herbicola pv. *gypsophilae*	Ab	Roots	Yes	Yes
Pectobacterium chrysanthemi	Ab	Roots	Yes	Yes
Pectobacterium rhapontici	Ab	Whole plant	Yes	Yes
Pseudomonas marginalis pv. *marginalis*	Ab	Leaves	Yes	Yes
Rhizobium radiobacter	Pr	Whole plant	Yes	No
Rhizobium rhizogenes	Ab	Roots	Yes	Yes
Rhodococcus fascians	Ab	Leaves	Yes	Yes
Xanthomonas oryzae pv. *oryzae*	Pr	Leaves	Yes	No
FUNGI				
Alternaria alternata	Pr	Vegetative parts	Yes	No
Alternaria dauci	Pr	Whole plant	Yes	No
Alternaria dianthi	Pr	Whole plant	Yes	No
Alternaria dianthicola	Ab	Leaves, stems	Yes	Yes
Alternaria saponariae	Ab	Leaves	Yes	Yes
Armillaria mellea	Pr	Roots	Yes	No
Ascochyta dianthi	Ab	Information gap	-	-
Botryotinia fuckeliana	Pr	Leaves & stems	Yes	No
Cladosporium herbarum	Pr	Information gap	-	-
Cochliobolus heterostrophus	Pr	Leaves	Yes	No
Cochliobolus setariae	Ab	Information gap	-	No
Colletotrichum coccodes	Ab	Flowers	No	No
Colletotrichum dematum	Pr	Seedlings	Yes	No
Corticium stevensii	Ab	Roots	Yes	Yes
Cylindrocladium scoparium	Ab	Information gap	-	-
Fusarium culmorum	Ab	Roots, stems	Yes	Yes
Fusarium oxysporium pv. *dianthi*	Pr	Whole plant	Yes	No
Fusarium poae	Ab	Information gap	-	-
Fusarium redolens	Ab	Roots	Yes	Yes
Gibberella avenaceae	Ab	Buds	No	No
Gibberella intricans	Pr	Roots	Yes	No
Gibberella tricincta	Ab	Foot	Yes	Yes
Gibberella zeae	Pr	Whole plant	Yes	No

Pest	*Presence/ Absence in Sri Lanka*	*Affected plant parts*	*Potential of entry*	*Potential quarantine pest*
Hypocrea rufa	Pr	Stem	Yes	No
Leveillula taurica	Pr	Vegetative parts	Yes	No
Mycosphaerella dianthi	Ab	Information gaps	-	-
Nectria haematococca	Pr	Whole plant	Yes	No
Oidium dianthi	Ab	Leaves	Yes	Yes
Penicillium funiculosum	Ab	Flowers	No	No
Peronospora dianthicola	Ab	Information gaps	-	-
Phialophora cinerescens	Ab	Vascular system	Yes	Yes
Phymatotrichopsis omnivora	Ab	Whole plant	Yes	Yes
Phytophthora cactorum	Pr	Whole plant	Yes	No
Phytophthora capsici	Ab	Stem	Yes	Yes
Phytophthora cryptogea	Ab	Whole plant	Yes	Yes
Phytophthora megasperma	Ab	Whole plant	Yes	Yes
Phytophthora nicotianae var. *parasitica*	Pr	Whole plant	Yes	No
Phytophthora porri	Ab	Leaves, stem	Yes	Yes
Pleospora herbarum	Pr	Flowers	No	No
Puccinia arenariae	Pr	Leaves	Yes	No
Pythium aphanidermatum	Pr	Whole plant	Yes	No
Pythium irregulare	Pr	Whole plant	Yes	No
Pythium vexans	Pr	Whole plant	Yes	No
Rhizoctonia solani	Pr	Roots, stems	Yes	No
Rosellinia necatrix	Ab	Whole plant	Yes	Yes
Sclerotium rolfsii	Pr	Roots	Yes	No
Septoria dianthi	Ab	Information gap	-	-
Stemphylium lycopersici	Ab	Information gap	-	-
Trichothecium roseum	Ab	Information gap	-	-
Uromyces dianthi	Pr	Leaves, stem	Yes	No
Ustilago violaceae	Ab	Information gap	-	-
Verticillium dahliae	Ab	Roots	Yes	Yes
Zygophiala jamaicensis	Ab	Information gap	-	-
INSECTS				
Agrotis segetum	Pr	Whole plant	Yes	No
Aphis gossypii	Pr	Whole plant	Yes	No
Aphis helichrysi	Ab	Leaves	Yes	Yes
Aspidiotus nerii	Ab	Whole plant	Yes	Yes
Aulacophora nigripennis	Ab	Vegetative parts	Yes	Yes
Cacoecimorpha pronubana	Ab	Leaves, inflorescence	Yes	Yes
Chrysodeixis eriosoma	Pr	Vegetative parts	Yes	No
Chrysodeixis includens	Ab	Whole plant	Yes	Yes
Coccus hesperidum	Pr	Leaves, stems	Yes	No

Pest	*Presence/ Absence in Sri Lanka*	*Affected plant parts*	*Potential of entry*	*Potential quarantine pest*
Delia echinata	Ab	Information gap	-	-
Epichoristodes acerbella	Ab	Whole plant	Yes	Yes
Frankliniella occidentalis	Pr	Leaves, inflorescence	Yes	No
Gymnoscelis rufifasciata	Ab	Information gaps	-	-
Hercinothrips femoralis	Ab	Leaves	Yes	Yes
Lacanobia oleracea	Ab	Leaves	Yes	Yes
Liriomyza trifolii	Pr	Leaves	Yes	No
Lobesia botrana	Ab	Inflorescence, fruits, pods	No	No
Mamestra brassicae	Ab	Whole plant	Yes	Yes
Myzus persicae	Pr	Whole plant	Yes	No
Noctua pronuba	Ab	Whole plant	Yes	Yes
Otiorhynchus cribricollis	Ab	Information gap	-	-
Peridroma saucia	Pr	Whole plant	Yes	No
Phytonemus pallidus	Ab	Whole plant	Yes	Yes
Platynota stultana	Ab	Leaves	Yes	Yes
Spodoptera eridania	Ab	Whole plant	Yes	Yes
Spodoptera exigua	Pr	Whole plant	Yes	No
Spodoptera frugiperda	Ab	Whole plant	Yes	Yes
Spodoptera littoralis	Pr	Leaves	Yes	No
Tetranychus cinnabarinus	Pr	Leaves	Yes	No
Tetranychus urticae	Pr	Leaves	Yes	No
Thrips angusticeps	Ab	Whole plant	Yes	Yes
Thrips tabaci	Pr	Vegetative parts	Yes	No
Trichoplusia ni	Pr	Leaves	Yes	No
NEMATODES				
Criconemella curvata	Ab	Roots	Yes	Yes
Ditylenchus dipsaci	Ab	Whole plant	Yes	Yes
Helicotylenchus pseudorobustus	Pr	Roots	Yes	No
Heterodera schachtii	Ab	Roots	Yes	Yes
Heterodera trifolii	Ab	Roots, leaves	Yes	Yes
Meloidogyne arenaria	Pr	Roots	Yes	No
Meloidogyne hapla	Pr	Leaves, roots	Yes	No
Meloidogyne incognita	Pr	Roots	Yes	No
Meloidogyne javanica	Pr	Roots	Yes	No
Paratylenchus dianthus	Ab	Information gap	-	-
Pratylenchus penetrans	Pr	Roots	Yes	No
Scutellonema brachyurus	Pr	Whole plant	Yes	No
PHYTOPLASMA				
Aster yellows	Ab	Information gap	-	-

Pest	*Presence/ Absence in Sri Lanka*	*Affected plant parts*	*Potential of entry*	*Potential quarantine pest*
VIRUSES				
Arabis mosaic nepovirus	Ab	Whole plant	Yes	Yes
Beet curly top hybrigeminivirus	Ab	Information gap	-	-
Carnation 1 alphacryptovirus	Ab	Whole plant	Yes	Yes
Carnation 2 (?) alphacryptovirus	Ab	Whole plant	Yes	Yes
Carnation etched ring caulimovirus	Ab	Whole plant	Yes	Yes
Carnation Italian ringspot tombusvirus	Ab	Whole plant	Yes	Yes
Carnation latent carlavirus	Ab	Whole plant	Yes	Yes
Carnation mosaic virus	Ab	Information gap	-	-
Carnation mottle carmovirus	Pr*	Whole plant	Yes	Yes
Carnation necrotic fleck closterovirus	Ab	Whole plant	Yes	Yes
Carnation (?) rhabdovirus	Ab	Whole plant	Yes	Yes
Carnation ringspot dianthovirus	Ab	Whole plant	Yes	Yes
Carnation vein mottle potyvirus	Ab	Whole plant	Yes	Yes
Carnation yellow stripe(?) necrovirus	Ab	Whole plant	Yes	Yes

Ab: absent in Sri Lanka; Pr: Present in Sri Lanka, Pr*: one record without any details

During the analysis of entry potential, it was not possible to find information on 19 pests and therefore, their risk analysis was not continued thereafter (Table 3). According to the administrative report of the Department of Agriculture of Sri Lanka (Anon, 1997) carnation mottle carmovirus is reported to occur in the country but further details are not available. Since its distribution is not yet studied in a systematic way, it still can be considered as a potential quarantine pest.

Table 3. Number of carnation pests analyzed for potential of entry and their occurrence in Sri Lanka.

Category	*Number of pests considered*	*Occurrence in Sri Lanka*		*Entry potential*		*Information not available*	*Possible quarantine pest*
		Yes	No	Yes	No		
Bacteria	12	3	9	12	0	0	9
Fungi	53	24	29	37	4	12	15
Insects and mites	33	14	19	29	1	3	15
Nematodes	12	7	5	11	0	1	4
Phytoplasma	1	0	1	0	0	1	-
Viruses	14	1	13	12	0	2	12
Total	125	49	76	101	5	19	55

If a pest is wide-spread in the country, it cannot be considered as a quarantine pest (Anon, 1999b; IPPC, 1996a; 1999a). However, it can be a regulated non-quarantine pest. After considering the occurrence and potential of entry, 55 pests qualified at this stage to be possible quarantine pests (Table 3).

After the entry into the PRA area, the pests should find favourable conditions for them to get established. Several factors (Table 4) would encourage them to complete their life cycles and start spreading within the area. Conducive climatic and ecological conditions and presence of other hosts and vectors would be important criteria for consideration.

Table 4. Possibility of establishment and spread of selected pests in PRA area.

Pest	*Other hosts*	*Favourable conditions*	*Vector present or natural spread*	*Possible quarantine pest*
BACTERIA				
Burkholderia andropogonis	Yes	Yes	Natural	Yes
Burkholderia caryophylli	Yes	Yes	Natural	Yes
Erwinia chrysanthemi pv. *chrysanthemi*	Yes	Yes	Natural	Yes
Erwinia herbicola pv. *gypsophilae*	Yes	Yes	Natural	Yes
Pectobacterium chrysanthemi	Yes	Yes	Natural	Yes
Pectobacterium rhapontici	Yes	Yes	Natural and vector pr	Yes
Pseudomonas marginalis pv. *marginalis*	Yes	Yes	Natural	Yes
Rhizobium rhizogenes	Yes	Yes	Natural	Yes
Rhodococcus fascians	Yes	Yes	Natural	Yes
FUNGI				
Alternaria dianthicola	Yes	Yes	Natural	Yes
Alternaria saponariae	Information gap	Information gap	Information gap	?
Corticium stevensii	Yes	Yes	Natural	Yes
Fusarium culmorum	Yes	Yes	Natural	Yes
Fusarium redolens	Yes	Yes	Natural	Yes
Gibberella tricincta	Yes	Yes	Natural	Yes
Oidium dianthi	Yes	Yes	Natural	Yes
Phialophora cinerescens	No	Yes	Natural	Yes
Phymatotrichopsis omnivora	Yes	Yes	Natural	Yes
Phytophthora capsici	Yes	Yes	Natural	Yes

Pest	*Other hosts*	*Favourable conditions*	*Vector present or natural spread*	*Possible quarantine pest*
Phytophthora cryptogea	Yes	Yes	Natural	Yes
Phytophthora megasperma	Yes	Yes	Natural	Yes
Phytophthora porri	Host specific	Yes	Natural	Yes
Rosellinia necatrix	Yes	No	Natural	No
Verticillium dahliae	Yes	Yes	Natural	Yes
INSECTS				
Aphis helichrysi	Yes	Yes	Natural	Yes
Aspidiotus nerii	Yes	Yes	Natural	Yes
Aulacophora nigripennis	Information gap	Information gap	Information gap	?
Cacoecimorpha pronubana	Yes	Yes	Natural	Yes
Chrysodeixis includens	Yes	Yes	Natural	Yes
Epichoristodes acerbella	Yes	Yes	Natural	Yes
Hercinothrips femoralis	Yes	Yes	Natural	Yes
Lacanobia oleracea	Yes	Yes	Natural	Yes
Mamestra brassicae	Yes	Yes	Natural	Yes
Noctua pronuba	Yes	Yes	Natural	Yes
Phytonemus pallidus	Yes	Yes	Natural	Yes
Platynota stultana	Yes	Yes	Natural	Yes
Spodoptera eridania	Yes	Yes	Natural	Yes
Spodoptera frugiperda	Yes	Yes	Natural	Yes
Thrips ungusticeps	Yes	Yes	Natural	Yes
NEMATODES				
Criconemella curvata	Yes	Yes	Natural	Yes
Ditylenchus dipsaci	Yes	Yes	Natural	Yes
Heterodera schachtii	Yes	Yes	Natural	Yes
Heterodera trifolli	Yes	Yes	Natural	Yes
VIRUSES				
Arabis mosaic nepovirus	Yes	Yes	Vector pr	Yes
Carnation 1 alphacryptovirus	No	Yes	Vector not involved	Yes
Carnation 2 (?) alphacryptovirus	Information gap	Information gap	Information gap	?
Carnation etched ring caulimovirus	No	Yes	Vector pr	Yes
Carnation Italian ringspot tombusvirus	No	Yes	Information gap	?
Carnation latent carlavirus	No	Yes	Vector pr	Yes

Pest	*Other hosts*	*Favourable conditions*	*Vector present or natural spread*	*Possible quarantine pest*
Carnation mottle carmovirus	Yes	Yes	Vector pr	Yes
Carnation necrotic fleck closterovirus	No	Yes	Vector pr	Yes
Carnation (?) rhabdovirus	Information gap	Yes	Information gap	?
Carnation ringspot dianthovirus	Yes	Yes	Yes	Yes
Carnation vein mottle potyvirus	No	Yes	Vector pr	Yes
Carnation yellow stripe (?) necrovirus	Yes	Yes	Information gap	?

Vector pr: Vector present in PRA area

Of the 55 pests considered, 48 were chosen for further analysis (Table 5), since they have the potential for establishment and spread within carnation growing areas and also within the country.

Table 5. Number of carnation pests having the potential for establishment and spread.

Category	*Number considered*	*Positive potential*	*Unknown or negative potential*	*Possible quarantine pests*
Bacteria	9	9	0	9
Fungi	15	13	2	13
Insects and mites	15	14	1	14
Nematodes	4	4	0	4
Viruses	12	10	4	8
Total	55	50	5	48

A pest may establish and spread within an area, but may or may not cause serious economic impact. Some are reported to be minor pests in other similar localities. If the pest affects other hosts of economic importance to the country, special attention must be given. By definition, a pest must have a potential economic impact for it to be qualified as a quarantine pest (Anon, 1999b and IPPCa). Table 6 shows the perceived economic impact of the 48 pests of carnation if established in the PRA area. Here, impacts on both carnation and other important crops have been considered.

Table 6. Perceived economic impact of some pests of carnation in PRA area.

Pest	*Economic impact if established in the PRA area*	*Possible quarantine pest*
BACTERIA		
Burkholderia andropogonis	Insignificant	No
Burkholderia caryophylli	Significant loss	Yes
Erwinia chrysanthemi pv. *chrysanthemi*	Information gap	?
Erwinia herbicola pv. *gypsophilae*	Information gap	?
Pectobacterium chrysanthemi	Significant loss	Yes
Pectobacterium rhapontici	Significant loss	Yes
Pseudomonas marginalis pv. *marginalis*	Significant loss	Yes
Rhizobium rhizogenes	Significant loss	Yes
Rhodococcus fascians	Significant loss	Yes
FUNGI		
Alternaria dianthicola	Significant loss	Yes
Corticium stevensii	Significant loss	Yes
Fusarium culmorum	Significant loss	Yes
Fusarium redolens	Information gap	?
Gibberella tricincta	Insignificant	No
Oidium dianthi	Insignificant	No
Phialophora cinerescens	Significant loss	Yes
Phymatotrichopsis omnivora	Significant loss	Yes
Phytophthora capsici	Significant loss	Yes
Phytophthora cryptogea	Significant loss	Yes
Phytophthora megasperma	Significant loss	Yes
Phytophthora porri	Significant loss	Yes
Verticillium dahliae	Significant loss	Yes
INSECTS		
Aphis helichrysi	Significant loss	Yes
Aspidiotus nerri	Insignificant	No
Cacoecimorpha pronubana	Significant loss	Yes
Chrysodeixis includens	Significant loss	Yes
Epichoristodes acerbella	Significant loss	Yes
Hercinothrips femoralis	Significant loss	Yes
Lacanobia oleracea	Significant loss	Yes
Mamestra brassicae	Significant loss	Yes
Noctua pronuba	Insignificant	No
Phytonemus pallidus	Significant loss	Yes
Platynota stultana	Significant loss	Yes
Spodoptera eridania	Significant loss	Yes
Spodoptera frugiperda	Significant loss	Yes
Thrips ungusticeps	Significant loss	Yes

Pest	*Economic impact if established in the PRA area*	*Possible quarantine pest*
NEMATODES		
Criconemella curvata	Significant loss	Yes
Ditylenchus dipsaci	Significant loss	Yes
Heterodera schachtii	Significant loss	Yes
Heterodera trifolli	Significant loss	Yes
VIRUSES		
Arabis mosaic nepovirus	Significant loss	Yes
Carnation 1 alphacryptovirus	Significant loss	Yes
Carnation etched ring caulimovirus	Significant loss	Yes
Carnation latent carlavirus	Significant loss	Yes
Carnation mottle carmovirus	Significant loss	Yes
Carnation necrotic fleck closterovirus	Significant loss	Yes
Carnation ringspot dianthovirus	Significant loss	Yes
Carnation vein mottle potyvirus	Significant loss	Yes

Consideration of the perceived economic impact of 48 pests resulted in the selection of 40 pests for further analysis (Table 7).

Table 7. Number of pests with potential economic impact.

Category	*Number considered*	*Significant impact*	*Insignificant impact*	*Impact unknown*	*Possible quarantine pests*
Bacteria	9	6	1	2	6
Fungi	13	10	2	1	10
Insects and mites	14	12	2	0	12
Nematodes	4	4	0	0	4
Viruses	8	8	0	0	8
Total	48	40	5	3	40

Stage 3: Risk management

It is a known fact that there is always the risk of introduction of pests with international trade. Therefore, zero tolerance was considered unattainable and the management of the pests was the viable option (Table 8). Some pests could be effectively eradicated in the consignments if proper control measures are available. On the other hand, according to information available, some pests could not be easily controlled. The presence of potential natural enemies in the PRA area could help in the control of new pests.

Table 8. Availability of pest management options.

Pest	*Pest management*	*Potential natural enemies in PRA area*	*Possible quarantine pest*
BACTERIA			
Burkholderia caryophylli	Difficult	No	Yes
Pectobacterium chrysanthemi	Difficult	No	Yes
Pectobacterium rhapontici	Difficult	No	Yes
Pseudomonas marginalis pv. *marginalis*	Difficult	No	Yes
Rhizobium rhizogenes	Difficult	No	Yes
Rhodococcus fascians	Difficult	No	Yes
FUNGI			
Alternaria dianthicola	Difficult	No	Yes
Corticium stevensii	Difficult	No	Yes
Fusarium culmorum	Available	Yes	No
Phialophora cinerescens	Difficult	No	Yes
Phymatotrichopsis omnivora	Difficult	No	Yes
Phytophthora capsici	Available	-	No
Phytophthora cryptogea	Available	Yes	No
Phytophthora megasperma	Available	-	No
Phytophthora porri	Available	-	No
Verticillium dahliae	Difficult	No	Yes
INSECTS			
Aphis helichrysi	Available	-	No
Cacoecimorpha pronubana	Difficult	No	Yes
Chrysodeixis includens	Available	-	No
Epichoristodes acerbella	Difficult	No	Yes
Hercinothrips femoralis	Difficult	No	Yes
Lacanobia oleracea	Difficult	Yes	No
Mamestra brassicae	Available	-	No
Phytonemus pallidus	Difficult	No	Yes
Platynota stultana	Available	-	No
Spodoptera eridania	Available	-	No
Spodoptera frugiperda	Available	-	No
Thrips ungusticeps	Available	-	No
NEMATODES			
Criconemella curvata	No	No	Yes
Ditylenchus dipsaci	No	No	Yes
Heterodera schachtii	No	No	Yes
Heterodera trifolli	No	No	Yes

Pest	*Pest management*	*Potential natural enemies in PRA area*	*Possible quarantine pest*
VIRUS			
Arabis mosaic nepovirus	Difficult	No	Yes
Carnation 1 alphacryptovirus	Difficult	No	Yes
Carnation etched ring caulimovirus	Difficult	No	Yes
Carnation latent carlavirus	Difficult	No	Yes
Carnation mottle carmovirus	Difficult	No	Yes
Carnation necrotic fleck closterovirus	Difficult	No	Yes
Carnation ringspot dianthovirus	Difficult	No	Yes
Carnation vein mottle potyvirus	Difficult	No	Yes

Of 40 pests considered, management of 27 pests was found to be difficult. These pests may, therefore, qualify as quarantine pests when importing carnation rooted cuttings (Table 9).

Table 9. Number of pests of carnation that could be managed by various means.

Category	*Number considered*	*Management options available*	*Management difficult*	*Quarantine pests*
Bacteria	6	0	6	6
Fungi	10	5	5	5
Insects and mites	12	8	4	4
Nematodes	4	0	4	4
Viruses	8	0	8	8
Total	40	13	27	27

According to this study, 27 pests qualified to be considered as quarantine pests during the importation of carnation rooted cuttings. Table 10 indicates the suggested entry conditions for each pest. Phytosanitary measures could be applied for the effective protection of the endangered area.

Table 10. Suggested entry conditions for importation of carnation nursery stocks.

Pest	*Entry condition*
BACTERIA	
Burkholderia caryophylli	Area freedom
Pectobacterium chrysanthemi	Area freedom
Pectobacterium rhapontici	Area freedom
Pseudomonas marginalis pv. *marginalis*	Area freedom
Rhizobium rhizogenes	Area freedom
Rhodococcus fascians	Area freedom
FUNGI	
Alternaria dianthicola	Area freedom

Pest	*Entry condition*
Corticium stevensii	Area freedom
Phialophora cinerescens	Area freedom
Phymatotrichopsis omnivora	Area freedom
Verticillium dahliae	Area freedom
INSECTS	
Cacoecimorpha pronubana	Area freedom
Epichoristodes acerbella	Inspection and found free
Hercinothrips femoralis	Inspection and found free
Phytonemus pallidus	Inspection and found free
NEMATODES	
Criconemella curvata	Area freedom
Ditylenchus dipsaci	Area freedom
Heterodera schachtii	Area freedom
Heterodera trifolli	Area freedom
VIRUS	
Arabis mosaic nepovirus	Area freedom
Carnation 1 alphacryptovirus	Inspection and found free
Carnation etched ring caulimovirus	Inspection and found free
Carnation latent carlavirus	Inspection and found free
Carnation mottle carmovirus	Inspection and found free
Carnation necrotic fleck closterovirus	Area freedom
Carnation ringspot dianthovirus	Inspection and found free
Carnation vein mottle potyvirus	Inspection and found free

A simple procedure was adopted for this IRA. None of the criteria, such as effect of natural enemies, and effectiveness of the pest management strategies were quantified for evaluation in a mathematical model (Sanford, 2002). Also, some pests may have other pathways such as hosts, which are allowed to enter into the country with a more liberal attitude. WTO/SPS agreement permits the countries to determine the technically justified appropriate level of protection (ALOP). To declare a pest as quarantinable, all pathways (hosts, non-hosts etc.) must be critically evaluated (IPPC, 1996a).

According to Crop Protection Compendium (CAB International, 2002), two weeds have some effects on carnation. However, they were not considered in this study. Plant quarantine inspection done so far on imported carnation nursery stocks did not detect any weeds in the consignments. However, contaminant weeds have been detected in consignments of vegetable seeds imported into Sri Lanka (Sajeewani *et al.*, 2000 and Perera, 2002).

Brunt *et al.*(1996) considered that some viruses of carnation were found worldwide. However, no data have been published on the incidence of such viruses in Sri Lanka. If any viruses of carnations are detected, the level of their tolerance during importation must be stipulated because carnation nursery stocks are always imported into the country.

While assessing the economic impact, the effect on all identified hosts of the pest could not be quantified. It is important to identify all the hosts of the particular pest in the PRA area, extent of the area likely to be damaged, and speed of spread by natural means (Sanford, 2002). If any complex study is planned, effect of the pest in the PRA area, direct effect on crop yield and/or quality, effect of existing biological and integrated systems on the pest, effect on carnation growers' profits due to changes in production costs and yields, effect on consumer demand and export markets, and effect on the environment and or social damage should be evaluated.

Recommendation for requesting area freedom for certain pests should consider locality of production of the nursery stocks. IPPC has recognized pest-free areas (IPPC, 1996b), pest-free places of production and pest-free production sites (IPPC 1999b). It is important to clearly indicate the locality of origin of the consignment for implementation of these aspects of area freedom.

According to this IRA, certain pests could be taken out of stipulated entry conditions for carnation nursery stocks but addition of new pests is suggested (Table 11). Even though Horst (1996) has listed some pests (e.g. Aster yellows, beet curly top virus, carnation mosaic virus, *Pythium ultimum*, and carnation yellows), Crop Protection Compendium (CAB International, 2002) did not list them as pests of carnation. According to Brunt *et al.* (1996) carnation is experimentally susceptible to clover wound tumor phytoreovirus. None of the literature referred give information on *Phytomyza syngenesiae* (synonym *Chromatomyia syngenesiae*) as a pest of carnation. As it was not possible to find any source of information on these pests, a PRA was not carried out.

Table 11. Comparison of pests stipulated in the present entry conditions and suggested quarantine pests for carnation nursery stocks.

Pests listed in present entry conditions	*Suggested quarantine pests*
BACTERIA	
-	*Burkholderia caryphylli*
Corynebacterium fascians (synonym *Rhodococcus fascians*)	*Rhodococcus fascians*
Erwinia chrysanthemi	Deletion suggested
-	*Pectobacterium chrysanthemi*
-	*Pectobacterium rhapontici*

Pests listed in present entry conditions	*Suggested quarantine pests*
-	*Pseudomonas marginalis* pv. *marginalis*
-	*Rhizobium rhizogenes*
Xanthomonas oryzae pv. *oryzae*	Deletion suggested
FUNGI	
-	*Alternaria dianthicola*
Fusarium spp.	Deletion suggested
Pellicularia koleroga (synonym *Corticium stevensii*)	*Corticium stevensii*
Phialophora spp.	*Phialophora cinerescens*
Phytophthora nicotianae	Deletion suggested
Phytophthora omnivorum (synonym *Phytophthora cactorum*)	Deletion suggested
-	*Phymatotrichopsis omnivora*
Pythium ultimum	?
Uromyces spp.	Deletion suggested
Ustilago violaceae	?
-	*Verticillium dahliae*
INSECTS AND MITES	
Cacoecimorpha pronubana	*Cacoecimorpha pronubana*
-	*Epichoristodes acerbella*
-	*Hercinothrips femoralis*
Liriomyza trifolii	Deletion suggested
Phytomyza syngenesiae	?
Spodoptera exigua	Deletion suggested
Spodoptera littoralis	Deletion suggested
-	*Phytonemus pallidus*
NEMATODES	
-	*Criconemella curvata*
-	*Ditylenchus dipsaci*
-	*Heterodera schachtii*
Heterodera trifolii	*Heterodera trifolli*
PHYTOPLASMA	
Aster yellows	?
VIRUSES	
-	Arabis mosaic nepovirus
Beet curly top hybrigeminivirus	?
-	Carnation 1 alphacryptovirus
Carnation etched ring virus	Carnation etched ring caulimovirus
Carnation latent disease	Carnation latent carlavirus
Carnation mosaic virus	?
-	Carnation mottle carmovirus
Carnation necrotic fleck virus	Carnation necrotic fleck closterovirus
Carnation ringspot virus	Carnation ringspot dianthovirus
Carnation streak virus (synonym carnation necrotic fleck closterovirus)	Carnation necrotic fleck closterovirus
	Carnation vein mottle potyvirus

Pests listed in present entry conditions	*Suggested quarantine pests*
Carnation yellows	?
Clover big vein virus (synnym Clover wound tumor phytoreovirus)	?

CONCLUSIONS

The IRA revealed that the following 27 pests of carnation deserve to be treated as quarantine pests: -

Bacteria: *Burkholderia caryophylli*, *Pectobacterium chrysanthemi*, *Pectobacterium rhapontici*, *Pseudomonas marginalis* pv. *marginalis*, *Rhizobium rhizogenes*, and *Rhodococcus fascians*;

Fungi: *Alternaria dianthicola*, *Corticium stevensii*, *Phialophora cinerescens*, *Phymatotrichopsis omnivora*, and *Verticillium dahliae*;

Insects: *Cacoecimorpha pronubana*, *Epichoristodes acerbella*, and *Hercinothrips femoralis*;

Mites: *Phytonemus pallidus*;

Nematodes: *Criconemella curvata*, *Ditylenchus dipsaci*, *Heterodera schachtii*, and *Heterodera trifolii*; and

Viruses: arabis mosaic nepovirus, carnation 1 cryptovirus, carnation etched ring caulimovirus, carnation latent carlavirus, carnation mottle carmovirus, carnation necrotic fleck closterovirus, carnation ringspot dianthovirus, and carnation vein mottle potyvirus,

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