Strategies for the Management of Cactus Pear Diseases: A Global Perspective Part II

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Outline of Presentation

INTRODUCTION

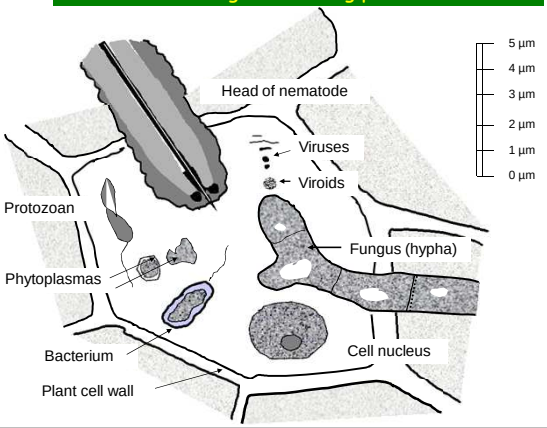
- Intensive cultivation of *Opuntia ficus-indica* varieties has resulted in appearance of numerous new disease problems over the past 3 decades in SA.

- Few major diseases of cactus pear (CP) reported in the world; most pathogens cause minor yield losses.
- Usually associated with bad management practices leading to opportunistic/secondary infection.

Significance of CP diseases

- Limit cultivation of CP and associated industries in certain geographic areas;
- Reduce the quantity and quality of plant products derived from the crop;
- Can make products poisonous to humans and animals;
- Cause direct and indirect financial losses.

Infectious agents causing plant disease



Effects of pathogens on CP

- Absorb food from cells thus weakening host plant leading to reduced yield.
- Consume host cells upon contact.
- Kill host cells or disturb their metabolism through toxins, enzymes or growth hormones.
- Block the transportation of food, mineral nutrients and water in host plant.

The Cryptic nature of CP diseases

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- Very few systematic studies on etiology of CP diseases and their management.
- Micro-organisms associated with visible symptoms often based on tenuous ID.

- Proof of true pathogenic ability often lacking.
- Usually involve secondary pathogens due to predisposition by abiotic factors.

The Cryptic Nature of CP diseases

- Physiology of CP is highly conducive to disease complexes.
- Colonization by fungi and/or bacteria very rapid due to high sugar concentration in cladodes and fruit.
- Symptoms of CP diseases thus difficult to attribute to a specific biotic or abiotic cause.

DISEASE SYMPTOMS

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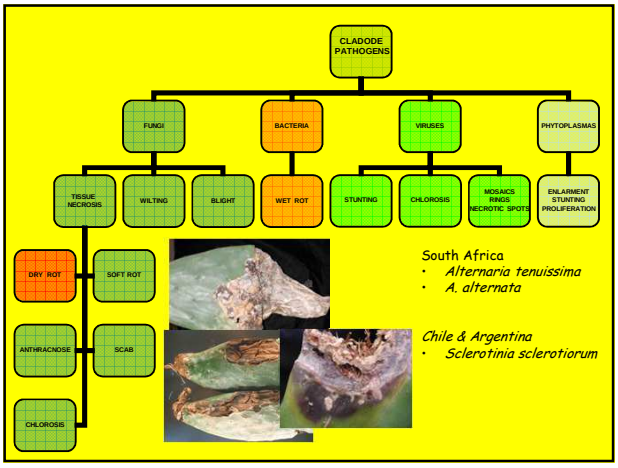
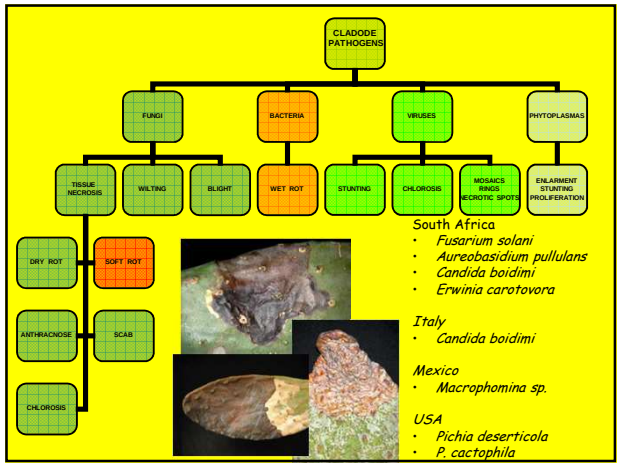
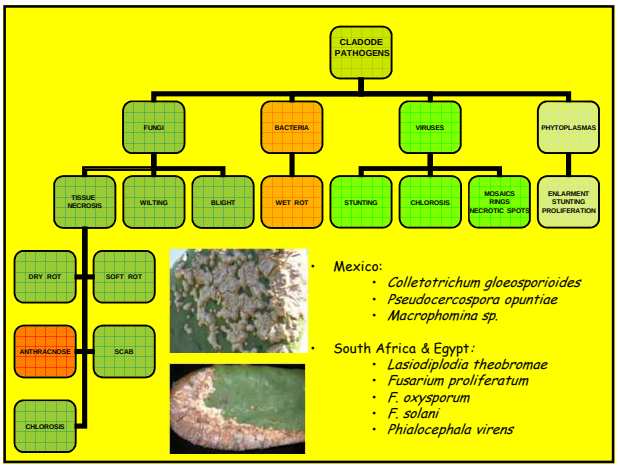
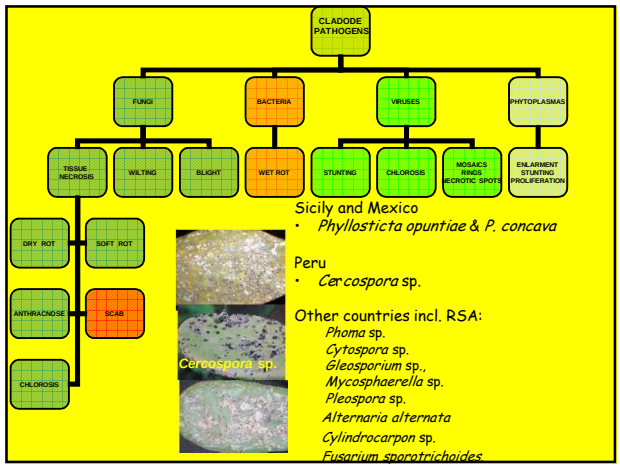
- Under-development of tissues/organs.
- Over-development of tissues/organs.
- Abnormal appearance of organs
- Necrosis, rot or death of tissues/organs.

Cladode Diseases






CLADODE PATHOGENS
FUNGI
BACTERIA
VIRUSES
PHYTOPLASMAS
TISSUE NECROSIS
WILTING
BLIGHT
WET ROT
STUNTING
CHLOROSIS
MOSAICS RINGS NECROTIC SPOTS
ENLARMENT STUNTING PROLIFERATION
DRY ROT
SOFT ROT
ANTHRACNOSE
SCAB
CHLOROSIS
• Mexico:
• Colletotrichum gloeosporioides
• Pseudocercospora opuntiae
• Macrophomina sp.
• South Africa & Egypt:
• Lasiodiplodia theobromae
• Fusarium proliferatum
• F. oxysporum
• F. solani
• Phialocephala virens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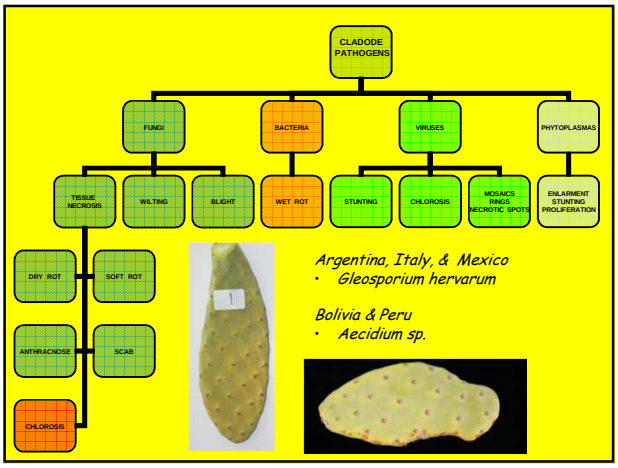
SCAB
CHLOROSIS
Sicily and Mexico
• Phyllosticta opuntiae & P. concava
Peru
• Cercospora sp.
Other countries incl. RSA:
Phoma sp.
Cytospora sp.
Gleosporium sp.,
Mycosphaerella sp.
Pleospora sp.
Alternaria alternata
Cylindrocarpon sp.
Fusarium sporotrichoides
Cercospora sp.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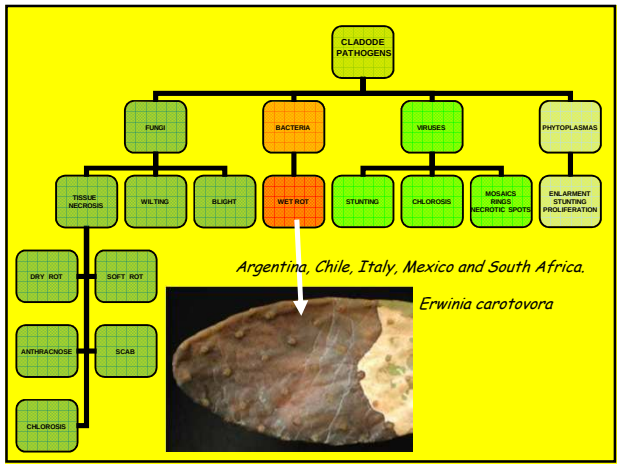
Argentina, Italy, & Mexico
• Gleosporium hervarum
Bolivia & Peru
• Aecidium sp.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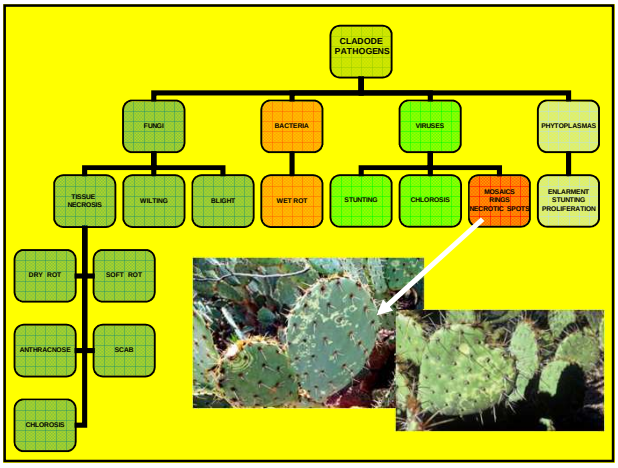
Argentina, Chile, Italy, Mexico and South Africa.
Erwinia carotovora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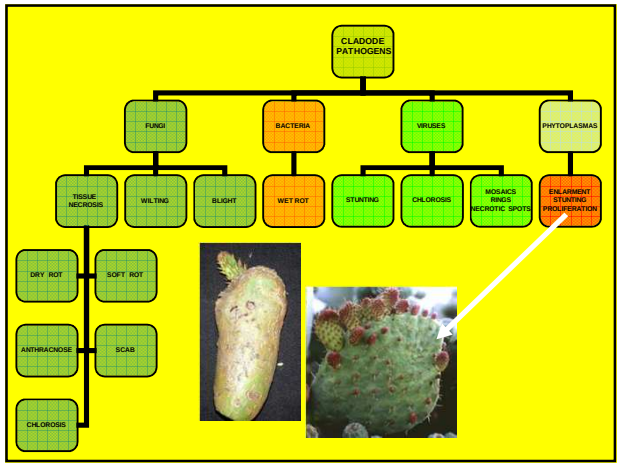
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CHLOROSIS

Fruit diseases

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Fungal Pathogens

Italy
- *Alternaria* spp.

Egypt
- *Alternaria alternata*
- *Lasiodiplodia theobromae*
- *Fusarium solani*

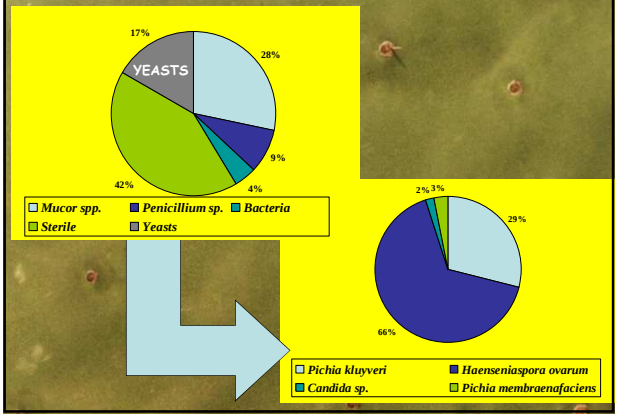
South Africa
- *Lasiodiplodia theobromae*
- *Alternaria tenuissima*
- *Penicillium spp.*
- *Botrytis cinerea*
- *Mucor spp.*
- *Various yeasts*



Soft Rot of *O. ficus-indica* (cv Algerian)

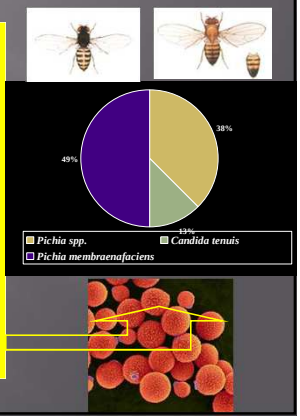
- Symptomatic fruit is soft and oozes a red, sticky exudate.
- Fermentation of fruits is evident since many fruits become distended to the point of almost bursting.
- The tissue from symptomatic fruit was plated onto Petri plates containing malt extract agar (MEA) in an attempt to isolate fungi and bacteria.

Microorganisms isolated from fruit tissue



Microorganisms isolated from *Drosophila* species

Fungi	% recovery from *Drosophila* spp.	
	D. m.	*D. h.*
Arthrographis. sp.	1.7	6.8
Alternaria sp.	0.0	4.9
Aspergillus niger Tiegh	0.9	2.9
Aschochyta sp.	0.0	1.0
Aureobasidium sp.	0.0	1.0
Cladosporium sp.	4.2	0.0
Fusarium spp.	12.9	5.0
Michrodochium spp.	3.2	2.7
Mucor spp.	43.3	32.0
Paecilomyces sp.	0.0	2.9
Penicillium spp.	3.4	9.7
Phoma spp.	2.5	6.8
Trichoderma sp.	0.0	1.0
Yeasts	22.0	20.4
Unidentified fungi	5.9	2.9



Stem and Root diseases

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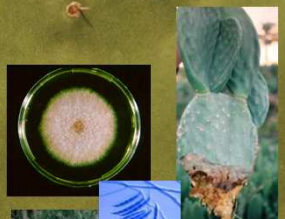
- *Opuntia* spp. very vulnerable to root rot.
- *Fusarium* spp. especially important since they flourish in hot, humid areas.
- Disease development is encouraged by poor soil conditions characterised by increased acidity, low permeability, and elevated humidity.



Stem and Root Diseases

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Argentina & Italy
- *Armillaria mellea*

Mexico
- *Fusarium solani*
- *F. oxysporum*
- *Agrobacterium tumefaciens*

USA
- *F. cactorum*
- *Pythium aphanidermatum*
- *Phytophthora nicotianae*

South Africa
- *F. proliferatum*
- *F. solani*
- *F. oxysporum*


Armillaria mellea

•Fusarium solani

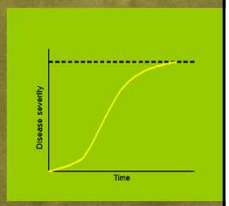
Pythium aphanidermatum

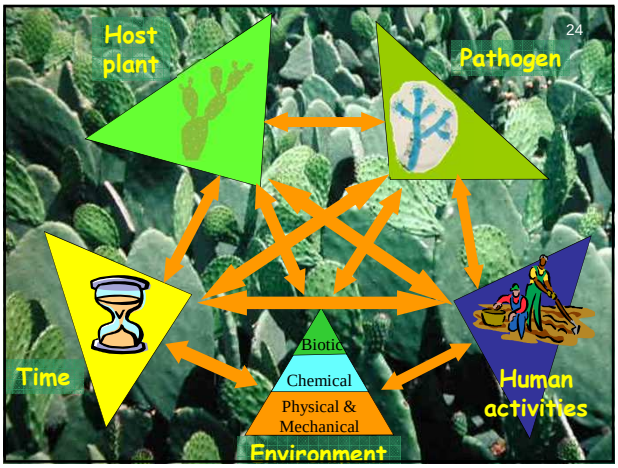
MANAGING CACTUS PEAR DISEASES
The Role of the Environment

BIOTIC (living)	ABIOTIC (non-infectious)	
BIOLOGICAL	**CHEMICAL**	**PHYSICAL**
Infectious agents:	Soil acidity / alkalinity	Compacted soil
Fungi	Air pollution	Day length
Bacteria	Mineral toxicities	Drought
Viruses / viroids	Growth hormones	Water logging
Phytoplasmas	Nutrient deficiencies	Fire
Parasitic plants	Pesticides	Frost
Nematodes	Soil salinity	Heat stress
Protozoa		Lightning
Non-infectious agents:		Light intensity
Insects		UV radiation
Mammals		Wind
Mites		
Birds		
Slugs, snails		
Weeds		

Development of Disease Epidemics

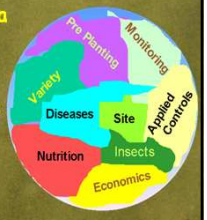
- The biotic and abiotic environment plays a crucial role in the development of a disease epidemic.
- The occurrence of a plant disease epidemic is dependant on opportunities for disease that arise from many biotic and abiotic interactions that take place within a changing environment over time.
- Categories of environmental change:
  - Cyclic changes (e.g. seasons)
  - Directional changes (e.g. soil erosion)
  - Erratic changes (e.g. floods, droughts)





MANAGING CACTUS PEAR DISEASES
Understanding and Decoding Interactions

- Role of abiotic factors in predisposing single cactus pear plants to infection, or in exacerbating disease severity in a population of plants, is vague.
- Better understanding of biotic/abiotic interactions crucial for formulation of a long-term, sustainable disease management strategy
- Holistic approach to diagnosis and disease management is thus imperative!



MANAGING CACTUS PEAR DISEASES
The Importance of Accurate Diagnosis

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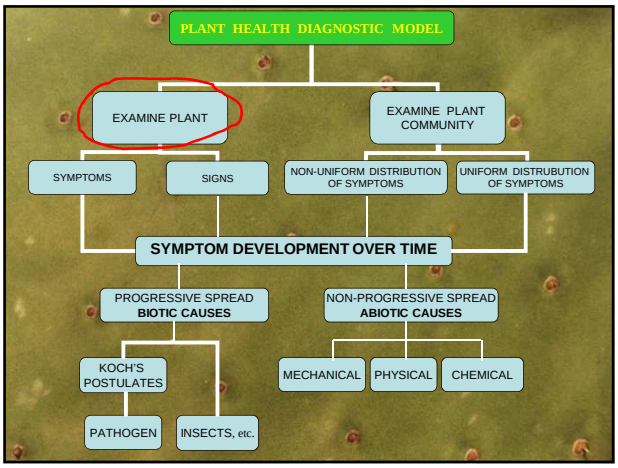
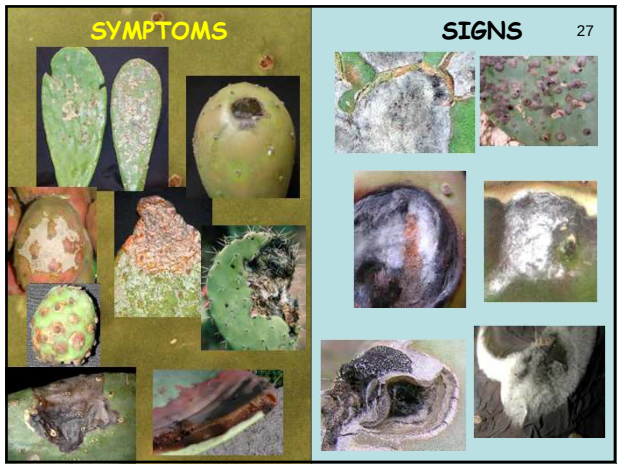
- Misidentification can lead to control failure.
- Different management tactics have different influences on different pathogens.
- Fungicides target only certain pathogens while others remain unscathed.
- Fertilizers may selectively influence pathogens;
  - e.g. some fungal pathogens suppressed by N application while others benefit.

MANAGING CACTUS PEAR DISEASES
Pitfalls of disease diagnosis

- Macro symptoms of different diseases may be similar.
- Symptoms for different pathogens are often the same.
- The same pathogen may cause many different symptoms.
- Pathogens may look the same but cause different symptoms.


PLANT HEALTH DIAGNOSTIC MODEL
EXAMINE PLANT
EXAMINE PLANT COMMUNITY
SYMPTOMS
SIGNS
NON-UNIFORM DISTRIBUTION OF SYMPTOMS
UNIFORM DISTRUBUTION OF SYMPTOMS
SYMPTOM DEVELOPMENT OVER TIME
PROGRESSIVE SPREAD BIOTIC CAUSES
NON-PROGRESSIVE SPREAD ABIOTIC CAUSES
KOCH'S POSTULATES
MECHANICAL
PHYSICAL
CHEMICAL
PATHOGEN
INSECTS, etc.


SYMPTOMS
SIGNS
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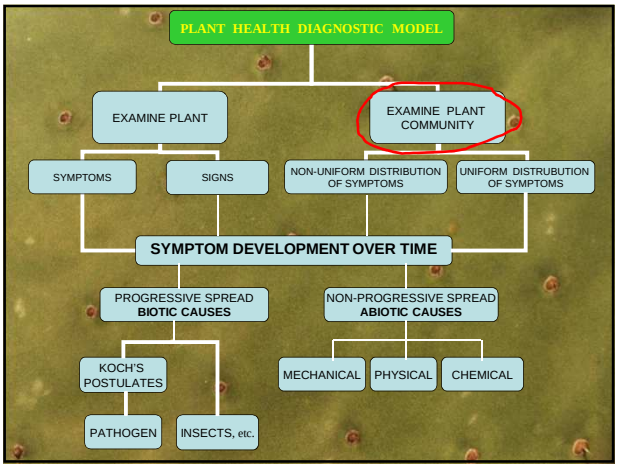
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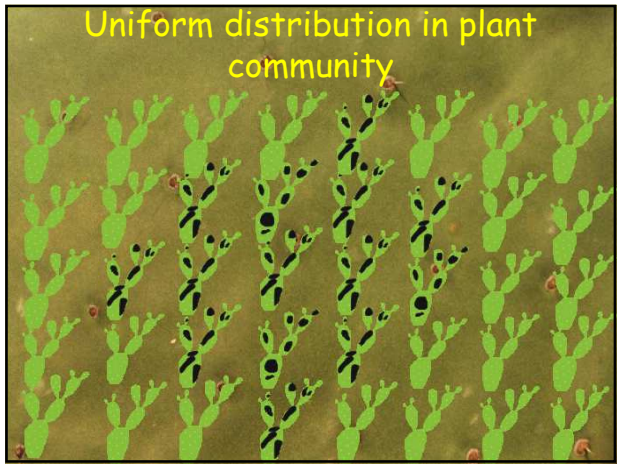
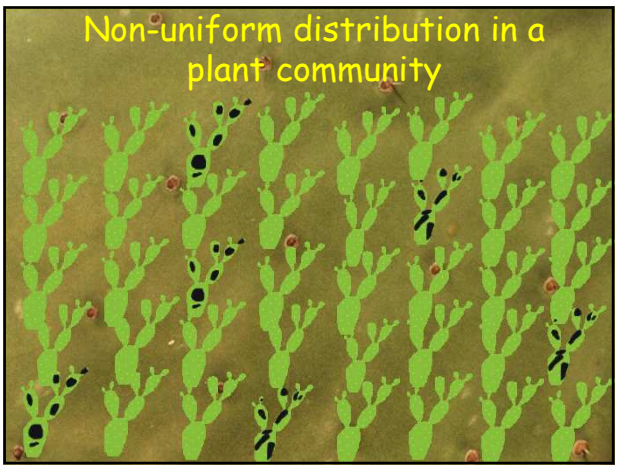
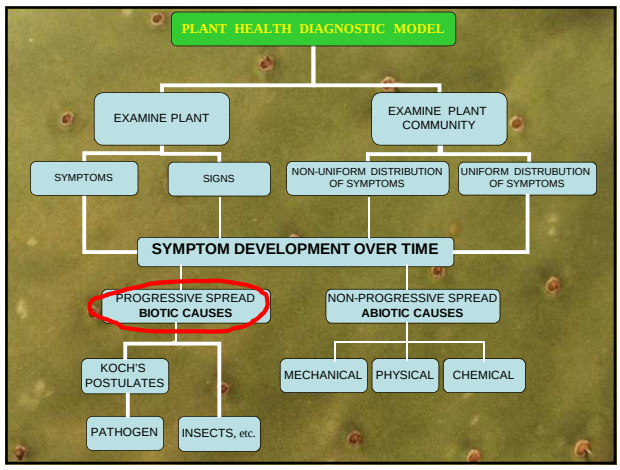

Uniform distribution in plant community


Non-uniform distribution in a plant community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PROGRESSIVE SPREAD IN A SINGLE PLANT

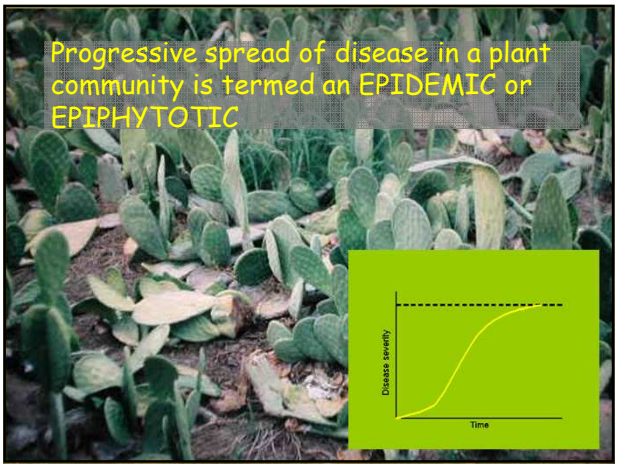
BIOLOGICAL

Infectious agents:
- Fungi
- Bacteria
- Viruses / viroids
- Phytoplasmas
- Parasitic plants
- Nematodes
- Protozoa

Non-infectious agents:
- Insects
- Mammals
- Mites
- Birds
- Slugs, snails
- Weeds

Progressive spread in a plant community

Progressive spread of disease in a plant community is termed an EPIDEMIC or EPIPHYTOTIC



PLANT HEALTH DIAGNOSTIC MODEL

- EXAMINE PLANT
  - SYMPTOMS
  - SIGNS
- EXAMINE PLANT COMMUNITY
  - NON-UNIFORM DISTRIBUTION OF SYMPTOMS
  - UNIFORM DISTRUBUTION OF SYMPTOMS

SYMPTOM DEVELOPMENT OVER TIME

- PROGRESSIVE SPREAD **BIOTIC CAUSES**
  - KOCH'S POSTULATES
    - PATHOGEN
    - INSECTS, etc.
- NON-PROGRESSIVE SPREAD **ABIOTIC CAUSES**
  - MECHANICAL
  - PHYSICAL
  - CHEMICAL

NON-PROGRESSIVE SPREAD IN A SINGLE PLANT

ABIOTIC FACTORS

CHEMICAL	PHYSICAL
Soil acidity / alkalinity	Compacted soil
Air pollution	Hail
Mineral toxicities	Drought
Growth hormones	Water logging
Nutrient deficiencies	Fire
Pesticides	Frost/freezing
Soil salinity etc.	Heat stress
	Lightning
	Light intensity
	UV radiation
	Wind etc.

Abiotic agents

- Freezing, hail and sun-scald can cause similar symptoms to biotic agents.


Sun damage


Hail damage


Freezing damage

Non-progressive spread in a plant community

Non-uniform distribution

Uniform distribution

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  - PHYSICAL
  - CHEMICAL

MANAGING CACTUS PEAR DISEASES
Koch's postulates

1. Suspected pathogen must be consistently associated with same symptoms.
2. Suspected pathogen must then be isolated and grown in pure culture on nutrient agar away from host and its characteristics described.
3. Organism from pure culture must be re-inoculated into a healthy host plant of same species.
4. Symptoms identical to original disease should then develop.
5. Organism should then be re-isolated from test host to pure culture and must be identical with organism initially isolated.

MANAGING CACTUS PEAR DISEASES
The "Total System Approach"

- **Should a pathogenic organism be convincingly associated with specific symptoms it is necessary to ask questions such as:**
  - Why is the organism causing damage?
  - How did organism arrive in the system?
  - Why did it establish in the system?
  - How is it disseminated in the system?
  - What natural/biological controls exist in system?

MANAGING CACTUS PEAR DISEASES
New Perspectives

- Answers to be found by "looking beyond" the pest or pathogen.
- This is where the reactive/diagnostic approach becomes more proactive.

REACTIVE	PROACTIVE
DIAGNOSIS	
Defining the problem	Definining the system
ANALYSIS	ANALYSIS
Understanding the problem	Understanding the system
CONTROL	MANIPULATION
"Solving" the problem	Maintaining the system

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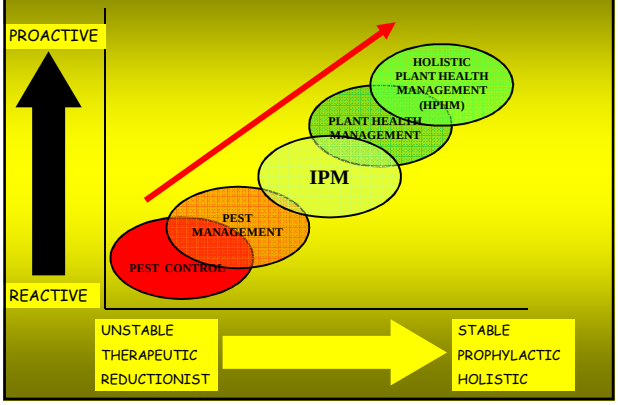

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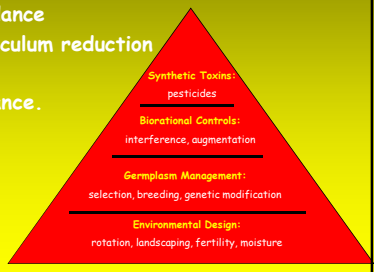
"Prevention is better than cure"

Prevention implies:

1. Exclusion/avoidance
2. Eradication/inoculum reduction
3. Protection
4. Genetic resistance.



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1. Exclusion/avoidance

- Best proactive approach is strict phytosanitary regulation.
- Quarantines and pathogen-free certification programmes should be based on sound ecological principles and properly implemented in order to be effective.
- Avoidance of areas where specific cactus pear diseases are known to occur.
- Practices aimed at excluding pathogens/inoculum which promote or facilitate onset of disease in orchards.

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2. Eradication/inoculum reduction (1):

- Inoculum includes spores, mycelium, cells, sclerotia and other structures whereby pathogens survive and are dispersed by rain, wind or insects.

- Destruction of diseased material removes inoculum & limits disease incidence and severity in cactus pear orchards.
- Methods for eradicating inoculum include pruning, sanitation, crop rotation, soil fumigation, trap crops, etc.
- Regular inspection of orchards necessary to determine the presence of diseases so that inoculum can be eliminated.

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2. Eradication/inoculum reduction (2):

- Cactus pear diseases are often exacerbated by insects attracted to sweet sticky exudations of rotting fruit.
- There are numerous reports of insects such as flies acting as vectors for micro-organisms that can cause disease in *Opuntia* sp.
- The families Syrphidae, Otitidae and Ephydridae have been shown to be vectors of *Erwinia carotovora* subsp. *carotovora* the causal agent of cladode soft rot.

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2. Eradication/inoculum reduction (3):

- **We identified at least 13 genera of mycelial fungi from two species of vinegar flies.**
- **Commonly found on fallen fruit in cactus pear orchards.**
- **Larvae and adults feed on fungi and bacteria in decaying cactus pear fruit.**

Drosophila spp.

2. Eradication/inoculum reduction (4): 39

- Sap beetles (*Carpophilus hemipterus*) breed prolifically under decaying cladodes and fruit.
- Associated with fungal pathogens known to cause fruit rot in South Africa.
- Adults gain access to fruit via areoles.

3. Protection 40

Direct approach:
- **Reactive**
- **Physical and chemical control**
- Entails application of synthetic fungicides, bactericides, insecticides, miticides, nematicides or plant extracts.

Indirect approach:
- **Proactive**
- **Biological control**
- Based on ecological principles that allow for a strategy that is environmentally friendly and sustainable.

Biological control

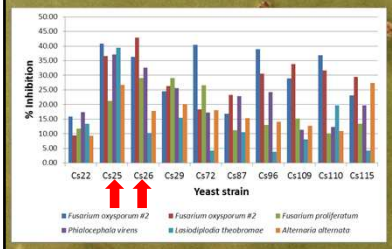
Yeast isolates with antifungal activity *in vitro*

Aim: To identify yeasts with biocontrol activity against cactus pear pathogens.

Over 270 strains isolated from the surface of cactus pear fruit were screened *in vitro* in dual culture tests.

Ten strains were selected for further *in vitro* evaluation on nutrient agar against six pathogens of cactus pear.

Post-harvest biological control



All strains significantly ($P \leq 0.05$) reduced colony diameter of the six pathogens, except for *L. theobromae*.

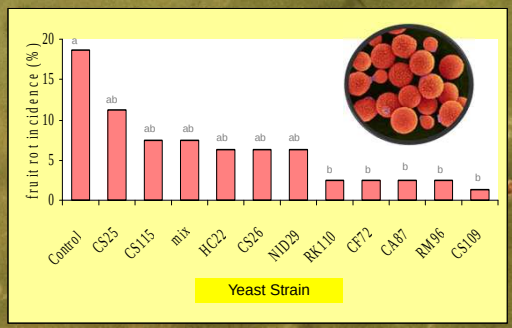
Seven days after incubation, colonies of most of the pathogens exposed to *Cryptococcus saitoi* (CS25) did not grow more than 50 mm in diameter while the colony diameters of yeast-free cultures were 80-100 mm.

Averaged over all pathogens, the highest inhibition of mycelial growth (35%) was obtained with *C. saitoi* (CS25) followed by *C. saitoi* (CS26) (28%).

Post-harvest biological control

- Ten yeast isolates which showed antifungal activity *in vitro* were tested for their effect on fruit rot on fruit ready for commercial packaging (brushed and washed).
- Yeast inoculum was prepared from 48 hr old cultures. Concentration adjusted to ~ 1×10^9 cells/ml.
- Fruits dipped in suspension for 30 sec and placed in carton used for commercial packaging.
- After 10 days in storage, all strains resulted in significantly lower incidence of fruit rot than the control treatment.
- Species of *Fusarium, Alternaria and Rhizopus* were isolated from rotting fruit.

Incidence of fruit rot after 10 days storage following treatment with 10 yeast isolates



4. Genetic resistance.

42

- Selective breeding for resistance to diseases is probably the best means of preventing plant disease
- Genotypic characterization of cactus pear cultivars can greatly facilitate such breeding strategies.
- The identification and exploitation of differences aided by biotechnological techniques such as AFLP-fingerprinting provides valuable information for parental selection.
- Valuable contributions made by Masters study of Rae Oelofse in 2002 and Ph.D. study of Dr Barbara Moshope in 2007 on AFLP fingerprinting of cactus pear germplasm in South Africa.

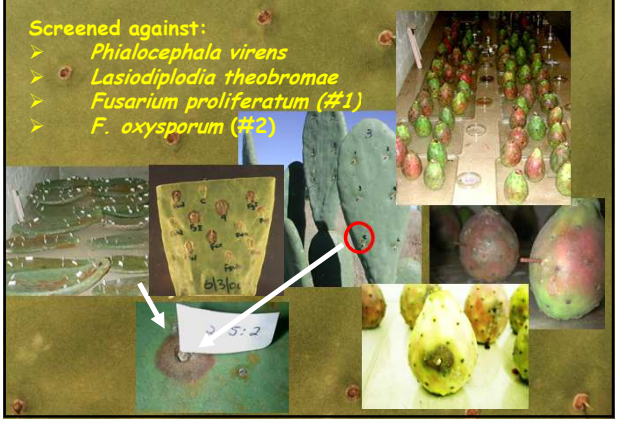
Oelofse, R.M. 2002. Characterization of *Opuntia ficus-indica* cultivars in South Africa. M.Sc. Agric. dissertation. UFS, Bloemfontein, South Africa.

- Plant material of 10 varieties was characterised based on:
  - General horticultural characteristics
  - characteristics for use as fodder
  - Susceptibility to four fungal pathogens
- Varieties were genetically characterised using AFLP markers.
- Morphological data were compared with genetic data

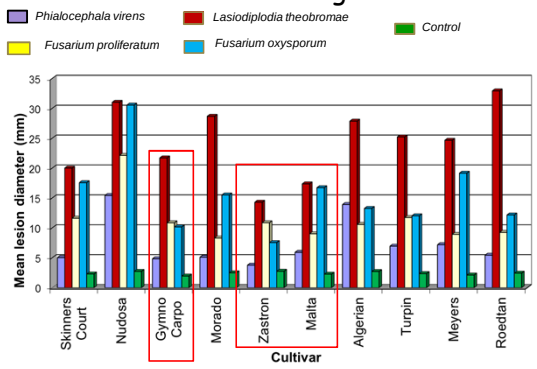
Disease Susceptibilty of *Opuntia* varieties

Screened against:

- ***Phialocephala virens***
- ***Lasiodiplodia theobromae***
- ***Fusarium proliferatum (#1)***
- ***F. oxysporum (#2)***

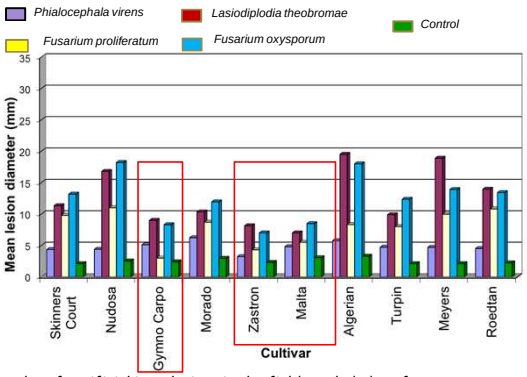


Cladodes in the glasshouse



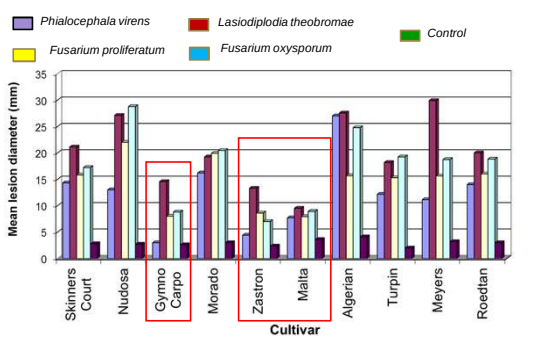
Results of artificial inoculations in the glasshouse on detached cladodes of 10 *O. ficus-indica* cultivars with 4 fungal pathogens (RM Oelofse, MSc, UFS).

Cladodes in the field



Results of artificial inoculations in the field on cladodes of 10 *O. ficus-indica* cultivars with 4 fungal pathogens. (RM Oelofse, MSc, UFS).

Fruit

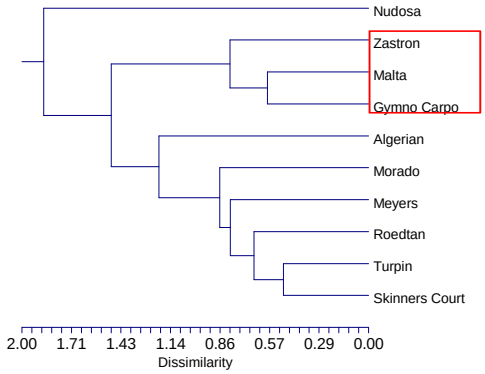


Results of artificial inoculations in the laboratory on fruit of 10 *O. ficus-indica* cultivars with 4 fungal pathogens. (RM Oelofse, MSc, UFS).

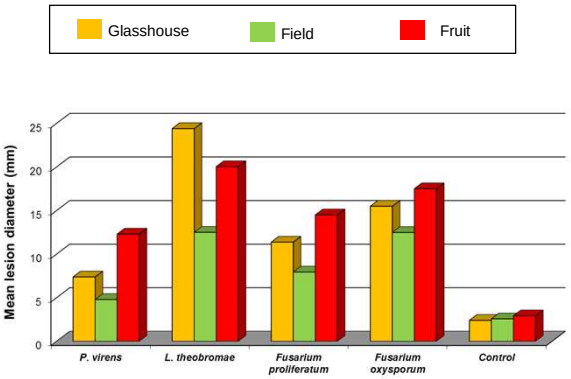
Cladodes GH		Fruit		Cladodes Field	
Zastron	9.14	Gymno Carpo	8.3	Zastron	5.665
Gymno Carpo	11.91	Zastron	8.33	Gymno Carpo	6.335
Skinners Court	13.58	Malta	8.51	Malta	6.45
Turpin	14	Turpin	16.22	Turpin	8.753
Morado	14.42	Skinners Court	17.12	Morado	9.305
Malta	14.55	Roedtan	17.21	Skinners Court	9.665
Roedtan	14.97	Morado	18.96	Roedtan	10.68
Meyers	15.07	Meyers	19.42	Meyers	11.88
Algerian	16.42	Nudosa	22.72	Nudosa	12.6
Nudosa	24.8	Algerian	23.99	Algerian	12.9

Mean lesion diameter (mm)

Ranking of cv's following artificial inoculations of cladodes (glasshouse & field) and fruit (laboratory)



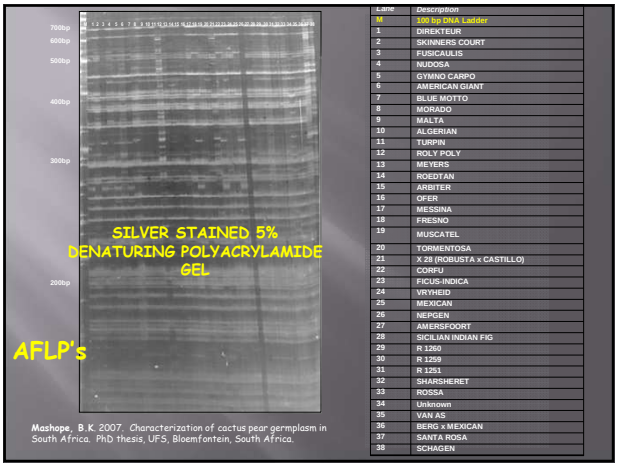
Dendogram generated by UPGMA analysis of the combined data collected from inoculation trials of cladodes (glasshouse and field) and fruit (laboratory).



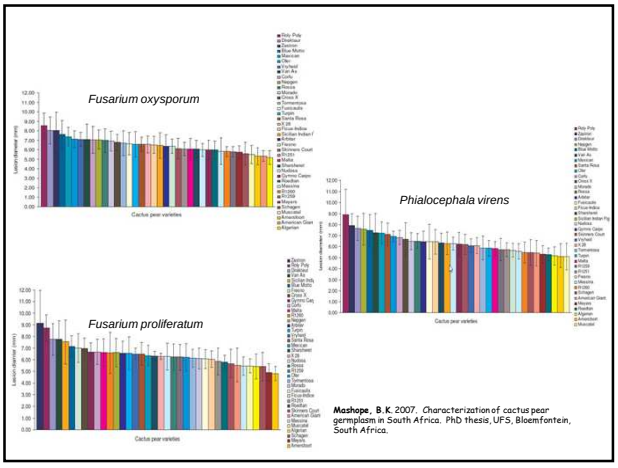
Mean lesion diameters on cladodes following artificial inoculations of cladodes in the glasshouse and field and fruit in the laboratory

Mashope, B.K. 2007. Characterization of cactus pear germplasm in South Africa. PhD thesis, UFS, Bloemfontein, South Africa.

- Genetically fingerprint germplasm of 38 varieties of *O. ficus-indica* using AFLP markers.
- Varieties were evaluated for disease resistance, cladode nutritional quality and fruit quality.
- In addition, a search to find yeasts able to limit post-harvest rot of fruit was undertaken.

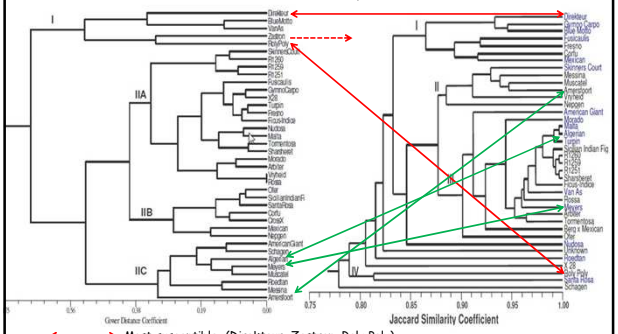


Lane	Description
M	100 bp DNA Ladder
1	DIREKTEUR
2	SKINNERS COURT
3	FUSICAULIS
4	NUDOSA
5	GYMNO CARPO
6	AMERICAN GIANT
7	BLUE MOTTO
8	MORADO
9	MALTA
10	ALGERIAN
11	TURPIN
12	ROLY POLY
13	MEYERS
14	ROEDTAN
15	ARBITER
16	OFER
17	MESSINA
18	FRESNO
19	MUSCATEL
20	TORMENTOSA
21	X 28 (ROBUSTA x CASTILLO)
22	CORFU
23	FICUS-INDICA
24	VRYHEID
25	MEXICAN
26	NEPGEN
27	AMERSFOORT
28	SICILIAN INDIAN FIG
29	R 1260
30	R 1259
31	R 1251
32	SHARSHERET
33	ROSSA
34	Unknown
35	VAN AS
36	BERG x MEXICAN
37	SANTA ROSA
38	SCHAGEN



Dendrogram of 38 CP varieties constructed on the basis of overall susceptibility to 3 fungal pathogens. The Gower dissimilarity coefficient was used to estimate dissimilarity between varieties.

Dendrogram of 38 South African CP varieties based on cluster analysis (UPGMA) of genetic similarity estimates (AFLP markers) using the Jaccard similarity coefficient. (Varieties in blue are those cultivated for fruit in SA).



Most susceptible (Direkteur, Zastron, Roly Poly)

Most resistant (Amersfoort, Meyers, Algerian)

Summary of Mashope's research

- AFLP fingerprinting data revealed distinct differences between the accessions currently cultivated in South Africa.
- The expression of disease resistance within the varieties surveyed indicates a quantitative mode of resistance across all varieties evaluated for all three pathogens tested.
- Roly Poly, Direkteur, and Zastron were the most susceptible varieties.
- The most resistant varieties were Amersfoort, Meyers, and Algerian.
- Mashope's results inconsistent with Oelofse's 2002 results where Zastron was most resistant and Algerian most susceptible to the same three pathogens.
- Inconsistency could be attributed to differences in climatic conditions prevailing during field trials, as the amount and occurrence of infection can be influenced by environmental conditions that influence the host and pathogen (i.e. GxE).

TO WRAP UP……

- Different ecological principles and management practices apply to the cultivation of new crops such as cactus pear. An integrated and holistic approach is thus important for the management of pests and diseases on the crop.
- Our research over the past ten years has revealed numerous interactions between insects such as *Drosophila* species & pathogenic fungi of *Opuntia ficus-indica* that were previously unknown.
- Similarly, new interactions between various fungal pathogens and genotypes of cactus pear have also been discovered.
- It is crucial that these interactions *inter alia* are taken into consideration within the context of a holistic plant health management strategy for cactus pear cultivation.

UFS Publications re: Cactus pear

1. Swart WJ and W-M. Kriel. 2002. Pathogens Associated with Necrosis of Cactus Pear Cladodes in S. Africa. Plant Disease 86: 693
2. Swart, W.J. & Swart, V.R. 2002. The current status of research on diseases of *Opuntia ficus-indica* in South Africa. Acta Horticulturae 581: 239-245.
3. Swart, W.J., Oelofse, R.M. & Labuschagne, M.T. 2003. Susceptibility of South African cactus pear varieties to four fungi commonly associated with disease symptoms. *Jnl of the Professional Association for Cactus Development* 5: 86-97.
4. Swart, W.J. & Swart, V.R. 2003. An overview of research on diseases of cactus pear in South Africa. *Journal of the Professional Association for Cactus Development* 5: 115-120.
5. Oelofse, R.M., Labuschagne, M. T. and Potgieter, J.P., 2006. Fruit and feed characteristics of cactus pear (*Opuntia* spp.) cultivars in South Africa. Journal of the Science of Food and Agriculture 86(12): 1921-1925
6. Swart, W.J. 2009. Strategies for the management of cactus pear diseases: A global perspective. *Acta Horticulturae* (ISHS) 811:207-216.
7. Louw, S. Parau, J.V. and Olevano, J.C. 2009. Bio-Ecology of Sap Beetles (Nitidulidae), a New Double Impact Pest on Cactus Pear in South Africa. . Acta Horticulturae (ISHS) 811:217-221.
8. Maryna de Wit, Philip Nel, Gernot Osthoff and Maryke T Labuschagne. 2010. The effect of variety and location on cactus pear (Opuntia ficus-indica) fruit quality. Plant Foods for Human Nutrition 2010 65:136-145.
9. N. Shongwe, M. De Wit, G. Osthoff, P. Nel and M. Labuschagne. 2013. The Influence of Location, Cultivar and Season on Cactus Pear Fruit Quality. Proc. 7th International Congress on Cactus Pear and Cochineal, Eds.: A. Nefzaoui et al. Acta Hort. 995, ISHS
10. Rothman, M.; de Wit, M.; Bothma, C.; and Hugo, A. 2012. Determination of seasonal influences on sensory attributes of South African cactus pear cultivars Jnl of the Professional Association for Cactus Development 14: 41-52
11. M. Rothman, M. de Wit, A. Hugo and H.J. Fouché. 2013. The Influence of Cultivar and Season on Cactus Pear Fruit Quality. Proc. 7th Int. Congress on Cactus Pear and Cochineal, Eds.: A. Nefzaoui et al. Acta Horticulturae 995, ISHS
12. De Wit, M., Bothma, C. Swart, P.; Frey, M. and Hugo, A. 2014. Thermal treatment, jelly processing and sensory evaluation of cactus pear fruit juice. Journal of the Professional Association for Cactus Development 16:1-14
13. Engelbrecht, G. M., Fouche, H.J. & Ntsane, S.M., 2013. Comparison of cactus pear (*Opuntia* spp.) cultivars for fruit yield and quality in the Central Free State, South Africa. Acta Hortic. 995(1), 225-228.

UFS Congress Presentations re: Cactus pear

1. Swart, V.R., Swart, W.J., Louw, S.VdM. & Kriel, W-M. 2003. Relationships between potentially phytopathogenic fungi and insect phytophages associated with cactus pear, pistachio and pigeon-pea in South Africa. 41st Annual Plant Pathology Congress, SASPP, Bain's Game Lodge, Bloemfontein, South Africa. 19-22 January. SA Journal of Science 99: ix
2. Swart, W.J. & Swart, V.R. 2004. Pests and diseases of cactus pear in South Africa. Fourth Symposium of the Southern African New Crop Research Association, ARC-Infruitec, Stellenbosch, South Africa. 6-8 September.
3. Swart, V.R., Swart, W.J., Louw, S.VdM. & Kriel, W-M. 2000. An ecological complex of parasitic fungi associated with Drosophila spp. that utilize Opuntia ficus-indica in South Africa. IVth International Congress on Cactus Pear and Cochineal, Hammamet, Tunisia. 22-28 October.
4. Swart, W.J., Amadi, J.E. & Viljoen, B.C. 2000. The current status of research on diseases of Opuntia ficus-indica in South Africa. IVth International Congress on Cactus Pear and Cochineal, Hammamet, Tunisia. 22-28 October.
5. Swart, W.J. 2006. Holistic health management in cactus pear orchards in South Africa. Proceedings of the 2006 International Cactus Pear Congress, University of the Free State, Bloemfontein, South Africa. 29-31 March. p. 8.
6. Tarekegn, G., Mashope, B.K. & Swart, W.J. 2006. Biological control of cactus pear pathogens using yeasts. Proceedings of the 2006 International Cactus Pear Congress, UFS, Bloemfontein, South Africa. 29-31 March. p. 10.
7. Swart, W.J. & Louw, S.VdM. 2006. A diagnostic procedure for identifying cactus pear pests and diseases. Proceedings of the 2006 International Cactus Pear Congress, UFS, Bloemfontein, South Africa. 29-31 March. p. 11.
8. Swart, V.R., Swart, W.J. & Louw, S.VdM. 2006. Ecological aspects of fungal pathogens and Drosophila spp. Proceedings of the 2006 International Cactus Pear Congress, UFS, Bloemfontein, South Africa. 29-31 March. p. 12.
9. Tesfaendrias, M.T., Tarekegn, G. & Swart, W.J. 2006. The pathogenicity of fungi isolated from cactus pears. Proceedings of the 2006 International Cactus Pear Congress, University of the Free State, Bloemfontein, South Africa. 29-31 March. p. 13.
10. Swart, W.J. 2007. Strategies for the management of cactus pear diseases: A global perspective. VI International Conference on Cactus Pear and Cochineal and the VI General Meeting of the FAO-CACTUSNET, João-Pessoa, Brazil. 22-26 October. (Invited keynote address)
11. Potgieter, J., Walker, S., Engelbrecht, G.M., Smith, M., 2007. Does environment influence fruit quality in cactus pear. VI International Cactus Pear and Cochineal Congress, Joao Pessau, Mexico.
12. Fouchè, H.J., Engelbrecht, G.M. & Avenant, P.L., 2009. The potential of cactus pear (O. ficus-indica) as an animal fodder. 44th Annual GSSA, 2009, Johannesburg, South Africa.
13. Engelbrecht, G. M., Fouche, H.J. & Ntsane, S.M., 2010. Comparison of cactus pear (Opuntia spp.) cultivars for fruit yield and quality in the Central Free State, South Africa. Seventh International congress on Cactus Pear and Cochineal. Agadir, Mexico.
14. Fouchè, H.J. & Engelbrecht, G.M., 2010. The potential of cactus pear (Opuntia ficus-indica) as animal feed. Seventh International congress on Cactus Pear and Cochineal. Agadir, Mexico.
15. Coetzer, G.M. & Fouche, H.J., 2014. Fruit yield and quality of cactus pear (Opuntia spp.) cultivars in the Central Free State, South Africa. Eight International congress on Cactus Pear and Cochineal. Italy.
16. Fouche, HJ & Coetzer GM, 2014. Response of cactus pear (Opuntia spp.) biomass production to fruit load. Eight International congress on Cactus Pear and Cochineal. Italy.

M.Sc. Agric. Studies at UFS re: Cactus pear

1. **Oelofse, R.M.** 2002. Characterization of *Opuntia ficus-indica* cultivars in South Africa. M.Sc. Agric. dissertation. UFS, Bloemfontein, South Africa.
2. **Potgieter, J.** 2007. The influence of environmental factors on spineless cactus pear (*Opuntia* spp.) fruit yield in Limpopo Province South Africa. M.Sc. Agric. dissertation. UFS, Bloemfontein, South Africa.
3. **Einkamerer, Ockert Bernard**, 2008. Animal performance and utilization of *Opuntia*-based diets by sheep. M.Sc. Agric. dissertation. UFS, Bloemfontein, SA
4. **Menezes, Carla Maria Dias da Conceição** 2008. Effects of sun-dried *Opuntia ficus-indica* cladodes on digestive processes in sheep. M.Sc. Agric. dissertation. UFS, Bloemfontein, SA
5. **Shiningavamwe, Katrina Lugambo**, 2009. Feedlot performance of Dorper lambs fed on *Opuntia*-based diets with different nitrogen sources. M.Sc. Agric. dissertation. UFS, Bloemfontein, SA
6. **Zeeman, Desirée Carla**, 2005. Evaluation of sun-dried *Opuntia ficus-indica* var. Algerian cladodes in sheep diets. M.Sc. Agric. dissertation. UFS, Bloemfontein, SA
7. **Nokuthula Chamsile Shongwe.** 2010. Lipid content, fatty acid composition and oil quality of South African cactus pear seeds. (Cum laude) M.Sc. Agric. dissertation. UFS, Bloemfontein, SA
8. **Rothman, AMP**. 2011. Food quality of South African Cactus pear cultivars. M.Sc. Agric. dissertation. UFS, Bloemfontein, SA
9. **Du Toit, Alba**. 2012. Antioxidant content and potential of fresh and processed cladodes and fruit from different coloured cactus pear (*O. ficus-indica* and *O. robusta*) cultivars. (Cum laude) M.Sc. Agric. dissertation. UFS, Bloemfontein, SA

Ph.D. Studies at UFS re: Cactus pear

1. **Mashope, B.K.** 2007. Characterization of cactus pear germplasm in South Africa. PhD thesis, UFS, Bloemfontein, South Africa.

Patents registered

1. A Patent regarding the extraction of mucilage by means of microwave cooking was registered in 2011. PA 153178 PA (De Wit and Du Toit, May 2011).


I
THANK
YOU!
CACTUS PEAR!