Appendix 1

Table 1 Major citrus postharvest diseases: typical symptoms on fruit, infection type, infection site and spread of infection with possible control strategies involved

Disease	Causal agent	Typical symptoms on fruit	Infection type	Infection site	Spread to adjacent fruit	General control strategies	Reference
Anthracnose	*Colletotrichum gloeosporioides* (Penz) Sacc.	-Initially are silvery gray and leathery, and later the infected ring becomes brown to grayish black and softens as the rot progresses. The pathogen grows and sporulates in deadwood on the trees, with water transmitting spores to the immature fruit surface by forming appressoria. The structure remain latent, do not cause decay prior to harvest.	Quiescent, infective pathogen.	Injured rind.	Yes.	-Improved cultural practices such as removal of dead wood and twigs to reduce inocula. -Proper handling of fruits at harvest to minimize injury. -Cooling of fruits immediately after harvest at or below 10 ^{o}C. -Application of sanitary measures by removing infected fruits.	Brown, 1994.

Table … continued

Black rot (stem-end rot)	*Alternaria citri* Ellis and Pierce -Cause premature coloring of a fruit on the tree (the most typical characteristic of the disease) and it causes fruit drop early in the season. -The fungus may cause stem-end rot infection of Valencia and grapefruits in long term cold storage	-Late infected fruit appear sound on the exterior and may escape. the attention of graders. -Some times exhibits external symptoms at the blossom end (top), but is more often found in the core of the fruit bottom. -Infected fruit appear to have a dray, black, decayed area at or near the stylar or stem end.	Quiescent, infective pathogen.	Natural openings at the stem-end.	No.	-Delay harvesting time until the infected fruit drop. -Application of postharvest treatments which delay fruit button (calyx) senescence may delay black rot development.	Brown, 1994. Browning *et al.*, 1995.
Black spot	*Guignardia citricarpa* Kiely	-Variable in symptoms it may appear as hard freckle or virulent (spreading) spots.	Quiescent, infective pathogen.	Intact or injured rind.	Yes.		Kotze, 1993.

Table… continued

Blue mould	*Penicillium italicum* Wehmer -Common in cold seasons.	-The decay first appears as watery discoloured spots that can easily punctured. -The white mycelium soon produces a mass of powdery blue coloured sporulating area surrounded by a white margin.	Active, wound pathogen.	Injured rind.	Yes.	-Mould sporulating may be inhibited by approved fungicide treatment. -Sanitation in the handling, packing and storage operations is very important. -Tests for pathogen resistance in the packinghouse- -Repacking *Penicillium* infected fruit is important and storage of packed fruits at or below 4.4 ^{o}C delay mould development.	
Greasy spot	*Mycosphaerella citri* Whiteside	-Form necrotic specks on fruit rind between epidermis and oil glands -The lesions are pink at first and become brown or black with rind blotch in 3 to 6 months time.	Quiescent, infective pathogen.	Intact or injured rind.			Whiteside *et al*., 1993. Browning *et al*., 1995.

Table… continued

Green mould	*Penicillium digitatum* Sacc. -These moulds are most common in a cold seasons.	-First appears as watery discoloured spots that are easily punctured by finger pressure and later as white fungal mycelium producing a mass of powdery olive green or light to bright blue spores surrounded by a large white margin. -Finally, the decayed fruit becomes soft, shrunken, and shrivelled and entirely covered with spores.	Active wound pathogen.	Injured rind.	No.	-Minimize scratches, punctures and plugging ensuring careful harvesting and handling. -Sanitary practices must be applied to avoid resistant strains to fungicides. -Remove all debris and decayed fruit from the packing site. -Application of disinfectants. -Application of tests periodically to detect resistant strains. -Application of approved fungicides before or after harvest provide control of moulds. -At packhouse and transition store fruits at or below 4.4 ^{o}C.	Brown, 1994. Browning *et al.*, 1995.

Table … continued

Lime Anthracnose	*Gloeosporium limetticola* Clausen	Young fruits attacked by a disease usually shed. -Fruits infected later develop corky lesions that vary from slightly sunken spots to deep cankers over much of the surface but lack yellow haloes unlike canker.	Quiescent, infective pathogen.	Intact or injured rind.			Whiteside *et al*., 1993. Browning *et al*., 1995.
Sour rot	*Geotrichum candidum* Lk ex Pers (*Endomyces geotrichum*)	-Slightly raised, water-soaked, clear to yellow initial lesions, which are confusing with those of Penicillium moulds are developed. -At high relative humidity, yeasty layer may cover the	Active, wound pathogen.	Injured rind.	Yes.	-Minimize scratches, punctures and plugging ensuring careful harvesting and handling. -Avoid harvesting fruits with high peel moisture early in the morning. -Avoid fruit contact with soil during harvest.	Brown, 1994; Wills *et al*., 1998.

Table … continued

		lesion and produces sour odour that attracts fruit flies which may enhance the spread of the fungus. -The infection quickly spreads into a soft decaying area favoured by moderate temperature 27 ^{o}C.				-Immediate cooling of picked fruits to below 10 ^{o}C will delay decay development. -Application of adequate sanitary practices (soak tanks with chlorine at proper pH). -Application of disinfectants. -Application of mixtures of fungicides.	
Stem-end rot	*Diplodia natalensis* P. Evans (syn. *Botryodiplodia theobromse* Pat.; *Physalospora rhodina* Berk and Curt	-Initially, decay occur at both ends of the fruit. -In infected fruit, lesions appear as dark discoloration	Quiescent, infective pathogen.	Natural openings at the stem-end.	No.	-Improve cultural practices such as removing dead trees, wood. -Harvesting by clipping rather than pulling.	Brown, 1994.

Table continued

		within 1-2 weeks during storage time. -Development of sour fermented odour as the fruit becomes black.				-Remove some buttons (sepal base) that harbour pathogen. -Spot picking for natural colours and delaying harvest until more colour develops (reduce degreening time). -In packhouse increase humidity to 90 – 95%. -Maintaining of temperature at 82- 84 ^{o}F and ethylene formation at 1 – 5 ppm during degreening and storage.	
Stem-end rot	*Phomopsis citri* Faw -The fungi colonize dead twigs and wood on the tree where spores are dispersed by rain and wind to fruit. -Decay occurs after harvest when the fungus grows from the calyx (button) into the fruit.	-Decay appears as a buff coloured to brown, leathery, pliable area encircling the button or stem-end of the fruit. -Infection spreads through the core in a nearly even rind pattern from the stem-end to the surrounding.	Quiescent, infective pathogen.	Injured rind.	Yes.	-Improved cultural practices such as removal of dead wood and twigs to reduce inocula. -Proper handling of fruits at harvest to minimize injury. -Cooling of fruits immediately after harvest at or below 10 ^{o}C. -Application of sanitary measures by removing infected fruits.	Whiteside *et al.*, 1988.

Table … continued

Trichoderma rot	*Trichoderma viride* Pos ex Gray. -The fungus is ubiquitous in soil growing on dead twigs. -Spores disseminated by contact with soil and / or infected wood. -The fungus mycelia are white and the conidia are globose with rough texture.	-Infection may be at any location of fruit rind. -Infected fruits develop cocoa brown colour with leathery and pliable appearances. -Decay on the fruit starts at the stem-end or stylar end. -Rotted fruits characteristically produce coconut odour.	Quiescent, infective pathogen.	Injured rind.	No.	-Improved cultural practices such as removal of dead wood and twigs is required to reduce inocula. -Proper handling of fruits at harvest to minimize injury. -Cooling of fruits immediately after harvest at or below 10 ^{o}C. -Application of sanitary measures by avoiding infected fruits.	Whiteside *et al.*, 1988.

Appendix 1

Table 2 Chemicals used as postharvest fungicides on citrus fruit and other crops

Name and formulation	Pathogens controlled	Host	Remarks	Extracted
Alkaline inorganic salts				
sodium tetraborate (borax)	*Penicillium* spp	Citrus	Only reasonably effective; Problem with residues	Willis *et al*., 1998
sodium carbonate	*Penicillium* spp	Citrus	Only slightly effective	
sodium hydroxide	*Penicillium* spp	Citrus	Only slightly effective	
Ammonia and aliphatic amines				
ammonia gas	*Penicillium*, *Diplodia*,	Citrus	Good for fumigation of degreening	
sec-butylamine	*Rhizopus*		and storage rooms	
	Penicillium, stem-end rots	Citrus	Good control as dip or fumigant	
Aromatic amines				
dichloran	*Rhizopus*, *Botrytis*	Stone fruits, carrot, sweet potato	Very effective	
Benzimidazoles				
benomyl, thiabendazole,	*Penicillium* spp	Citrus	Effective at low concentration;	
thiophanate methyl	*Colletotrichum* and other	Banana, apple,	resistance problem; residue	
carbendazim	fungi	pear, pineapple, stone fruit	tolerance 0-10µg/g	

Table … continued

Triazoles			
imazalil	*Penicillium*, stem-end rots	Citrus	Effective against benzimidazole-resistant strains and at low concentration
prochloraz	*Penicillium* spp	Citrus	Effective against benzimidazole-resistant strains
guanidine			
guazitine	*Penicillium*, *Geotrichum*	Citrus	Effective against benzimidazole-resistant strains
Hydrocarbons and derivatives			
biphenyl	*Penicillium*, *Diplodia*	Citrus	Smell unpleasant
methyl chloroform	*Penicillium*, stem end rots	Citrus	Inhibits spore germination only
Oxidising substances			
hypochlorous acid	Bacteria, fungi build up in wash water	Produce	Good sterilant, no penetration of injury sites, corrosive to metal
iodine	Bacteria, fungi	Citrus, grapes	Staining problem, expensive
nitrogen trichloride	*Penicillium* spp	Citrus, tomato	Hydrolyses to hypochlorous acid
Organic acids and aldehydes			
dehydroacetic acid	*Botrytis* and other fungi	Strawberry	Dip not accepted by industry
sorbic acid	*Alternaria*, *Cladosporium*	Fig	Sterilant for picking boxes, storage rooms
formaldehyde	Fungi		
Phenols			

Table … continued

o-phenylphenol	*Penicillium* spp	Citrus	Causes fruit injury
sodium o-phenylphenate	*Penicillium*, bacteria and other fungi	Produce	pH control needed to prevent injury; residue tolerance 10-12µg/g
Salicylanilide	*Penicillium*, *Phomopsis*, *Nigrospora*	Citrus, banana	Slight control
Sulphur (inorganic)			
sulphur dust	*Monilinia*	Peach	nd
lime-sulphur	*Sclerotinia*		
sulphurdioxide gas, bisulphate	*Botrytis*	Grapes	Sulphur dioxide gas needs moisture to be effective;
Sulphur (organic)			
captan	Storage rots	Various produce	Nd
thiram	*Cladosporium*, crown and stem-end rots	Strawberry, banana	Nd
ziram	*Alternaria*, crown and stem-end rots	Banana	Nd Nd
thiourea	*Penicillium* spores	Citrus	Toxic to man
thioacetamide	*Diplodia*		Nd

Legend: Nd = not determined

Appendix 1

Table 3 Microbial antagonists registered as biopesticide for control of fungal diseases

Species name	Type	Target pathogen	Product name	Manufactured (Country)	Extracted from
Bacteria					Montesinos, 2003
Bacillus poplliae	I	*Popilla japonica*	_	_	
B. thuringiensis var. *aizawai*	I	*Galleria melonella*	_	_	
B. thuringiensis var. EG2348	I	*Lymantria dispar*	_	_	
Burkholderia cepacia	F	Soil borne fungi, nematodes	_	_	
Pseudomonas fluorescens	F	Soil borne fungi	_	_	
P. syringae ESC- 10, ESC-11	F	Postharvest Fungi	_	USA	
P. chlororaphis	F	Soil borne fungi	_	_	
P. aureofaciens Tx-1	F	Antracnose, soil borne	_	_	
*Pseudomonas aeruginosa**	F	-Downy mildew of Grape, cucumber, pumpkin, pepper and melon; root rot by *Pythium spp.*; late blight of potato by *Phytophthora infestans.* -To control *Geotrichum candidum* infection on pome and citrus.	Biosave 110, 111	USA	Shachnal *et al*., 1996 Montesinos, 2003

Table … continued

Bacillus subtilis	F	Pre-and postharvest disease of avocado.	Avogreen	South Africa	Janisiewicz and Korsten, 2002; Montesinos, 2003
B. subtilis FZB24	F	Soil borne fungi	_	_	Motesinose, 2003
B. subtilis GB03	F	Soil borne and wilt	_	_	
B. subtilis GB07	F	Soil borne fungi	_	_	
Streptomyces griseoviridis K61	F	*Phythium, Fusarium, Botrytis, Alternaria, Rhizoctonia* and *Phytophthora* sp.	Mycostop	Kemira Argo of Finland	
S. lydicus	F	Soil borne fungi.	_	_	
Agrobacterium radiobacter K84, K1026	B	Crown gall *A. tumefaciens.*	_	_	
Ralstonia solanacearum non-pathogenic	B	Pathogenic *R. solanacearum*	_	_	
Pseudomonas fluorescens A506	B	Frost damage, fire blight (*Erwinia amylovora*).	_	_	
Pseudomonas syringae pv. *tagetis*	H	*Cirsium arvense*	_	_	
Xanthomonas campestris pv. *poae*	H	*Poa annua*	_	_	

Table … continued

Fungus biopesticides					
Trichoderma polysporum, T. harzianum	F	Soil borne fungi	_	_	Montesinos, 2003
T. harzianum KRL-AG2	F	Soil borne fungi	_	_	
T. harzianum	F	Foliar fungi	_	_	
T. harzianum, T. viride	F	Various	PlantShield	BioWorks, Inc.in Geneva	
T. viride	F	Phythium, Rhizocotonia, Fusarium and Botrytis	_	_	
T. lignorum	F	Vascular wilt	_	_	
Trichoderma spp	F	Soil borne	_	_	
Ampelomyces quisqualis M-10	F	Powdery mildew	_	_	
Talaromyces flavus V117b	F	Soil borne fungi	_	_	
Gliocladium virens GL-21	F	Pythium, Rhizocotonia and Sclerotinium sp. (Soil borne fungi).	SoilGuard	Cerit, USA	(http//www.cfgrower.com/tips/oct/biological.html) Montesinos, 2003
G. catenulatum	F	Soil borne fungi	_	_	Montesinos, 2003
Fusarium oxysporum non-pathogenic	F	Pathogenic Fusarium	_	_	
Pythium oligandrum	F	*Phytium ultimum*	_	_	
Phlebiopsis gigantean	F	Heterobasidium	_	_	

Table … continued

Coniothyrium minitans	F	*Sclerotinia sclerotiorum*			Montesinos, 2003
Candida oleophila 1- 182	F	Penicilium decay on citrus and pome fruits (postharvest decay).	Aspire ™	USA	Shachnal *et al*., 1996 Montesinos, 2003
Cryptococcus albidus	F	Postharvest disease of apples and pears (postharvest decay).	Yield plus	USA	Shachnal *et al*., 1996 Montesinos, 2003
Phytophthora palmivora MWV	H	*Morrenia odorata*	_	_	Montesinos, 2003
Colletotrichum gloeosporioides	H	Cuscuta and various	_	_	
C. gloeosporioides f. sp. *malvae*	H	*Malva pulsilla*	_	_	
C. g. f. sp. *aeschynomene*	H	*Curty indigo*	_	_	
C. coccodes	H	*Abutilon theophrasti*	_	_	
C. truncatum	H	*Sesbania exalta*	_	_	
Aiternaria cassia	H	*Senna obtusifolia*	_	_	
Viruses .					
Pine sawfly NPV	I	*Diprion similes*	_	_	
Heliothis NPV	I	*Helicoverpa zeae*	_	_	
Gypsy moth NPV	I	*Lymantria dispar*	_	_	
Tussok moth NPV	I	*Orgyia pseudotsugata*	_	_	
Mamestria brassicae NPV	I	*Heliothis*	_	_	
Spodoptera exigua virus	I	*S. exigua*	_	_	
Bacteriophage of *P. tolaasii*	F	Bacterial rot of mushroom	_	_	

Legend: B = bactericide; F = fungicide; H = herbicide; I = insecticide; N = nematicide.
* A winner of the 2004 Presidential Green Chemistry Challenge Award.
_ = status not known.

Appendix 1

Table 4 Microbial antagonists and their mode of action on fruits

Microbial antagonists	Pathogen	Mode of action	Compound/ Metabolite produced	Commodity/ fruit	References
Bacteria					
*Bacillus subtilis**	*Penicillium digitatum*	-Antibiosis -Competition for nutrients and space	Iturin -	Peaches Avocado	Pusey and Wilson, 1984; Demoz and Korsten, 2006
*Burkolderia (Pseudomonas) cepacia**	*P. digitatum*	-Antibiosis -Competition for nutrients and space.	Pryrrolnitrin	Apple, pears and citrus	Smilanick and Denis-Arrue, 1992.
P. syringae (ESCO-10 and ESC-11)*	*P. digitatum*	-Antibiosis -Competition for nutrients and space	Syringomycin	Citrus	Bull *et al.*, 1997.
Entrobacter cloacae	*P. digitatum*	-Competition for nutrients and space	-	Citrus and pome, peach.	Wilson *et al.*, 1987.
Yeasts					
Pichia guilliermondii Wicker*	*P. italicum*	-Competition for nutrients and space -Directly parasitizing the pathogen	-	Citrus	Arras *et al.*, 1998.
*Candida saitoana**	*P. italicum*	-Competition for nutrients and space. -Directly parasitizing the pathogen when co cultured with *Botrytis cinerea.*	-	Citrus/apple	El-Ghaouth *et al.*, 2000.
*Debaryomyces hansenii**	*P. italicum*	-Competition for -Directly parasitizing co cultured with *Botrytis cinerea.*	-	Citrus	Droby *et al.*, 1989.

Table … continued

Cryptococcus laurentii	*P. italicum*	-Competition for nutrients and space.	-	Citrus/ apple	Roberts, 1990.
Aureobasidium pullulans (de Bary) Arnaud	*P. italicum*	-Competition for nutrients and space	-	Citrus	Janisiewicz *et al*., 2000.
Sporobolomyces roseus	*P. italicum*	-Competition for nutrients and space	-	Citrus	Janisiewicz, 1994.

Legend: * = antagonists with multiple mode of actions.

- = status not known.

Table 5 Categories of information gathered in the informally structured questionnaire on citrus cultivation, pre- and postharvest disease control practices in Ethiopia

Category information	**Information requested**	**Dominant Response**
Geographical aspects	Summer and winter temperature	Table 2
	Water source relation: Rainfall	79.2%
	Irrigation	100%
	Altitude	Table 2
	Humidity	Table 2
History of citrus farm/ orchards	Ownership: Government	97%
	Private (Individual)	2.6%
	Private (Association)	0.4%
	Farm size (ha)	Table 3
	Cultivar variety:	
	Valencia	35.8%
	Washington navel	23.9%
	Hamlin	19.4%
	Pineapple	7.5%
	Shamuti	4.5%
	Jaffa	1.5%
	Robbins blood	1.5%
	Unknown cultivars	5.9%
	Scion/ root stock sources move in:	
	From certified growers (California (USA), Israel and Asmara (Erteria)	21.1%
	From local growers (UAAIE, Ghibe, Error)	36.8%
	Material source unknown	42.1
	Orchard establishment, age in:	
	Old orchards (>20 years)	70%
	Young orchards (<20 years)	30%
	Type of crop used in	Cereals, vegetables, fibre crops, oil crops
	Soil type and nutrient status	Table 2
	Fertilizer used	Table 2
Preharvest epidemiology and disease/ pest management practices	Disease type:	
	Gumosiss (bark irruption)	In all citrus farms (>70%)
	Leaf and fruit spot	Ghibe citrus farm
		Tisablaima association citrus farm
	Insect pests	Reported 50% fruit damage
	Nematodes	12.1%
	Control measures:	Mostly by UAAIE, Hursso, Ghibe and Error Gota farms
	Chemical spray (Insecticides)	
	Plant decoction with animal urine and planting of a legume (*Lablab purpureus* L.) between citrus trees	Tisabalima association farm

Average input cost statistics in major Government citrus farms as compared to annual gross income	Labour cost	7.76%
	Agrochemicals (Pesticides and Fertilizers)	38.3%
Fruit harvesting	Peak time of harvest	Table 4
	Harvesting temperature	Ambient average temperature (18-25 °C)
	Harvesting techniques	Hand picking, tree shaking and pulling with long stick
	Persons involved in fruit picking	Temporary workers
Fruit transportation and storage facility	Fruit storage facility after picking	None
	Means of transportation	Open private and air-conditioned Etfruit trucks.
	Storage facility, general imperession	Untidy and with no temperature control in private and Etfruit storage houses
	Postahrvest disease incidence	Fig. 10 and 11
	Pathogens	*Penicillium* spp.
	Disease control methods	Sorting out and remove decayed fruits
Fruit marketing	Local markets	Towns around farms and Addis Ababa, Harar and DireDawa
	Export markets	Djibouti and Somalia
Others	Pack house facilities	None
	Overall farm experience on pre- and posthavest disease control activities:	Involved cultural practices such as field sanitation and use of pesticides in Government farms and animal urine + plant decoction in private farms.

APPENDIX 1I

QUESTIONNAIRE: I

Code "A" 2003/04

PREHARVEST CITRUS DISEASE MANAGEMENT PRACTICES ASSESSMENT

This questionnaire was translated to the local language (Amharic) for fieldwork

SITE: Citrus Production units in Ethiopia

Brief description: **Date:** _____

This questionnaire was designed as part of a PhD study that will focus on citrus fruit diseases and its control in Ethiopia. The first part of the questionnaire deal with pre-and postharvest factors, citrus diseases, crop management, and the second section dealing with fruit handling, storage, distribution and marketing. Therefore, we are kindly requesting your sincere response in replaying to the questions. Your input and time is much appreciated. All data will be held confidential and will only be used for research purposes.

Thank you!

Region: _____

Farm Name: _____

Farm Address: _____

I. Geographical aspects

1. What is the average summer and winter temperatures? (mark the applicable answer with an "X")

1-a: Summer (day)

15-20^{o}C	21-25^{o}C	26-30^{o}C	>30^{o}C

1-b: Summer (night)

<10^{o}C	10-15^{o}C	16-20^{o}C

1-c: Winter (day)

<10^{o}C	10-15^{o}C	16-20^{o}C	21-25^{o}C

1-d: Winter (night)

<10^{o}C	10-15^{o}C	16-20^{o}C

2. Water source used in the farm

Rainfall	irrigation	Both

3. How often do you irrigate your orchards?

Twice in a week	Once in a week	Twice in a month	Once in a month	Any other

4. What is the average rainfall per a year in ml?

<250ml	250-500ml	501-750ml	751-1000ml	>1001

5. What is the general altitude in ft above sea level?

0-300	301-600	601-900	901-1200	1201-1500	1501-1800	>1800

6. What is the average humidity of the farm?

<30%	31- 50%	51-70%	71-90%	>90%

II. History of citrus farm and its orchards

7. How big is a farm in hectares?

_____

8. How many types of sweet orange cultivars are produced on the farm? Can you name them and put in order of their importance in terms of area planted percentage composition?

9. From where did you purchase the planting material?

Certified growers	Local growers	Any other source. Name the name

10. How was the citrus seedlings/trees produced?

By seeding	By grafting

11. How old are the orchards?

0-10 years	10-20 years	20-30 years	>30 years

12. What is the ownership status of the citrus plantation site

Government	Association	Private (own)

13. Are there any other crops growing in/ or around the citrus farm?

Yes	No

14. For question number 12 above, if your answer is yes, what type of crop is it?

15. What is the soil type of the farm?

16. Have you ever determined the nutrient status of the soil?

Yes	No

17. For the above question number 16, if your answer is yes, are their deficient chemical elements identified so far? List their names.

18. For question number 16, if your answer is no, how did you managed diseases and or disorders associated with mineral deficiencies?

_____
_____
_____

19. Do you use a fertilization program?

Yes	No

20. For question number 18, if your answer is yes, what type of fertilizer do you applied?

_____
_____
_____
_____
_____

21. Referring to question number 19, how often do you apply fertilizer to a farm with in a year?

_____
_____
_____

III. Pre-harvest Epidemiology and Disease management practices

22. Do you have problems of diseases on your citrus trees?

Yes	No

23. Which part of the tree is attacked with the most common diseases?

Root	Stem	Leaf	Fruit

24. Which type of infection is most prevalent? Put in order (1-4) according to their importance

Fungal infection	Bacterial infection	Virus infection	Nematode attack	Insect problems

25. If the disease has a microbial origin, which type? Can you name/ describe the type of disease and its pathogen in order of its importance?

_____
_____
_____

26. If insects are important, what type of insects?
Write their names in order of importance

a)_____
b)_____
c)_____
d)_____
e)_____
f)_____

27. If nematodes are present, which type? Mention by name according to their importance.
    a) _____
    b) _____
    c) _____

28. Referring to question number 25, when do you think does the fungal infection start to appear on the orchards?

a

At grafting	At flowering	Just at fruiting	At fruit ripening	

b

At grafting	At flowering	Just at fruiting	At fruit ripening	

c

At grafting	At flowering	Just at fruiting	At fruit ripening	

d

At grafting	At flowering	Just at fruiting	At fruit ripening	

e

At grafting	At flowering	Just at fruiting	At fruit ripening	

29. With reference to question 26, when do you think does insect problem start to appear on the orchard?

a

At grafting	At flowering	Just at fruiting	At fruit ripening	

b

At grafting	At flowering	Just at fruiting	At fruit ripening	

c

At grafting	At flowering	Just at fruiting	At fruit ripening	

d

At grafting	At flowering	Just at fruiting	At fruit ripening	

e

At grafting	At flowering	Just at fruiting	At fruit ripening	

f.

At grafting	At flowering	Just at fruiting	At fruit ripening	

g.

At grafting	At flowering	Just at fruiting	At fruit ripening	

30. Referring to question number 24, when do you think does the respective virus infection start to appear on the orchards?

a

At grafting	At flowering	Just at fruiting	At fruit ripening	

b

At grafting	At flowering	Just at fruiting	At fruit ripening	

c

At grafting	At flowering	Just at fruiting	At fruit ripening	

d

At grafting	At flowering	Just at fruiting	At fruit ripening	

e

At grafting	At flowering	Just at fruiting	At fruit ripening	

31. Referring to question number 24, when do you think does the respective nematode infection start to appear on the orchards?

a

At grafting	At flowering	Just at fruiting	At fruit ripening	

b

At grafting	At flowering	Just at fruiting	At fruit ripening	

c

At grafting	At flowering	Just at fruiting	At fruit ripening	

d

At grafting	At flowering	Just at fruiting	At fruit ripening	

e

At grafting	At flowering	Just at fruiting	At fruit ripening	

32. How do you control disease? Explain your experience on the farm.

_____
_____
_____
_____
_____
_____
_____

33. Did you apply pesticides on your farm?

Yes	No	

34. Referring to the above question number 25, if you have applied pesticides, mention their names and application involved.

Name the commercial pesticides	What concentrations are being applied?	When do you start spraying pesticides?	How often do you spray during the growing season	What is the type of insect controlled?

III. Input costs and production statistics

35. How many workers are there in the farm?

_____
_____
_____

36. What is the average working hours of the farm worker per day?

_____
_____

37. What is the average salary of a farm worker per month?

_____
_____

38. What is the average input invested for pesticides purchase per year?

_____
_____
_____
_____

39. What is the average input invested for fertilizer purchase per year?

_____
_____
_____
_____
_____

QUESTIONNAIRE: II **Code "B" 2003/04**

Postharvest citrus (sweet orange) fruit handling and disease management practices

SITE: _____ **Date:** _____

Name: _____

Region: _____

Packhouse/Market Name and address: _____

I. Fruit harvesting

1. What is the daily temperature of a farm?

<10°C	10-15 °C	16-20 °C	21-25 °C	>25°C

2. When is the peak time for harvesting fruit?

Jan.	Feb.	May	Apr.	Ma.	Jun.	Jul.	Au.	Sep.	Oct.	Nov.	Dec.

3. What is the average temperature in the region?

a) Day time

<10°C	10-15 °C	16-20 °C	21-25 °C	>25°C

b) Night time

<0 °C	0-5 °C	6-10 °C	11-15 °C	>15 °C

4. What is the average relative humidity (RH)?

<29	30-40	41-50	51-60	61-70	71-80	>81

5. How do you pick fruit from the orchard?

Hand picking with gloves	Without gloves	By pulling with long sticks	By climbing in the tree

Describe if you have another method of harvesting _____

_____

_____

6. Who are picking your fruits?

Farm workers	Retailing market dealers	Part time workers

Mention if there are any _____

_____

_____

7. Referring to question number 5, how many fruits are harvested at a time in a day?_____

_____

_____

8. Where do you put fruits while collecting?

In a sack (1/2 a quintal size	In plastic crates	Openly on the ground/soil

Mention if there is any fruit collection method

_____

_____

_____

9. At what temperature do you store fruits?

<0 ^{o}C	0-5 ^{o}C	6-10 ^{o}C	11-15 ^{o}C	>15 ^{o}C

Mention if there is any

_____

_____

II. Fruit Transportation

10. How do you transport fruits from farm to packhouse?

By vehicle	By cart	By human labor

Explain if there are any other methods used in your farm to transport fruits?

_____

_____

11. For how long do you store fruit in the packhouse?

<6hrs	A day (24hrs)	48hrs	A week	More than a week	We don't store fruits at all

12. Storage conditions of fruits during transit?

<0 ^{o}C	0-5 ^{o}C	6-10 ^{o}C	11-15 ^{o}C	>15 ^{o}C

III. Postharvest Diseases

13. Do you have problems of postharvest diseases in the storage /packhouses?

Yes	No

14. For the above question (9), if your answer is no, what do you think the case is? May you explain the detail?

_____

_____

_____

_____

_____

15. For question (13) above, if your answer is yes, what are the major diseases associated? May you write down their names in order of importance?

a)_____

b)_____

c)_____

d)_____

e)_____

f)_____

16. Referring to question number 15, how do you control postharvest diseases and their dissemination? Explain your experience?

_____

_____

_____

_____

17. Do you apply commercial chemicals to control postharvest citrus diseases?

Yes	No

18. For the above question (17) if your answer is yes, mention the type of chemical applied and how frequently used?

Chemical name	Formulation	Application (how frequently used)	Remarks

19. For the same question number 17, if your answer is no, why? May you explain the reason?

_____

_____

_____

_____

20. Referring to question 18, the spray of chemicals, by what equipment and is the machine calibrated?

Yes	No

21. For question number 20, if your answer is no, what is the hindrance?

a) lack of knowledge

b) lack of training

c) lack of economy

d) mention if there are any other factors

22. How far is the average distance to your local market? Name market places and their distance from the farm packhouse.

Name of market places	Approximate distance (km)	Safety measures taken to keep quality of fruits	Remarks

23. How do you transport the packed fruit to the local market?

By vehicle	On the back of animals	By human labor

Mention if there are any means of fruit transportation:

_____

_____

24. Do you have international market access for the fruit produced and or its product?

Yes	No

25. For the above question (24), if your answer is yes, where? Mention the name of the country according to their market importance?

Country	Fruit market	fruit product	Remarks

24. How do you transport the packed fruit to the international market?

By air	By ship	By train

25. What is the transit temperature used during export? If others, give

4°C	7 °C	10 °C	>11 °C	

26. Do you apply chemicals to control decay of fruits during transit?

Yes	No

27. For the above question number 26, if your answer is yes, what chemicals do you use? List the name of commercial chemicals applied?

Chemical name	Formulation	Application (how frequently used)	Remarks

28. For question number 24, if your answer is no, what is hindrances to export?

a) lack of knowledge, know how, contact
b) quality guarantee because of diseases and associated problems
c) mention if encountered other factors

_____

_____

_____

_____

_____

29. Write any experiences of your farm (cultural, physical, biological or a combination of them) in postharvest disease handling and management practices to control citrus fruit disease.

_____

_____

_____

_____

_____

_____

_____

_____

IV. Fruit Price and marketing

30. What is the average price of fruit per kilogram in the local market?

_____

_____

31. What is the average price of fruit per kilogram in the export market?

_____

_____

_____

APPENDIX III

SENSORY EVALUATION FORM

Name _____

Date _____

Time _____

Parameters	A	B	C	D	E	F	G	H	I
Skin colour									
Colour of the ediable portion									
Colour of the flavedo									
Appearance									
Flavour									
Odour or smell									
Juiciness									
Sweetness									
Sour or Bitterness									
Overall acceptability									

Attribute	Definition
Smell	Total intensity of smell
Fresh	smell of fresh oranges
Flavour	Total intensity of flavour during the first chewing
Sweetness	Sweet taste
Bitterness or sourness	bitter or sourness
Appearance	whether it is fresh, shriveled, firm, soft
Colour	natural colour of orange or presence of browning.

Hedonic scale 1-5, where,

1=very poor, 2 poor, 3 fair, limited acceptability, 4- good, 5= excellent

Signature of the participant

_____

Identification of citrus (*Citrus sinensis*) Postharvest Pathogens from Ethiopia and their Control

By

Sissay Bekele

Promoter: Prof. Lise Korsten
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Department: Microbiology and Plant Pathology
Faculty: Natural and Agricultural Sciences
Degree: Ph.D. (Plant Pathology)

SUMMARY

From a world prospective, the continuous application of chemical pesticides has serious long-term effects on human health and environmental pollution, and can result in resistant pathogen strains. However, postharvest diseases cause major losses on the markets and need to be controlled effectively. The search for biopesticides using microbial antagonists and natural plant products has subsequently become more important as viable alternatives to control postharvest diseases. Currently, little information exists in terms of citrus production practices, disease management measures and postharvest losses in Ethiopia. The aim of this study was therefore to determine what the current situation in the country is in terms of production, disease management and postharvest disease incidence, disease management practices in Ethiopia and to develop an effective and safe disease control strategy for the industry. Citrus production in Ethiopia is mainly done by Government enterprises with little technical expertise. Disease control strategies are ineffective with postharvest losses exceeding 46%. The most important postharvest pathogen identified was *Penicillium digitatum*. In development of biopesticides, three yeast antagonists [*Cryptococcus laurentii* (strain MeJtw 10-2 and strain TiL 4-3) and *Candida sake* (TiL 4-2)] and plant leaf extracts of *Acacia seyal* and *Withania somnifera* were found to have some potential to

control *Penicillium* in *in vitro* and *in vivo* trials and ensure fruit quality. The modes of action of the yeast antagonists were not based on antibiosis. Instead, it involved competitive colonization where the antagonists inhibited *P. digitatum* spore germination and reduced mycelial growth by 75-100%. Extracts from the two plant species showed broad-spectrum antimicrobial activity against a range of several fungal and bacterial pathogens. The semi-commercial application of the antagonists and plant extracts improve fruit quality and the integration of these biopesticides were found effective in semi commercial trials and may provide a commercial solution for the citrus industry.