UWI
ST. AUGUSTINE
CAMPUS

Pesticide Risk Reduction

Focus on Health Impacts & Alternatives

Professor Duraisamy Saravanakumar
Director, School for Graduate Studies and Research

THE UNIVERSITY OF THE WEST INDIES
ST AUGUSTINE

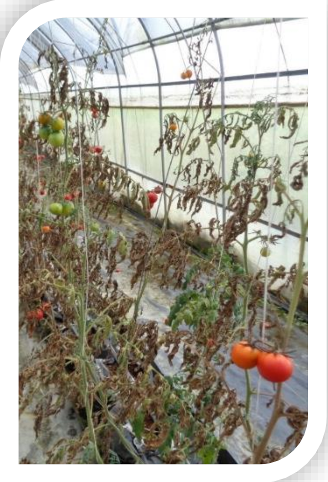
Pests & Diseases

Use of chemical Pesticides

HHPs

Trade impacts

Development of resistance



Impact of pesticides

Human Health

Food Safety

Environmental toxicity

How to reduce the risk of pesticides?

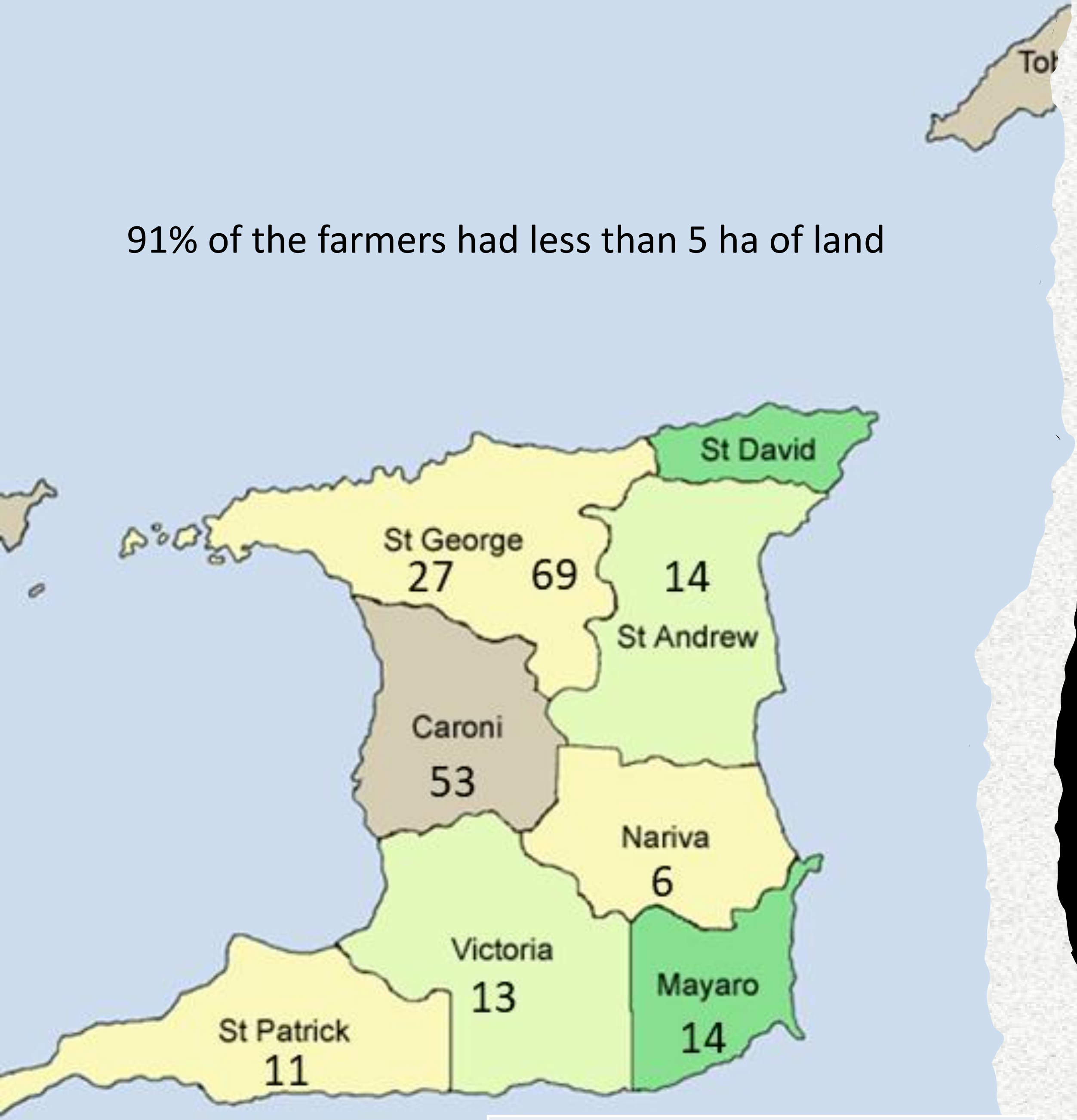
Is that simple?
Need evidence based data - Health, Food, Environment

- Replace the hazardous pesticides
- Reduce the use of pesticides

Ban Registration/De-registration

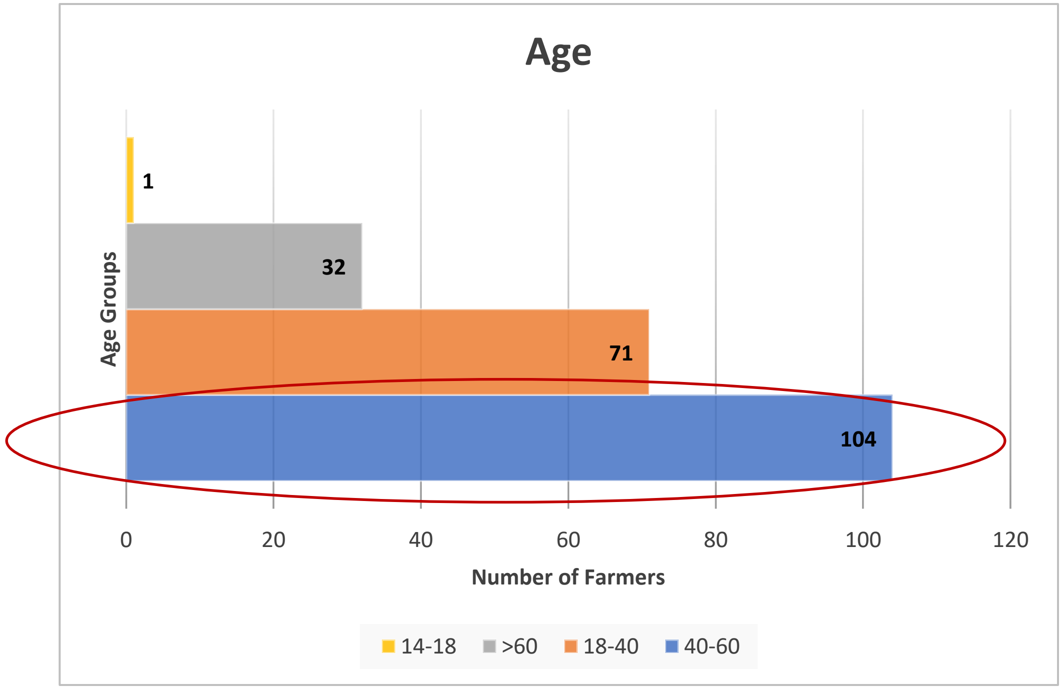
How to replace or reduce the risk of pesticides?

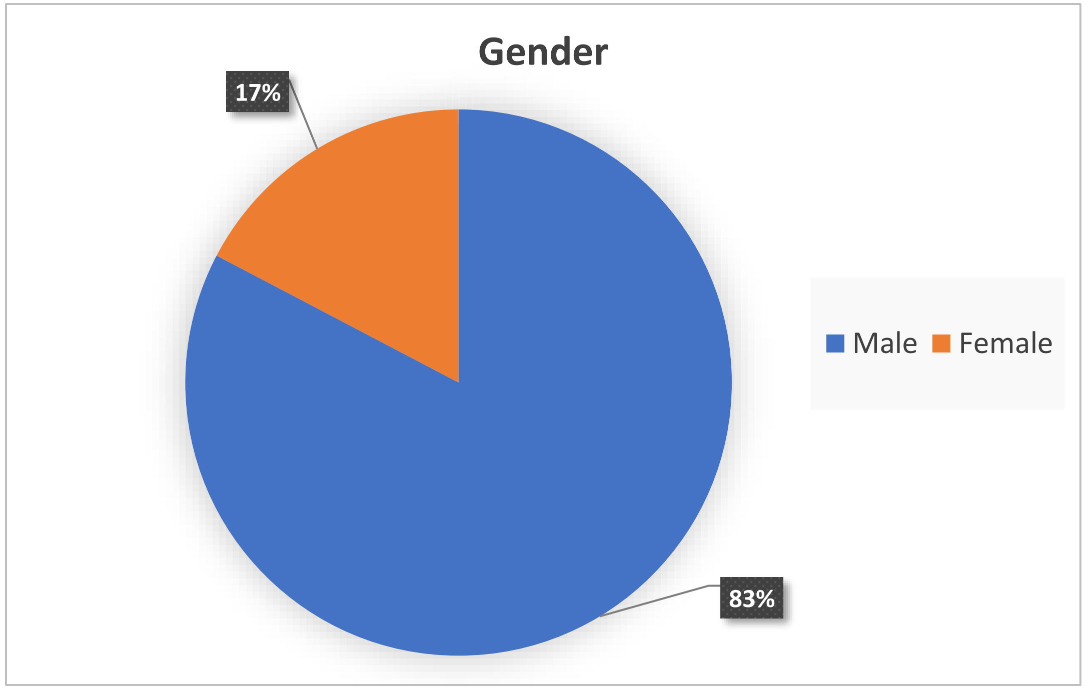
91% of the farmers had less than 5 ha of land



Adopted from: Jodhan, D.; Minter, D.W. (2006).

Age & Gender – 208 Farmers

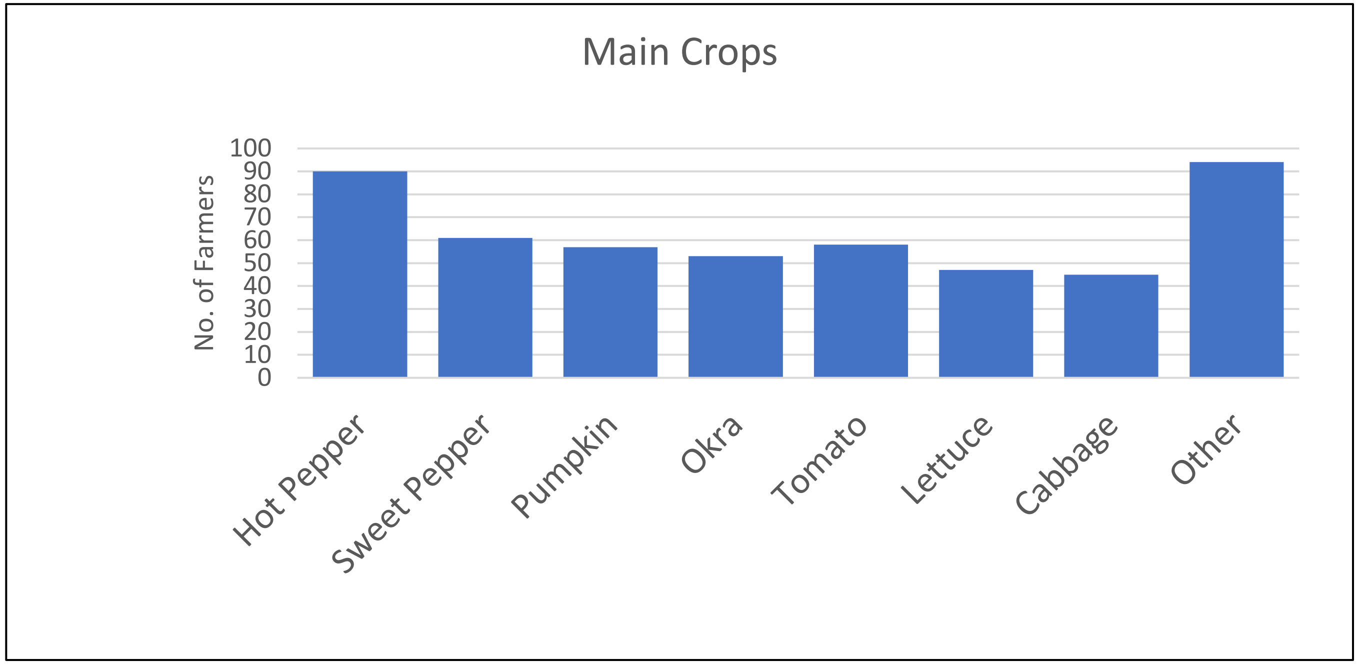


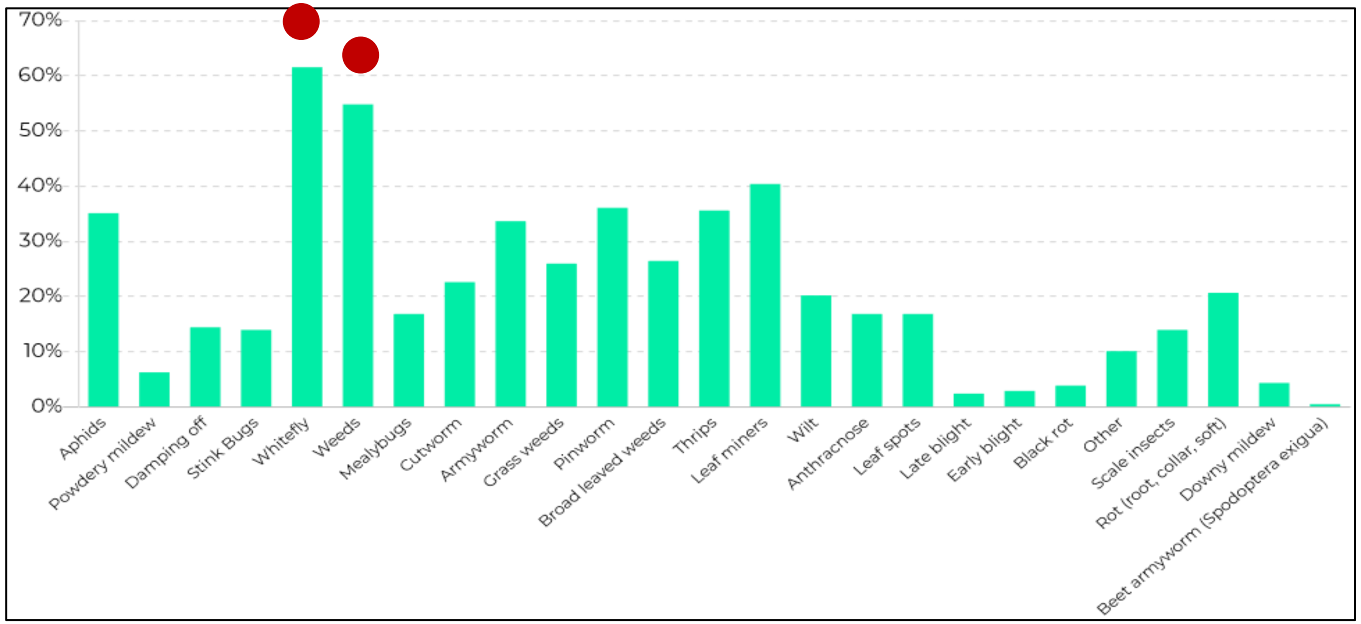


36 Female, 172 Male - 208 Farmers

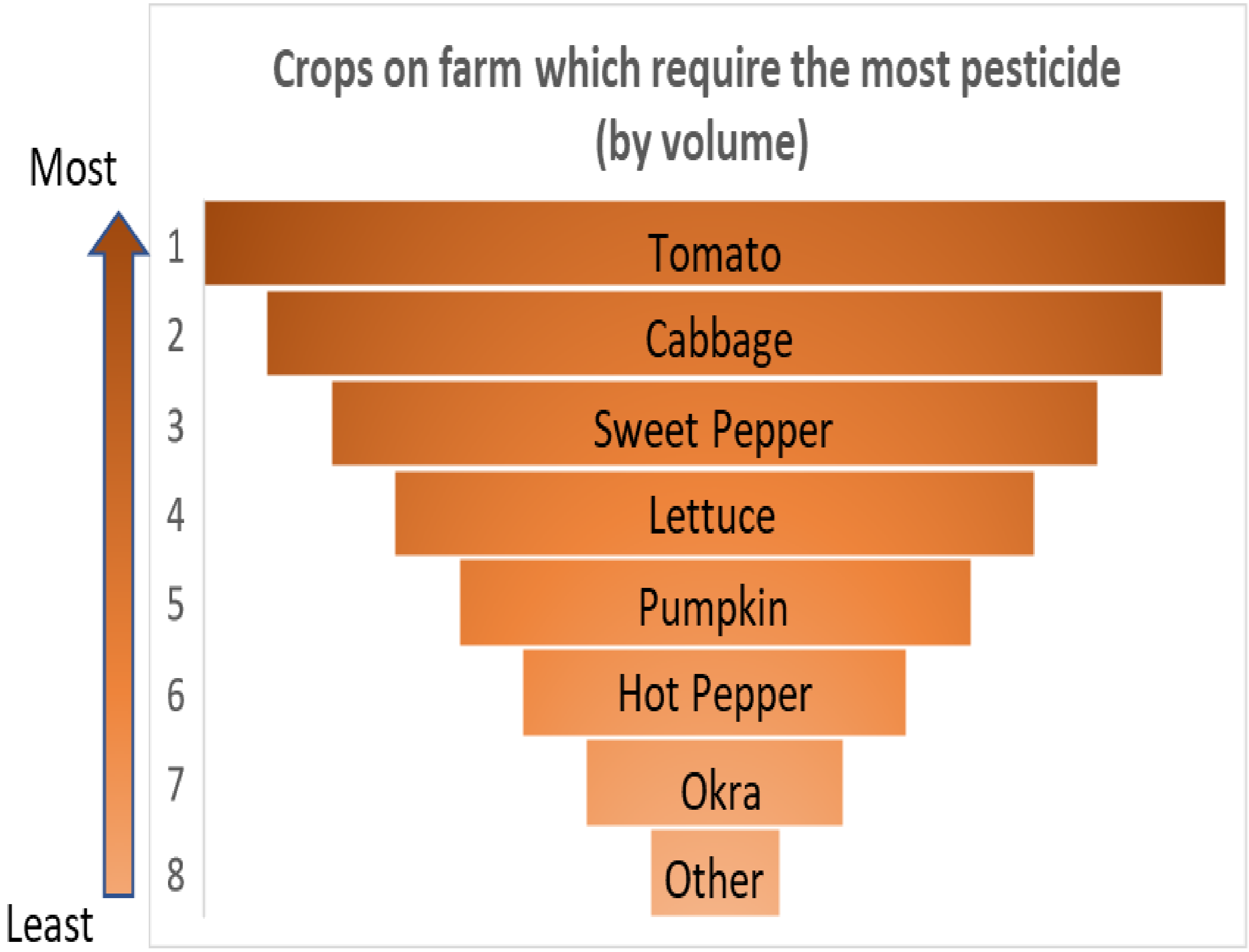
Main Crops Cultivated &

Pests require more pesticides

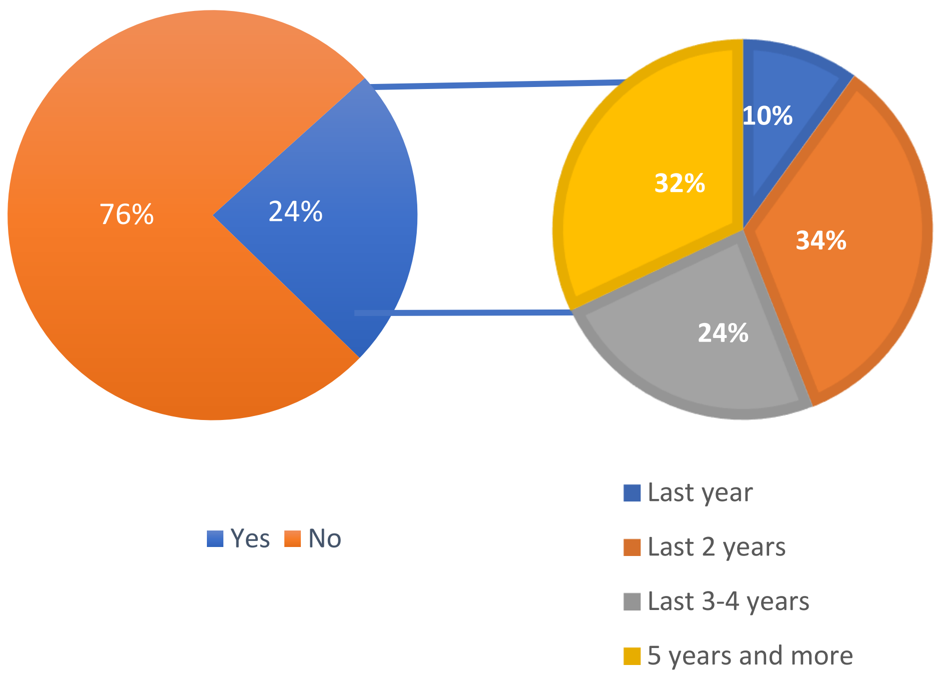


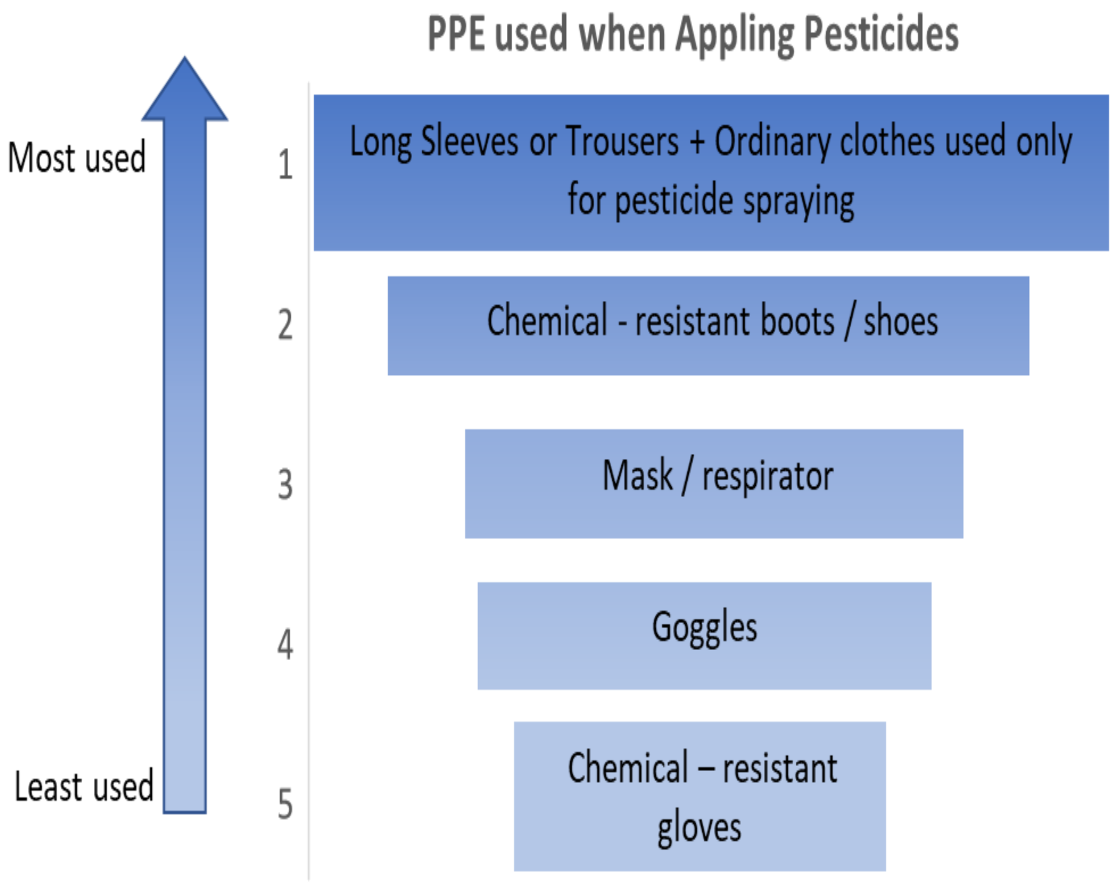


Crops require most pesticides

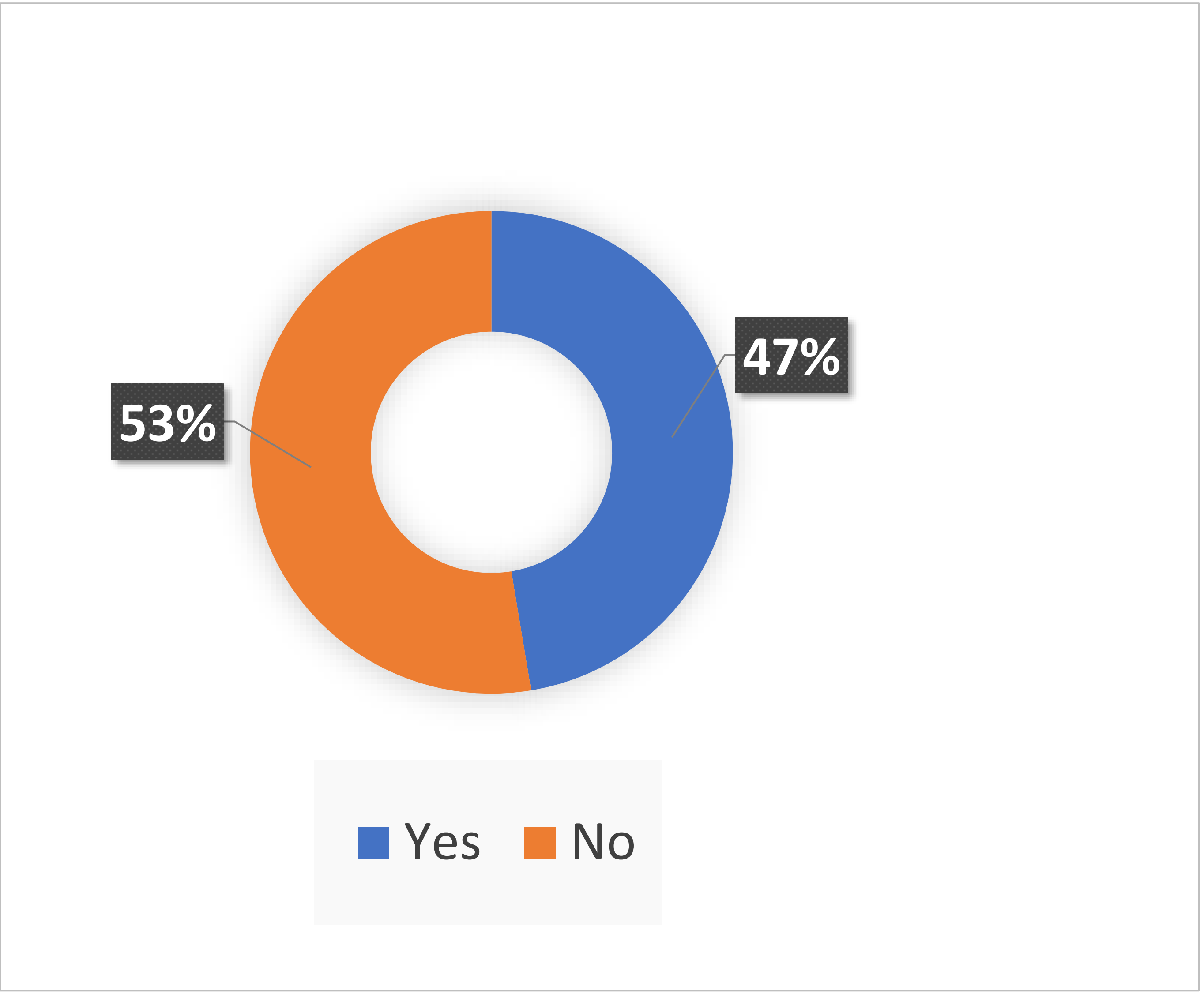


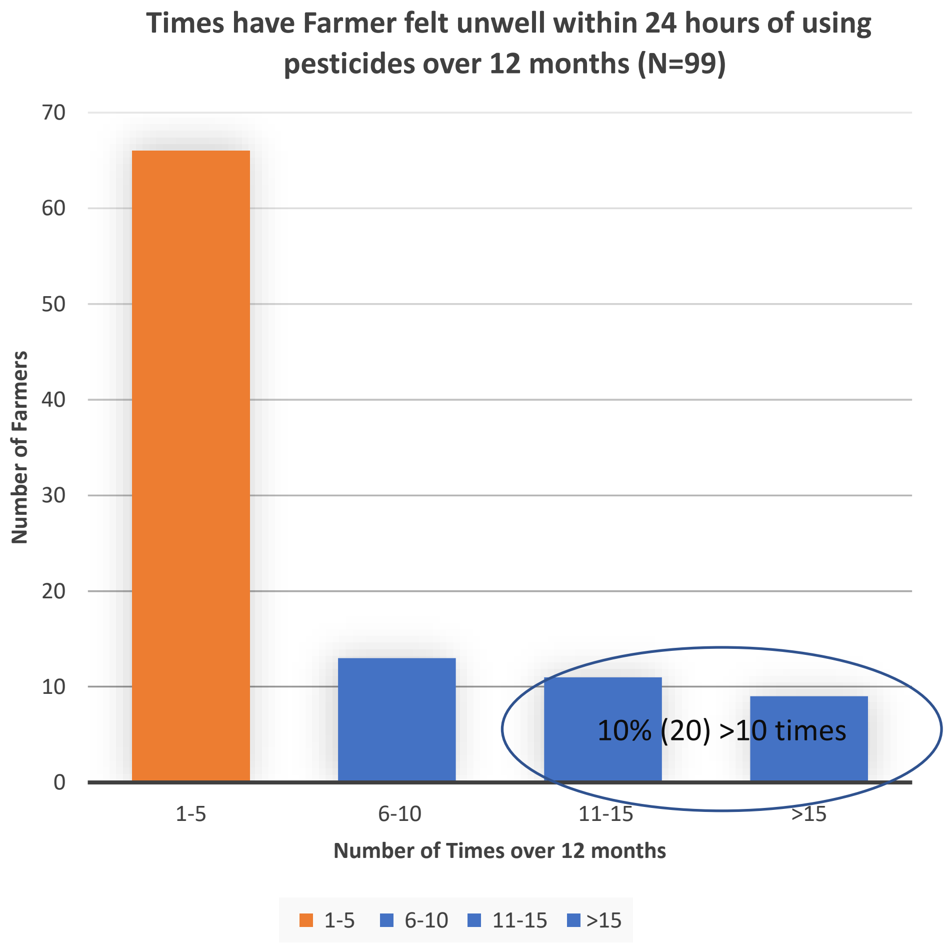
Farmers PPE training and type of PPE used



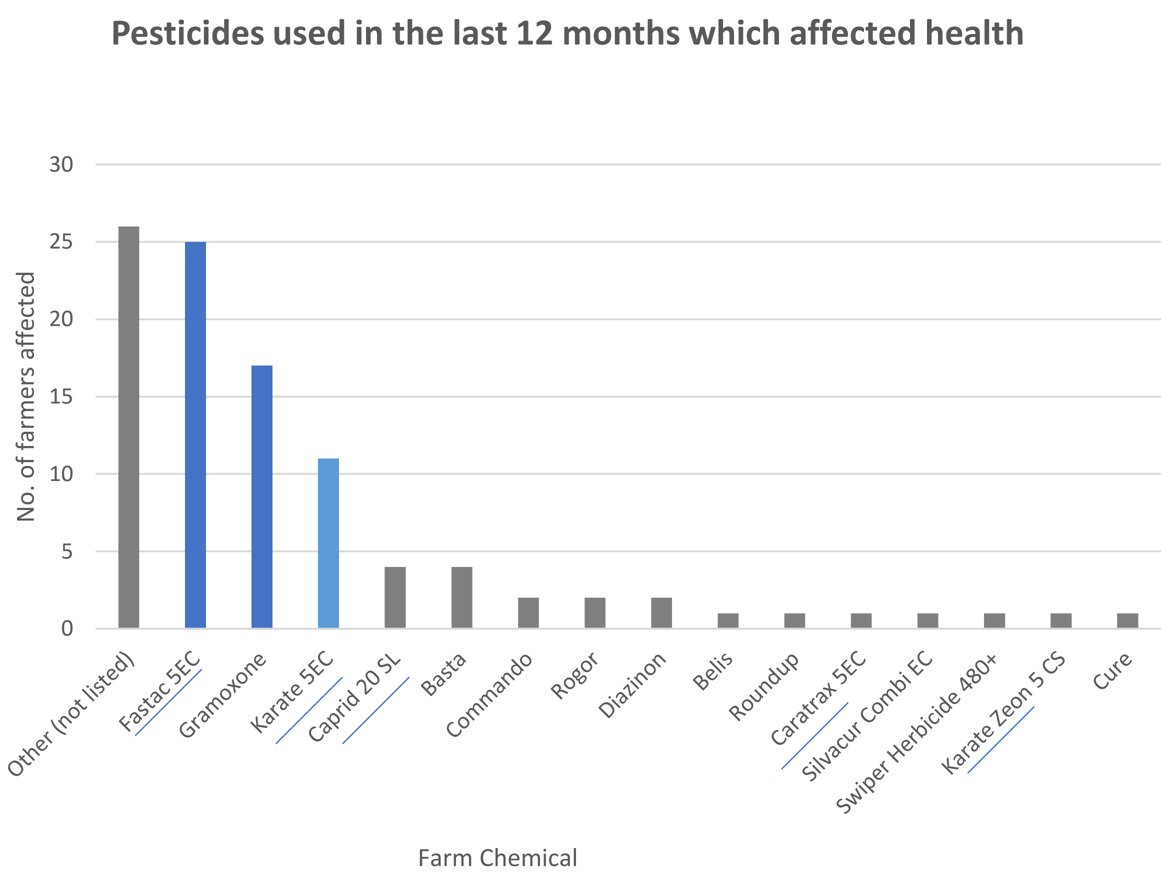


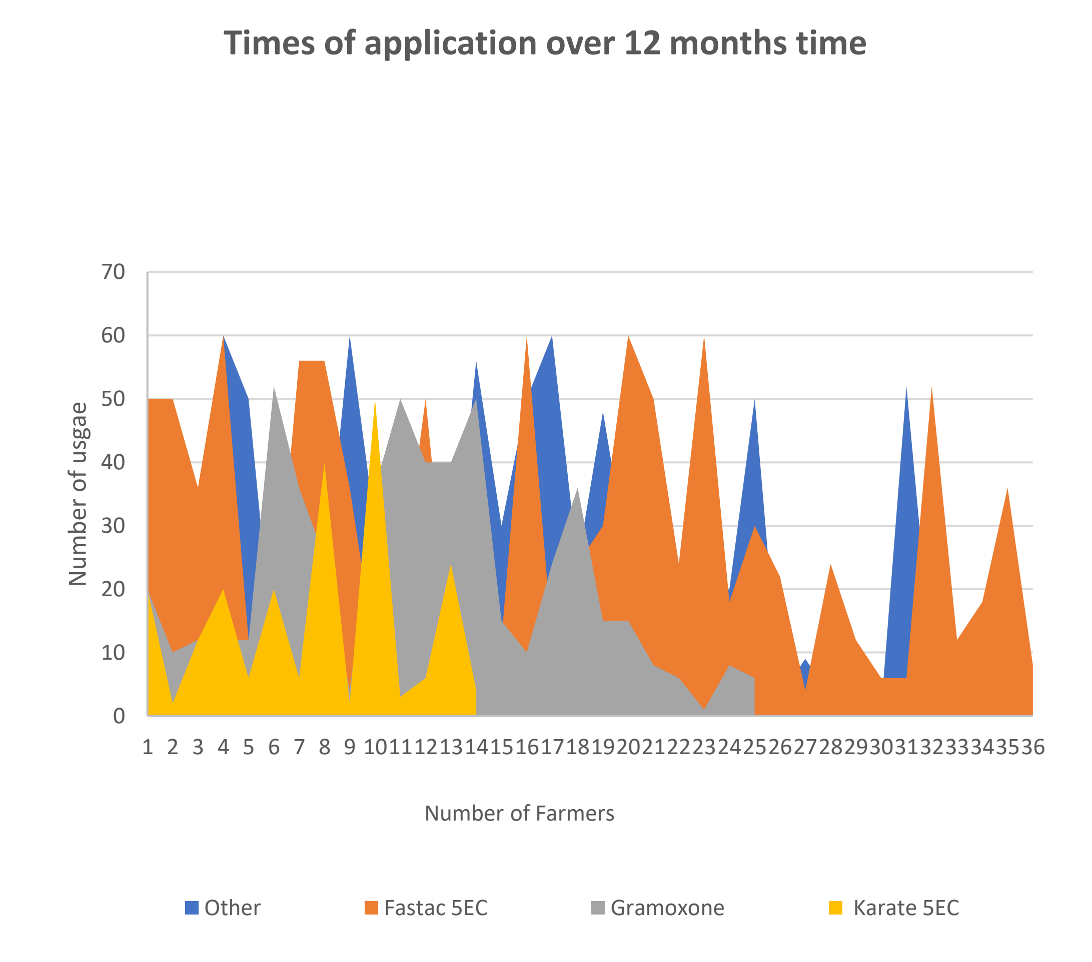
Farmers felt unwell over past 12 months within 24 hrs after application





Pesticides reported with health impact

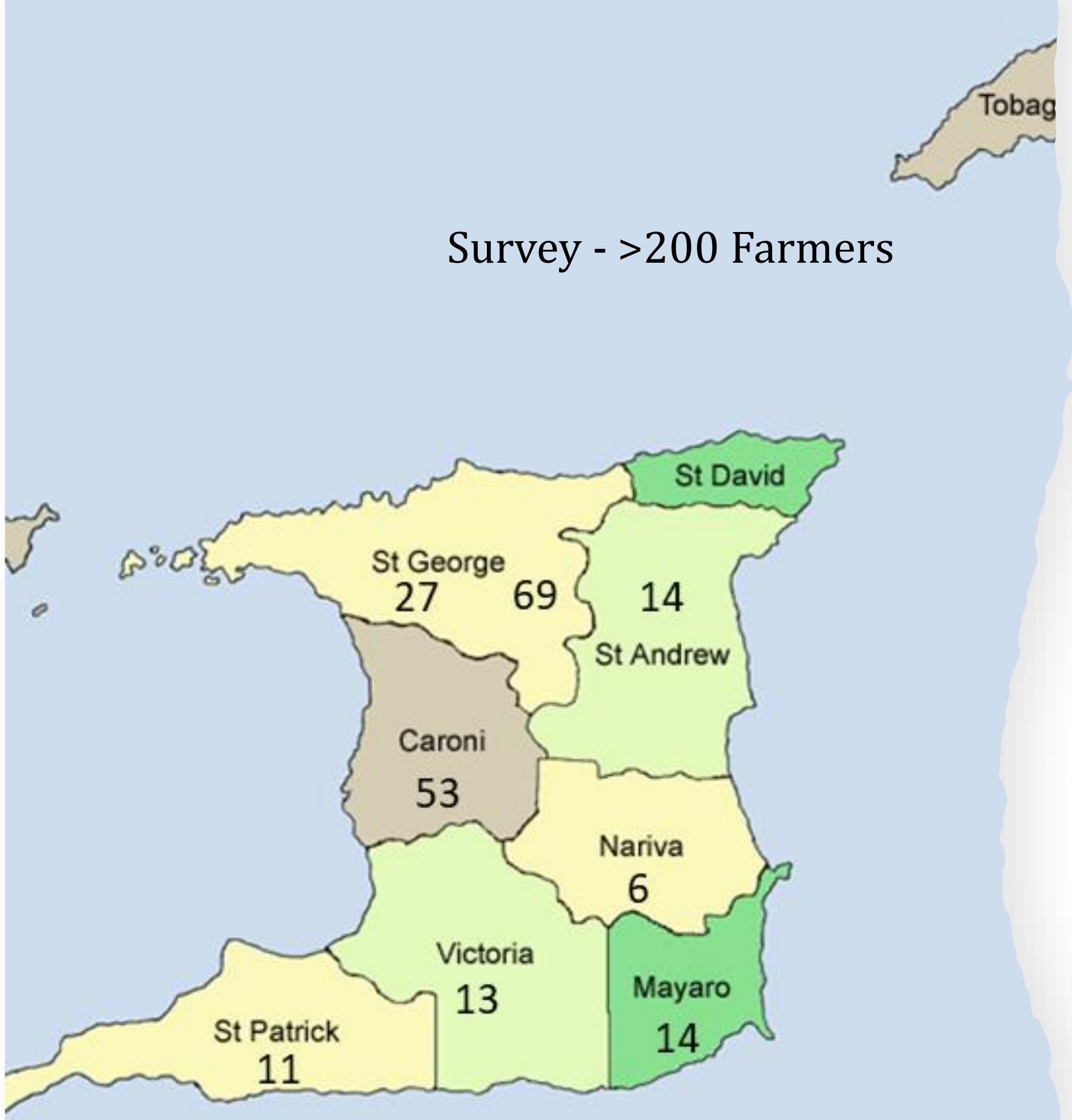




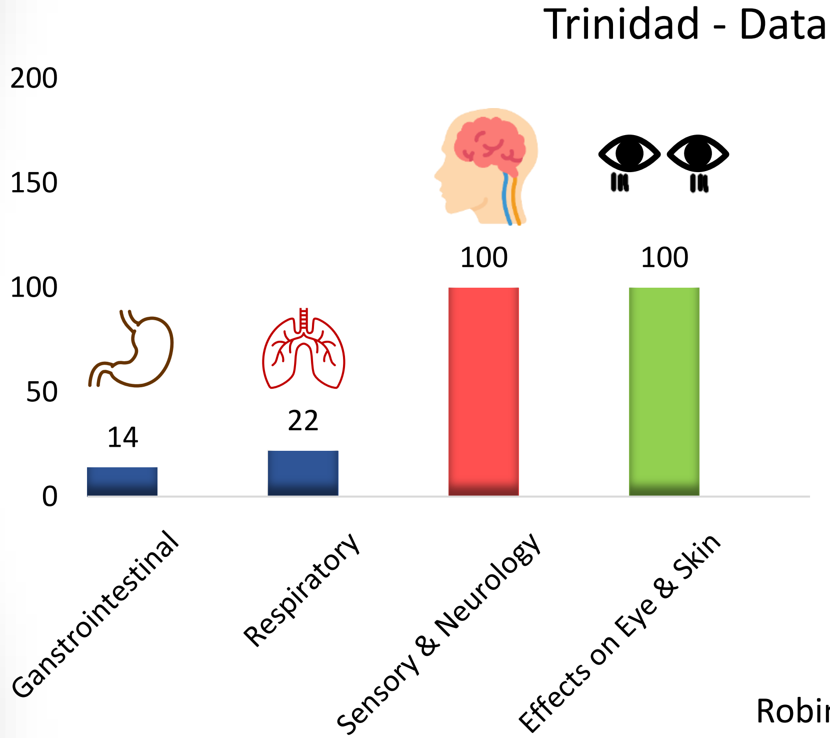
*Supertak (Alpha Cypermethrin), Agrinet (Methomyl), Ethrine-Plus (Ethion & Cypermethrin)

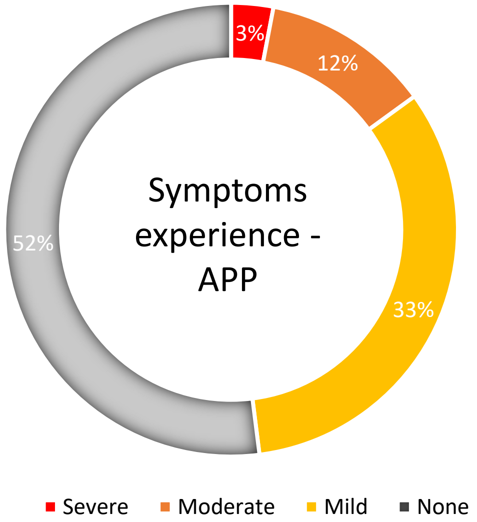
Symptoms associated with HHPs

Survey - >200 Farmers



Adopted from: Jodhan, D.; Minter, D.W. (2006).

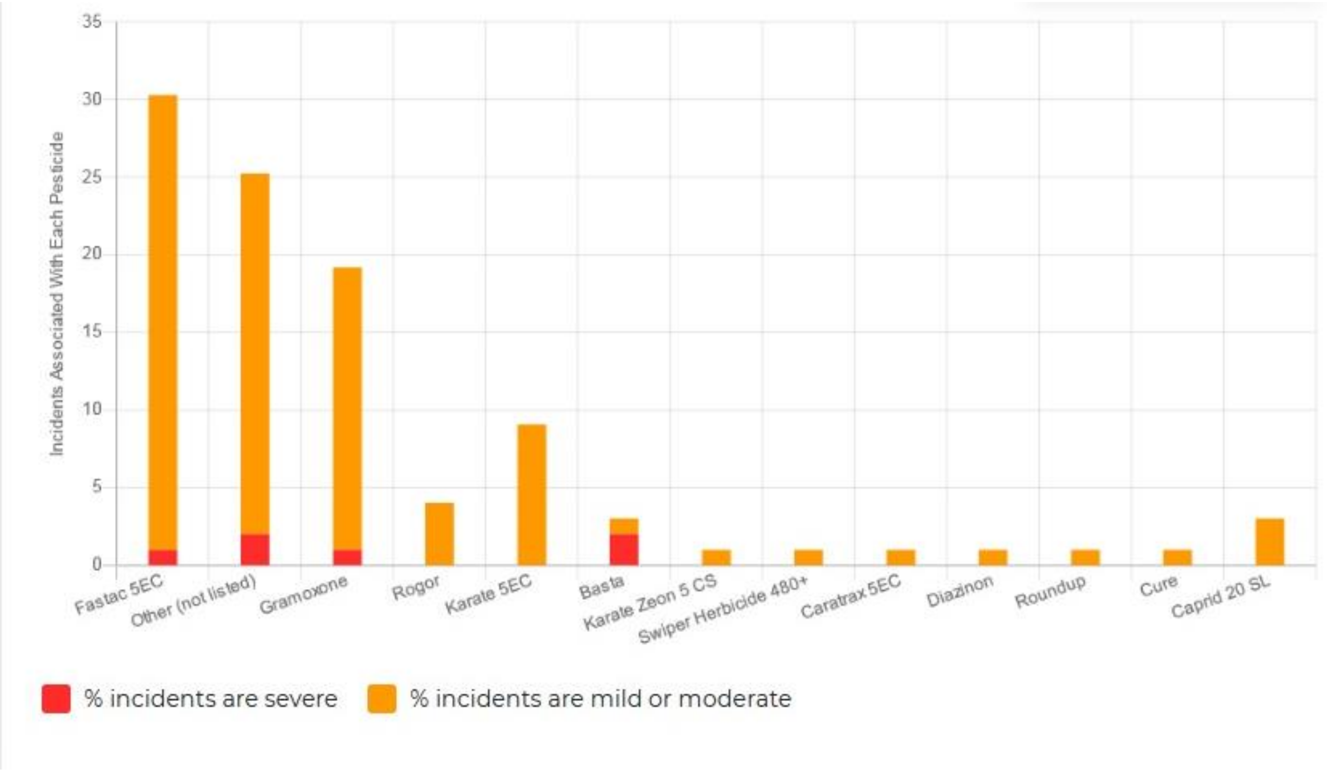




Robinson …..Saravanakumar et al., 2024

Percentage of people reporting signs & symptoms consistent with acute pesticide poisoning

Percent incidents associated with pesticides



Reports of pesticide incidents in Trinidad from the surveying of 208 participants

This report assisted the regulatory authorities to make decision to **DE-REGISTER** some of the HHPs!!!

How to reduce the risk of pesticides?

- Replace the hazardous pesticides
- Reduce the use of pesticides

Is that simple?
Need evidence based data - Health, Food, Environment

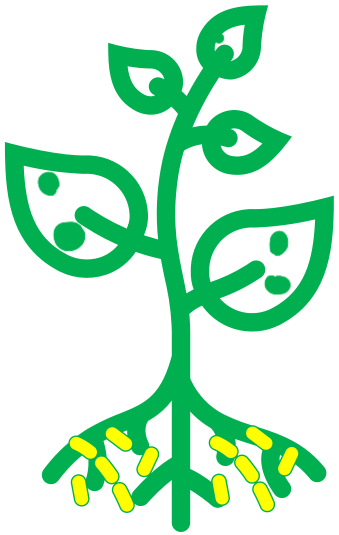
Ban Registration/De-registration

How to replace or reduce the risk of pesticides?

Alternatives
(i) Integrated management practices
- Cultural
- **Biologicals**
- **Crop Resistance (Genetic)**
- Low risk pesticides/mitigate risk

Biocontrol

- Use of microorganisms, genes or gene products in the management of plant diseases



Plant disease causing fungi

Plant Beneficial bacteria

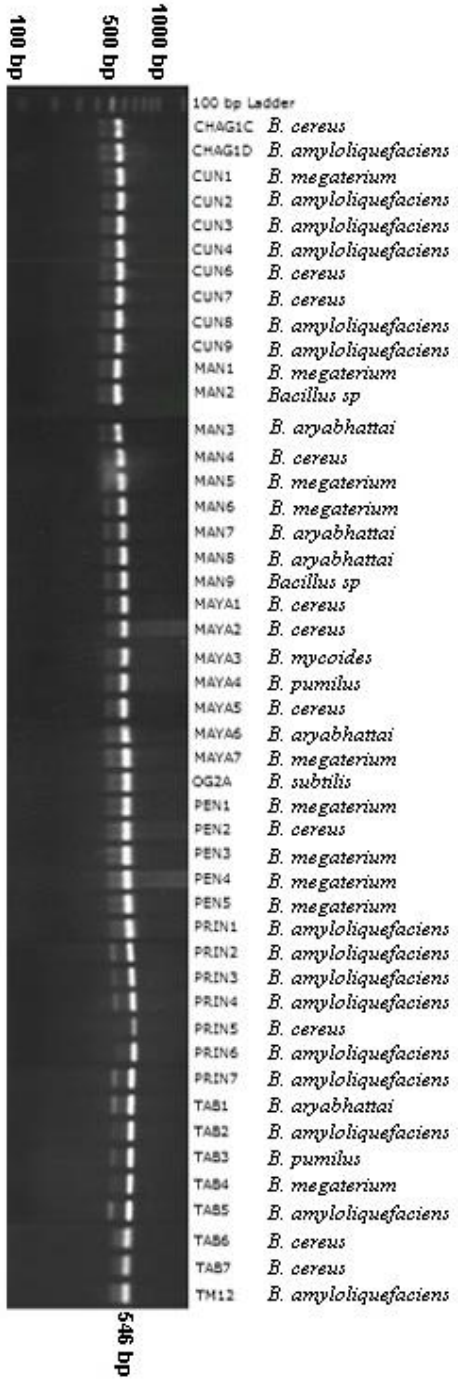
Vegetable disease control under tropical conditions

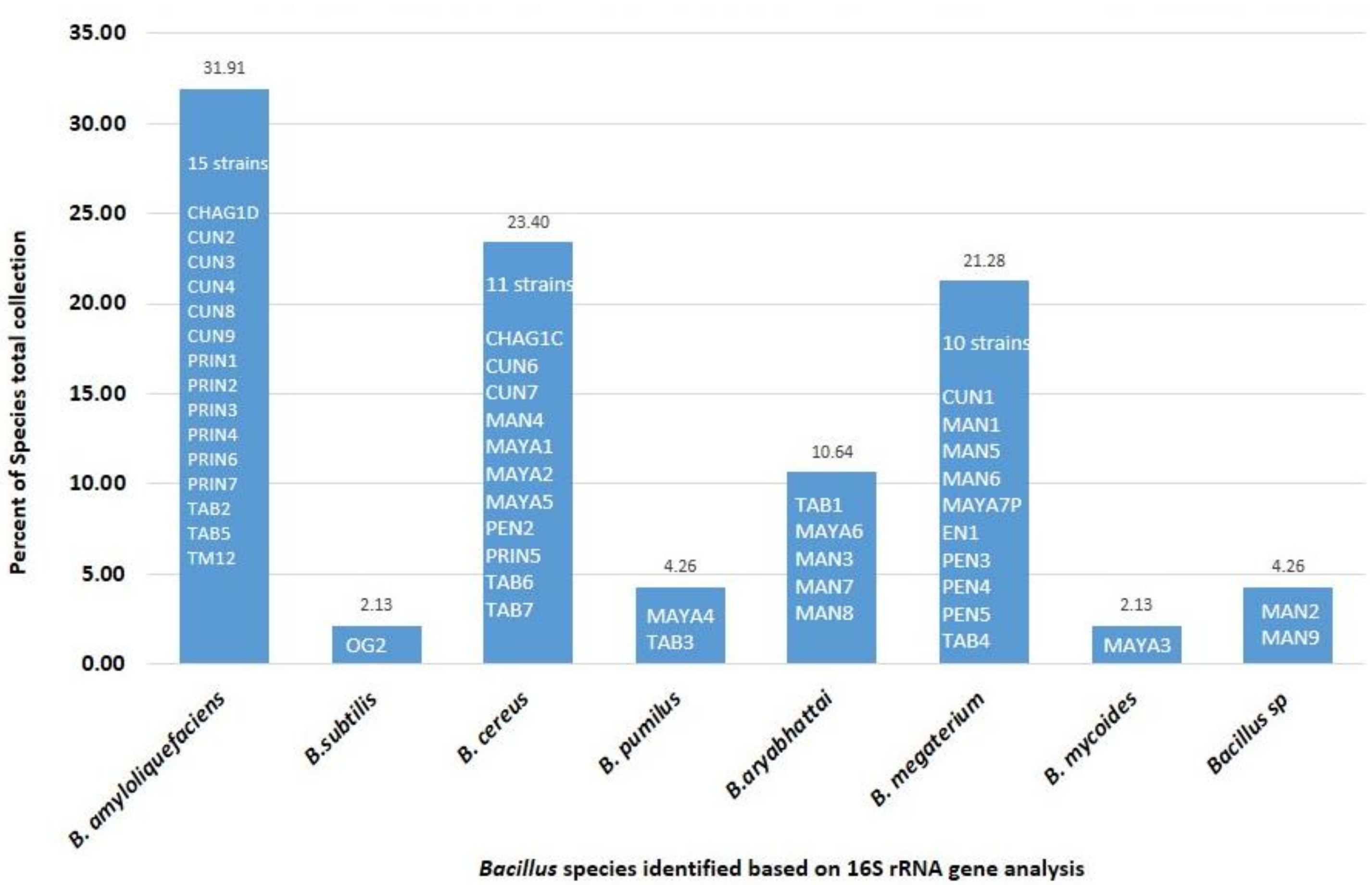
- Intensive collection of rhizosphere soil samples from various ecosystems of T&T with an intend of identifying beneficial microbes

- Isolation of fungal and bacterial cultures resulted in 200 isolates

- Based on morphology & biochemical characterization, a major group of organisms appeared Bacillus species

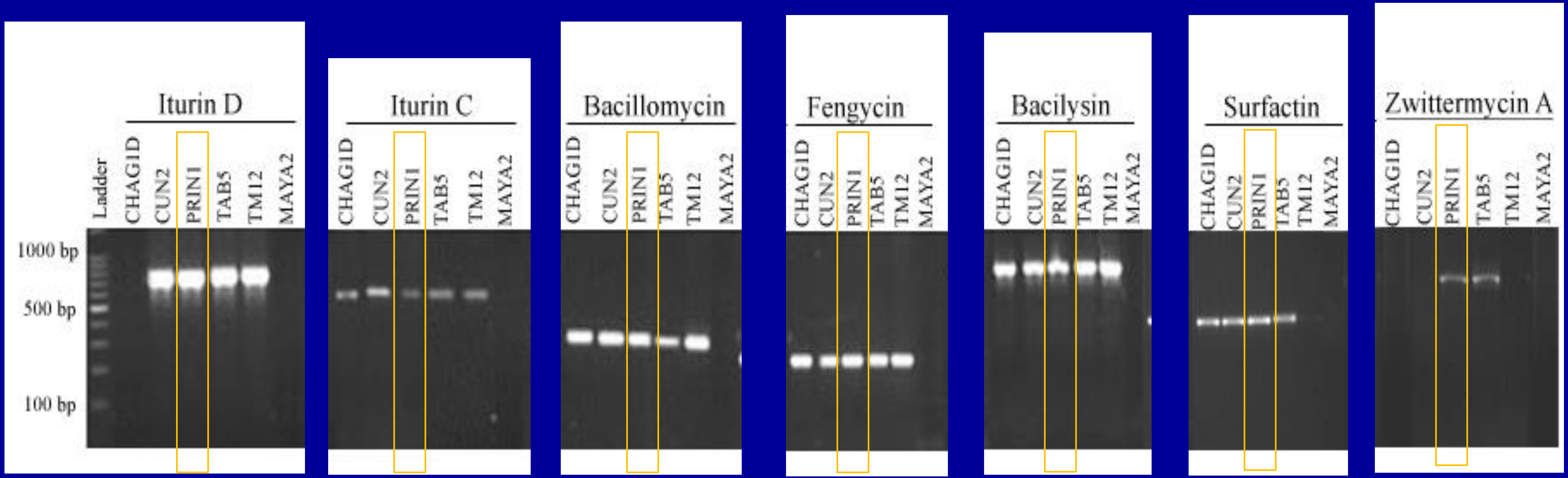
Identification of rhizosphere strains from rhizosphere soils of Trinidad based on 16S rRNA gene analysis





Saravanakumar, D., Thomas, A., Banwarie, N. 2019 EJPP

Detection of lipopeptide genes in *B. amyloliquefaciens*



Bacilysin (815 bp)
Iturin D (800 bp)
Zwittermycin (779 bp)
Iturin C (594 bp)
Surfactin (441 bp)
Bacillomycin D
Fengycin (220 bp)

Iturin A synthetase D (ituD)	***5'-CCCCTGTTCTAGATGATCGGAGGAATCTC-3'*** ***5'-TGCATCGATTCTGTCCATCTAACCGGCATC-3'***	**D: 95°C for 1 min** **A: 55°C for 1 min** **E: 72°C for 90S**

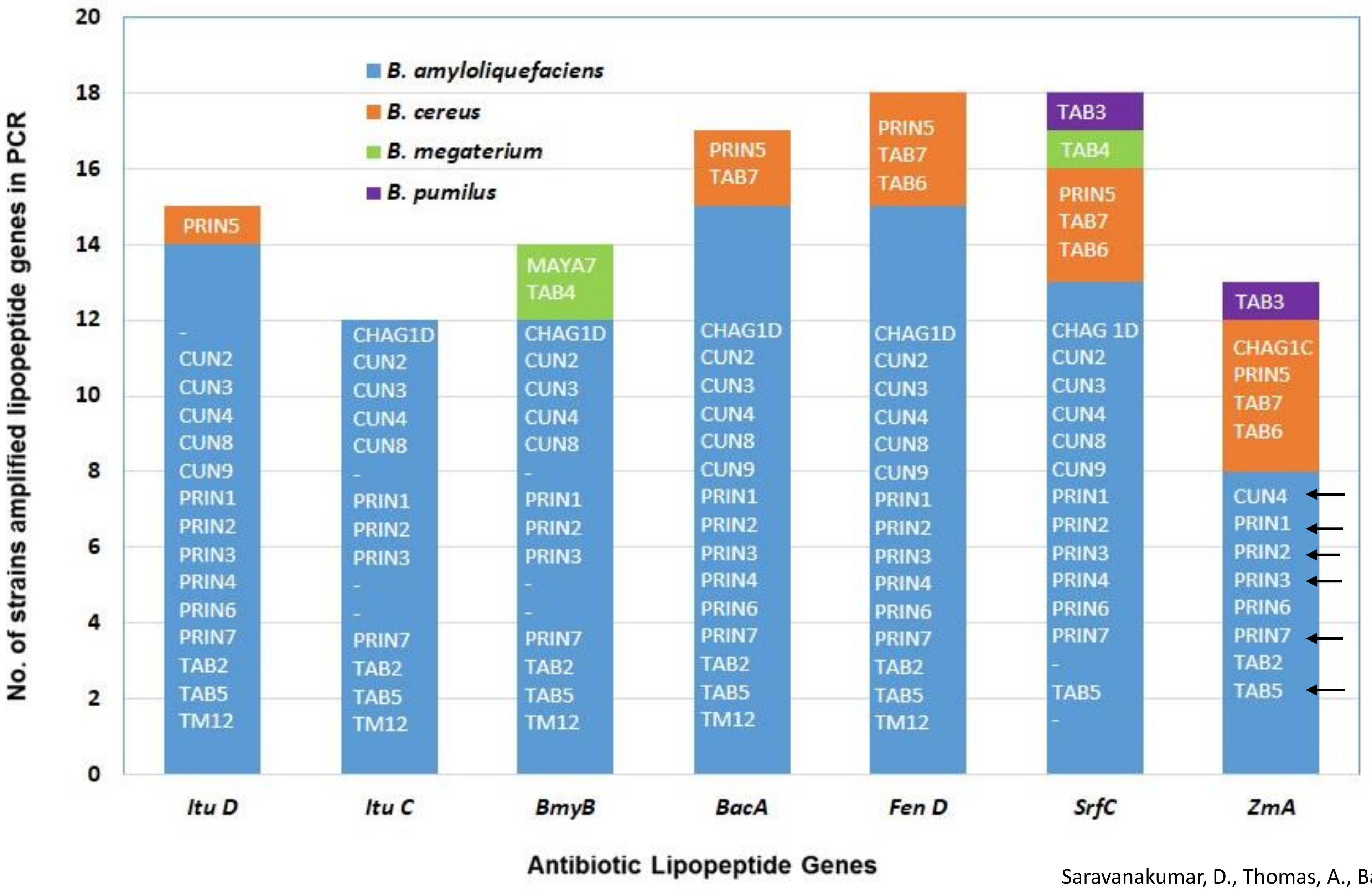
Iturin A synthetase C (ituC)	***5'-CCCCCTCGGTCAAGTGAATA-3'*** ***5'-TTGGTTAAGCCCTGATGCTC-3'***	**D: 94°C for 30 S** **A: 65°C for 45 S** **E: 72°C for 90 S**

Bacillomycin D Synthetase (BmyB)	***5'-TGAAACAAAGGCATATGCT-3'*** ***5'-AAAAATGCATCTGCCGTTCC-3'***	**D: 94°C for 1 min** **A: 58°C for 1 min** **E: 72°C for 1 min**

Fengycin synthetase (fenD)	***5'-CCTGCAGAAGGAGGAGAAGTGAAG-3'*** ***5'-TGCTCATCGTCTTCCGTTTC-3'***	**D: 94°C for 1 min** **A: 56°C for 1 min** **E: 72°C for 1 min**
Bacilysin synthetase A (bacA)	***5'-CTTCTCCAAGGGGTGAACAG-3'*** ***5'-TGTAGGTTTCACCGGCTTTC-3'***	**D: 94°C for 1 min** **A: 56°C for 1 min** **E: 72°C for 1 min**
Surfactin (SurC)	***5'-ACAGTATGGAGGCATGGTC-3'*** ***5'-TTCCGCCACTTTTTCAGTTT-3'***	**D: 95°C for 1 min** **A: 55°C for 1 min** **E: 72°C for 1 min**
Zwittermicin A (ZmA)	***5'-TTGGGAGAATATACAGCTCT-3'*** ***5'-GACCTTTTGAAATGGGCGTA-3'***	**D: 94°C for 1 min** **A: 57°C for 30S** **E: 72°C for 1 min**

Saravanakumar, D., Thomas, A., Banwarie, N. 2019 EJPP

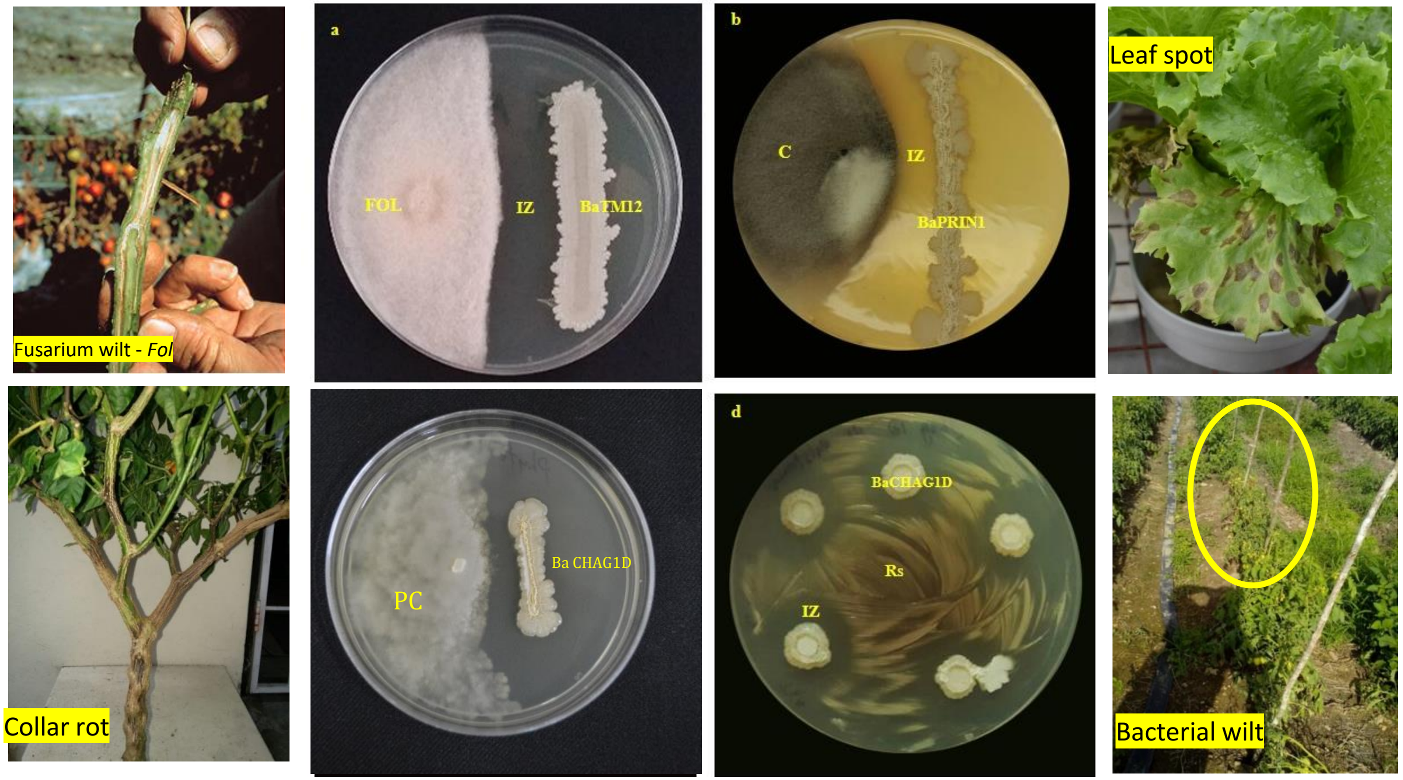
Bacillus strains showed positive to PCR amplification of antibiotic lipopeptide genes



Saravanakumar, D., Thomas, A., Banwarie, N. 2019 EJPP

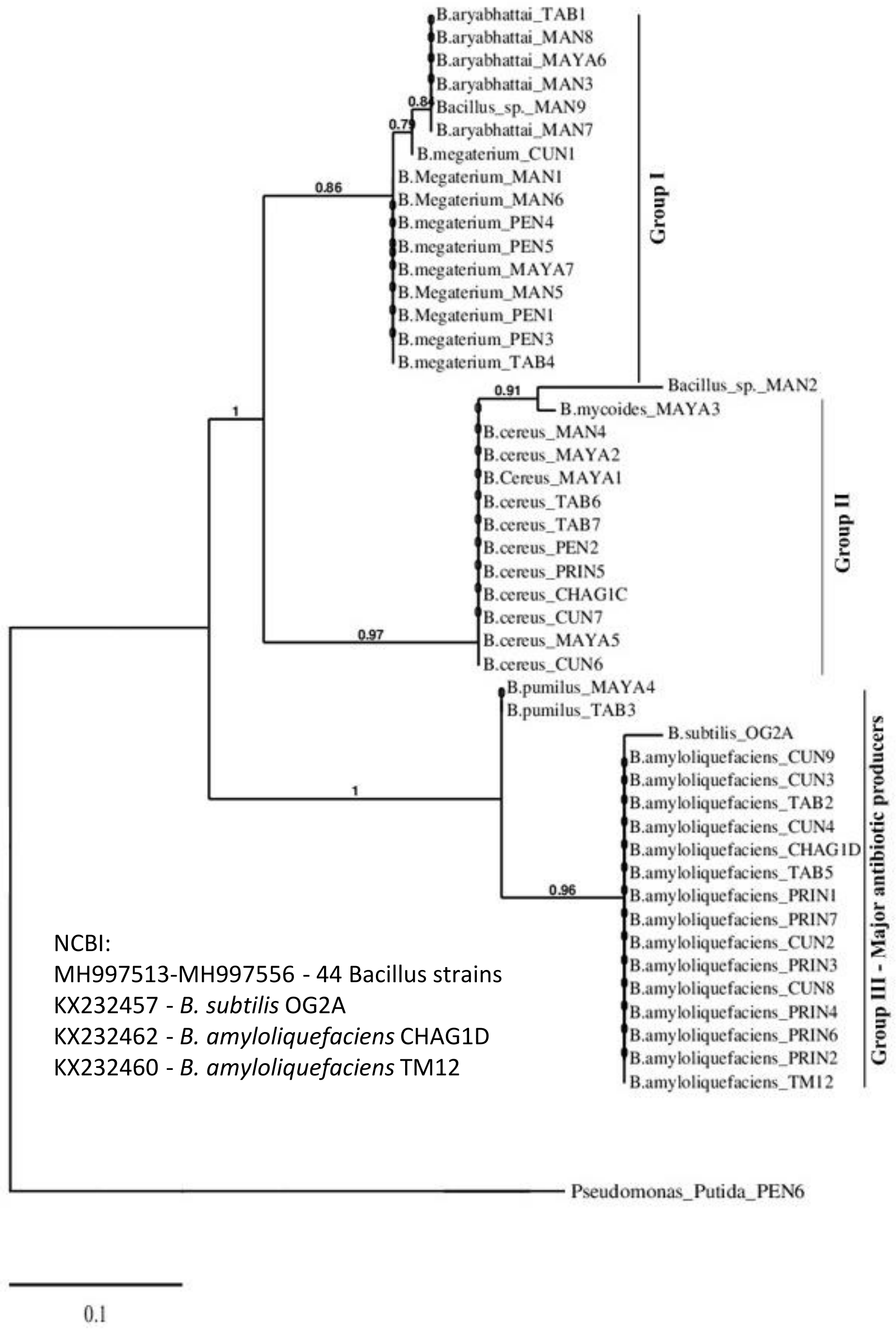
Strains	Percent mycelium inhibition of fungal pathogens				Inhibition against bacterial pathogen
	F. oxysporum f.sp. lycopersici	*C. gloesporioides*	*C. lactucae-sativae*	*A.Solani*	*R. solanacearum*
CHAG 1C	27.86^{d}	52.98^{e-l}	39.12^{j-p}	35.29^{ef}	++
CHAG 1D	52.86^{ef}	67.26^{j-l}	53.36^{pqr}	47.06^{gh}	++++
CUN 1	13.57^{abcd}	29.76^{a-h}	6.16^{ab}	17.65^{bc}	+
CUN 2	49.29^{ef}	59.52^{f-l}	52.23^{pqr}	52.94^{hi}	++++
CUN 3	52.86^{ef}	59.52^{f-l}	51.29^{o-r}	58.82^{ij}	++++
CUN 4	50.25^{ef}	63.69^{g-l}	54.26^{opq}	58.82^{hi}	++++
CUN 6	20.71^{bcd}	25.60^{a-f}	30.33^{e-m}	11.76^{ab}	++++
CUN 7	45.71^{e}	10.71^{ab}	53.16^{pqr}	35.29^{ef}	-
CUN 8	52.86^{ef}	54.17^{e-l}	54.26^{pqr}	64.71^{j}	+++
CUN 9	52.86^{ef}	58.33^{f-l}	62.33^{rs}	47.06^{gh}	+++
MAN 1	6.43^{ab}	66.67^{j-l}	3.33^{a}	3.33^{a}	-
MAN 2	20.71^{bcd}	14.88^{abcd}	28.16^{d-k}	11.76^{ab}	-
MAN 3	13.57^{abcd}	12.50^{abc}	20.24^{b-h}	23.53^{cd}	++
MAN 4	45.71^{e}	51.79^{e-l}	16.16^{a-f}	23.53^{cd}	-
MAN 5	17.14^{abcd}	35.12^{a-k}	8.54^{abc}	11.76^{ab}	+
MAN 6	17.14^{abcd}	30.95^{a-i}	16.26^{a-f}	11.76^{ab}	+
MAN 7	10.00^{abc}	65.56^{i-l}	3.36^{a}	3.33^{a}	+
MAN 8	24.29^{cd}	12.50^{abc}	14.26^{a-e}	17.65^{bc}	+
MAN 9	17.14^{abcd}	1.19^{a}	12.44^{abcd}	23.53^{cd}	+
MAYA 1	6.43^{ab}	28.57^{a-g}	38.36^{i-p}	17.65^{bc}	+
MAYA 2	20.71^{bcd}	47.02^{c-l}	12.36^{abcd}	17.65^{bc}	-
MAYA 3	2.86^{a}	13.69^{abc}	23.14^{c-j}	5.88^{a}	+
MAYA 4	45.71^{e}	32.74^{a-j}	43.12^{k-q}	23.53^{cd}	++++
MAYA 5	20.71^{bcd}	44.05^{b-l}	20.24^{b-h}	17.65^{bc}	-
MAYA 6	24.29^{cd}	35.71^{a-k}	29.36^{e-l}	11.76^{ab}	++
MAYA 7	10.00^{abc}	33.33^{a-j}	38.33^{i-p}	23.53^{cd}	++
OG2A	52.86^{ef}	49.40^{d-l}	53.24^{pqr}	52.94^{hi}	++++
PEN 1	10.00^{abc}	45.24^{b-l}	18.33^{a-g}	5.88^{a}	-
PEN 2	17.55^{abcd}	19.64^{a-e}	45.16^{l-q}	25.36^{cde}	++
PEN 3	10.00^{abc}	66.07^{i-l}	22.24^{b-i}	17.65^{bc}	+
PEN 4	6.43^{ab}	45.83^{b-l}	31.44^{f-n}	17.65^{bc}	++
PEN 5	5.59^{ab}	42.86^{b-l}	12.23^{abcd}	11.76^{ab}	+
PRIN 1	52.86^{ef}	66.07^{i-l}	74.26^{st}	47.06^{gh}	+
PRIN 2	52.86^{ef}	58.93^{f-l}	51.22^{m-q}	47.06^{gh}	++++
PRIN 3	52.86^{ef}	55.95^{f-l}	53.44^{pqr}	52.94^{hi}	++
PRIN 4	52.86^{ef}	62.50^{g-l}	74.26^{r}	41.18^{fg}	++++
PRIN 5	24.29^{cd}	54.76^{e-l}	34.21^{g-n}	41.18^{fg}	++
PRIN 6	50.68^{ef}	69.64^{k-l}	53.22^{pqr}	67.12^{j}	+++
PRIN 7	51.68^{ef}	64.88^{h-l}	51.22^{m-q}	52.94^{hi}	++++
TAB 1	13.57^{abcd}	13.69^{abc}	42.16^{k-q}	17.65^{bc}	-
TAB 2	45.71^{e}	35.71^{a-k}	46.16^{m-r}	58.82^{ij}	++++
TAB 3	49.29^{ef}	49.41^{d-l}	51.22^{o-r}	66.47^{j}	++++
TAB 4	13.57^{abcd}	42.26^{b-l}	42.36^{k-q}	17.65^{bc}	-
TAB 5	51.48^{ef}	61.91^{g-l}	58.16^{qrs}	41.18^{fg}	++++
TAB 6	27.86^{d}	66.67^{j-l}	52.26^{pqr}	29.41^{de}	++
TAB 7	17.14^{abcd}	50.60^{e-l}	47.33^{n-r}	29.41^{de}	++
TM 12	52.96^{ef}	57.14^{f-l}	52.23^{pqr}	58.82^{ij}	++++

Testing pathogen suppressing activity of LP producing strains against vegetable pathogens



a TM12 against *Fusarium oxysporum* f.sp. *lycopersici* (Fol).
b PRIN1 against *Cercospora lattucae-sativae* (C).
c CHAG1D (Ba CHAG1D) against *Phytophthora capsici* (Pc).
d CHAG1D (Ba CHAG1D) against *Ralstonia solanacearum* (Rs).
IZ: Inhibition Zone

Saravanakumar, D., Thomas, A., Banwarie, N. 2019 EJPP



NCBI:
MH997513-MH997556 - 44 Bacillus strains
KX232457 - *B. subtilis* OG2A
KX232462 - *B. amyloliquefaciens* CHAG1D
KX232460 - *B. amyloliquefaciens* TM12

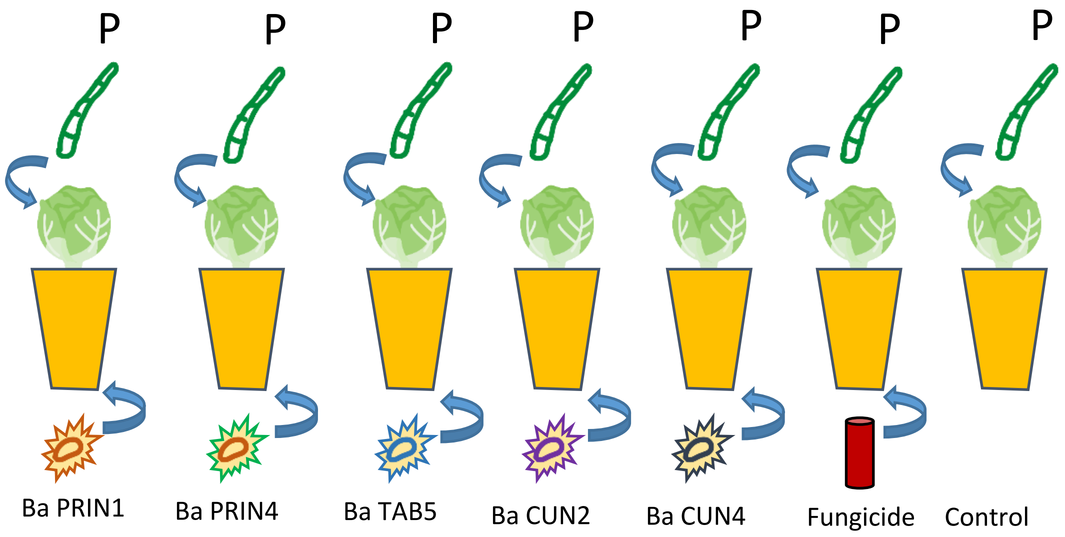
Phylogeny of *Bacillus* strains based on sequence analysis of 16S rRNA gene

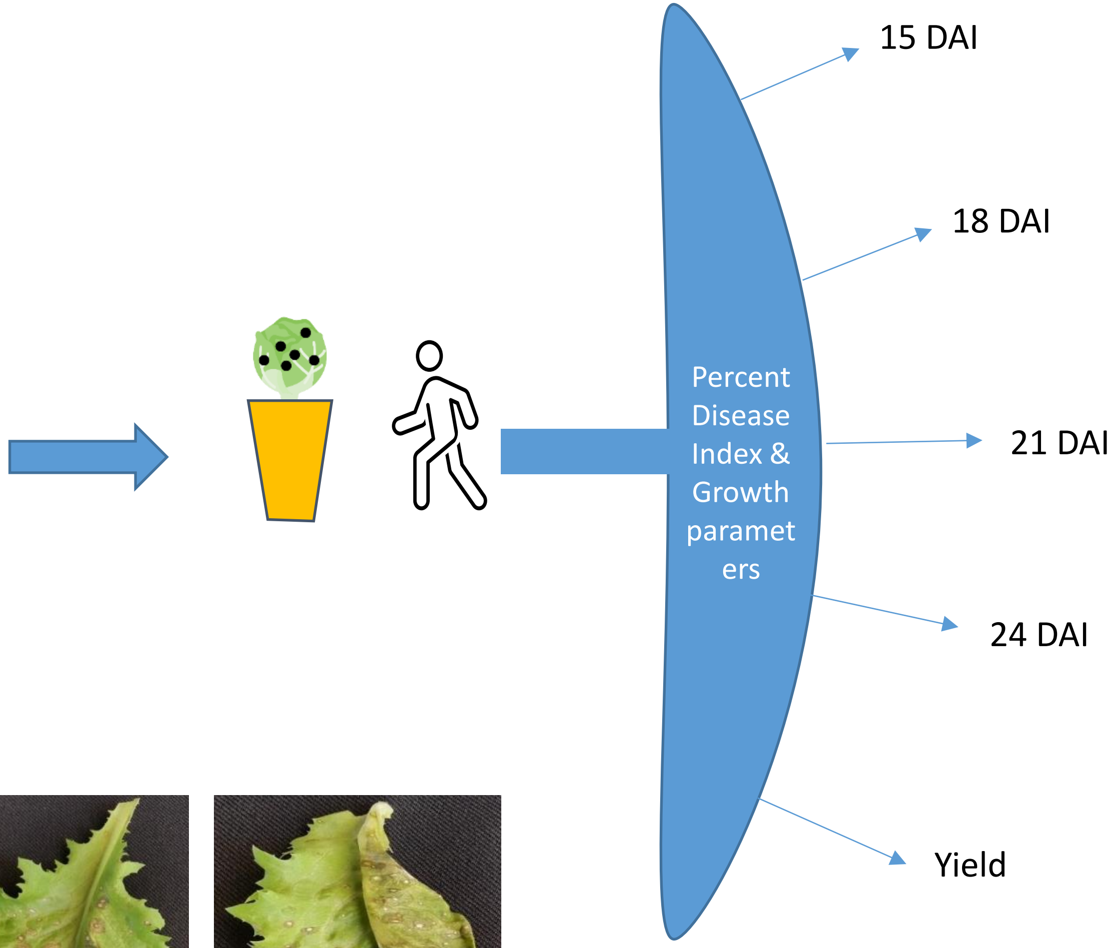
Clustering of antibiotic producers

Tested growth promoting activity of all *Bacillus* strains

Saravanakumar, D., Thomas, A., Banwarie, N. 2019 EJPP

Screening of *B. amyloliquefaciens* strains against *Cercospora* LS against artificial inoculation





Disease assessment for *Cercospora* leaf spot in lettuce

0: No leaf spot | 1: 1-10 % LA | 2: 11-20% LA | 3: 21-50% LA | 4: 51-80% LA | 5: >80% LA

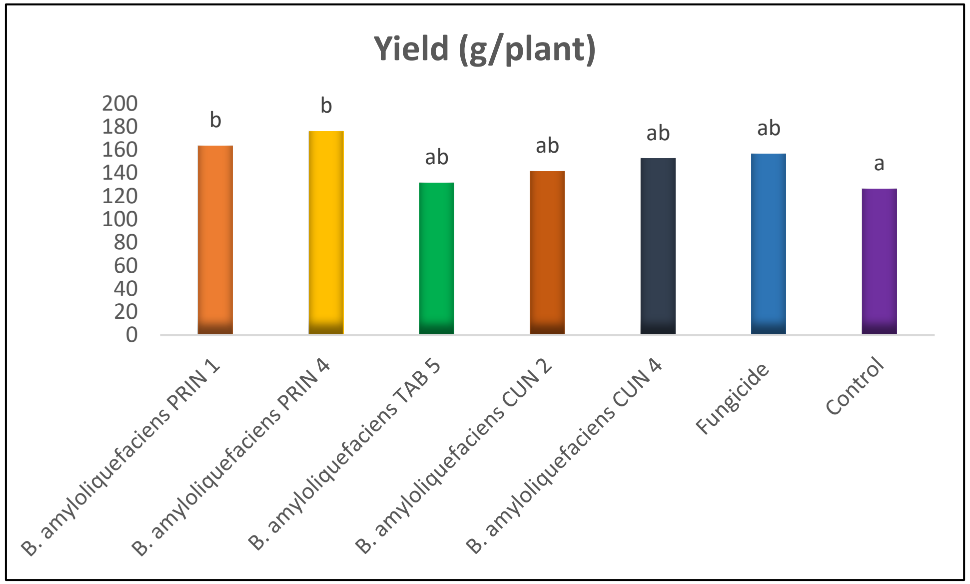
Saravanakumar, D., Thomas, A., Banwarie, N. 2019 EJPP

Treatment	No. of lesions /plant				Percent Disease Index			
	15 DAI	18 DAI	21 DAI	24 DAI	15 DAI	18 DAI	21 DAI	24 DAI
B. amyloliquefaciens PRIN 1	10.46^{a}	13.05^{a}	19.81^{a}	30.56^{a}	3.90^{a}	7.22^{ab}	11.67^{ab}	21.67^{b}
B. amyloliquefaciens PRIN 4	38.17^{a}	38.69^{a}	48.20^{a}	62.98^{a}	9.44^{a}	13.33^{b}	18.89^{b}	31.67^{b}
B. amyloliquefaciens TAB 5	33.26^{a}	51.59^{a}	60.93^{a}	93.10^{a}	7.22^{a}	11.67^{b}	22.22^{b}	42.22^{b}
B. amyloliquefaciens CUN 2	17.76^{a}	26.69^{a}	45.09^{a}	461.26^{b}	4.44^{a}	6.67^{ab}	14.44^{ab}	31.67^{b}
B. amyloliquefaciens CUN 4	29.02^{a}	50.21^{a}	79.91^{a}	106.60^{a}	10.56^{a}	12.22^{b}	22.22^{b}	38.89^{b}
Fungicide	0.00^{a}	0.00^{a}	0.00^{a}	0.00a	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}
Control	1075.14^{b}	978.81^{b}	1113.68^{b}	1060.74^{c}	47.78^{b}	66.11^{c}	77.78^{c}	91.11^{c}

Bacillus amyloliquefaciens strains against Cercospora leaf spot of lettuce under artificial inoculation settings

Control
Disease index - 91.11%
Lesions/plant - 1060.74

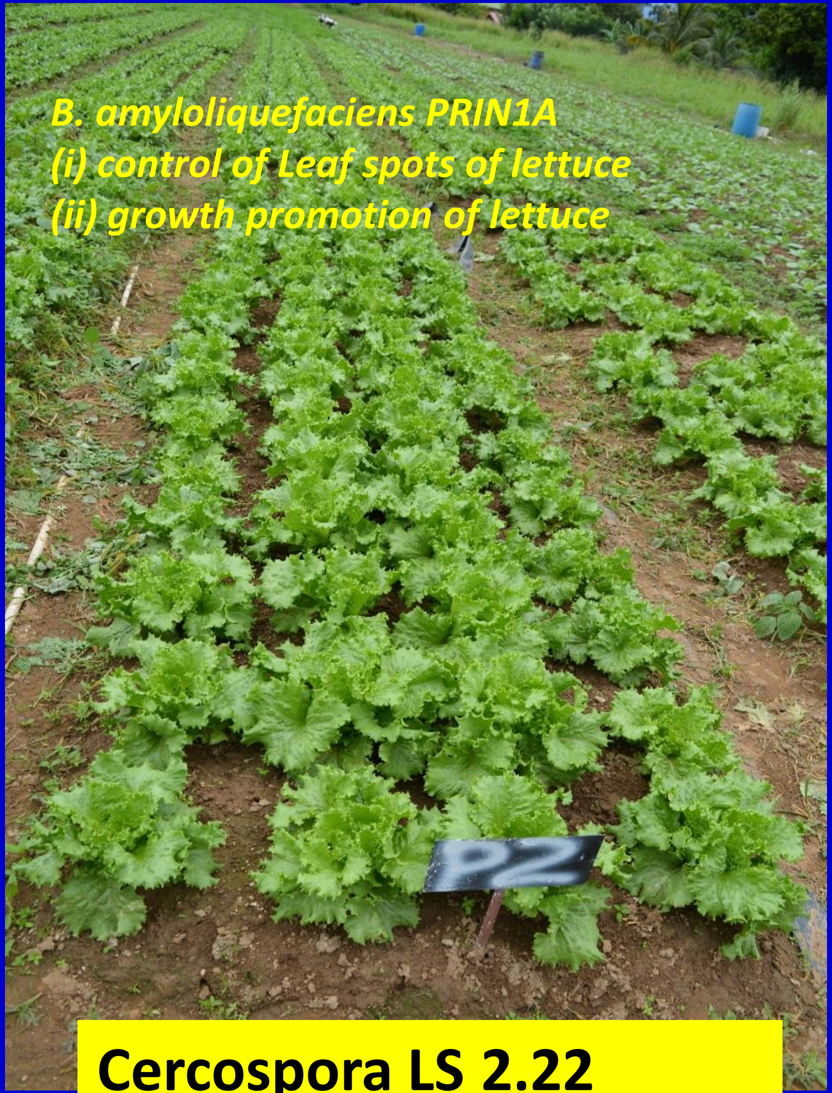
Ba PRIN1
Disease index - 21.67%
Lesions/plant - 30.56



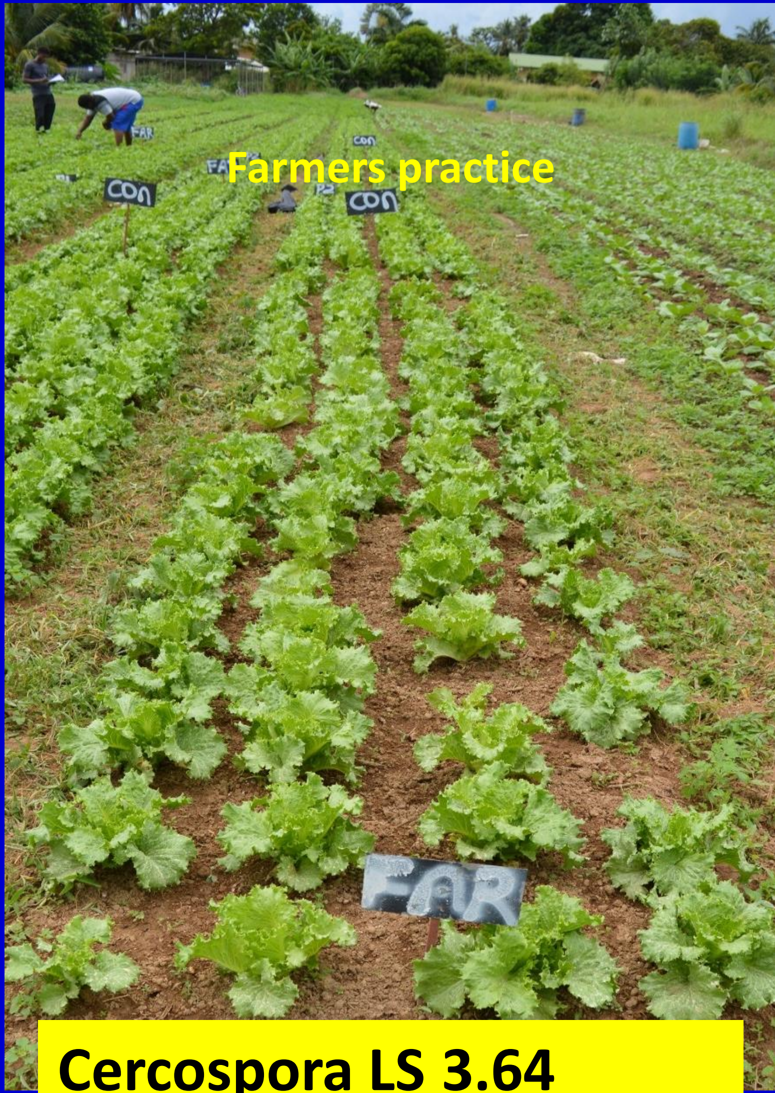
Saravanakumar, D., Thomas, A., Banwarie, N. 2019 EJPP

Field evaluation of *Ba* PRIN1A in lettuce

Cercospora LS	17.66
Bacteria LS	15.09
Yield (g)	201.49



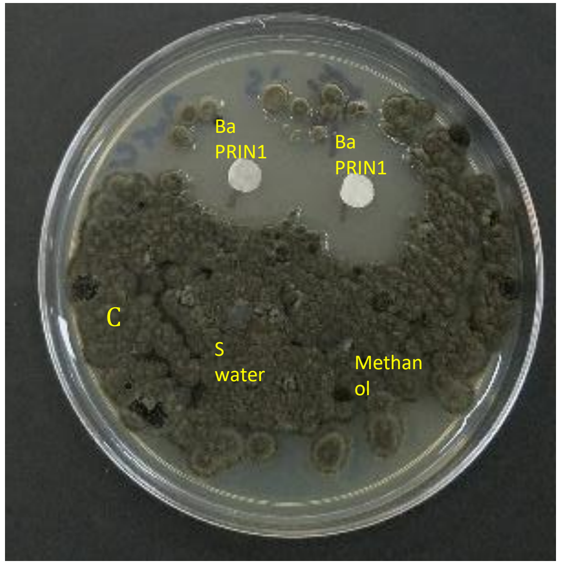
Cercospora LS	2.22
Bacteria LS	8.70
Yield (g)	281.87

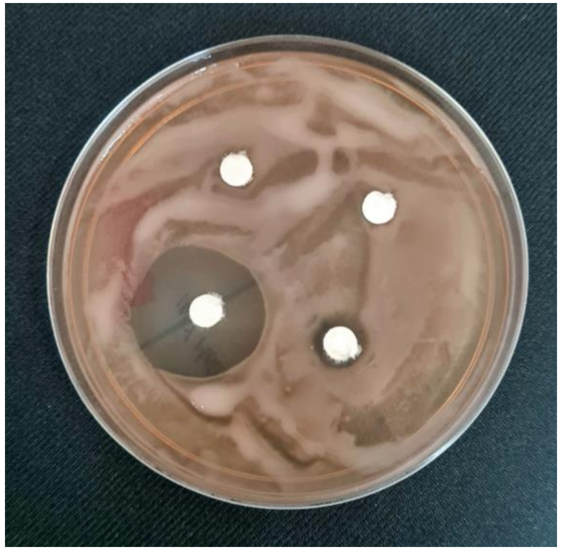


Cercospora LS	3.64
Bacteria LS	4.53
Yield (g)	247.64

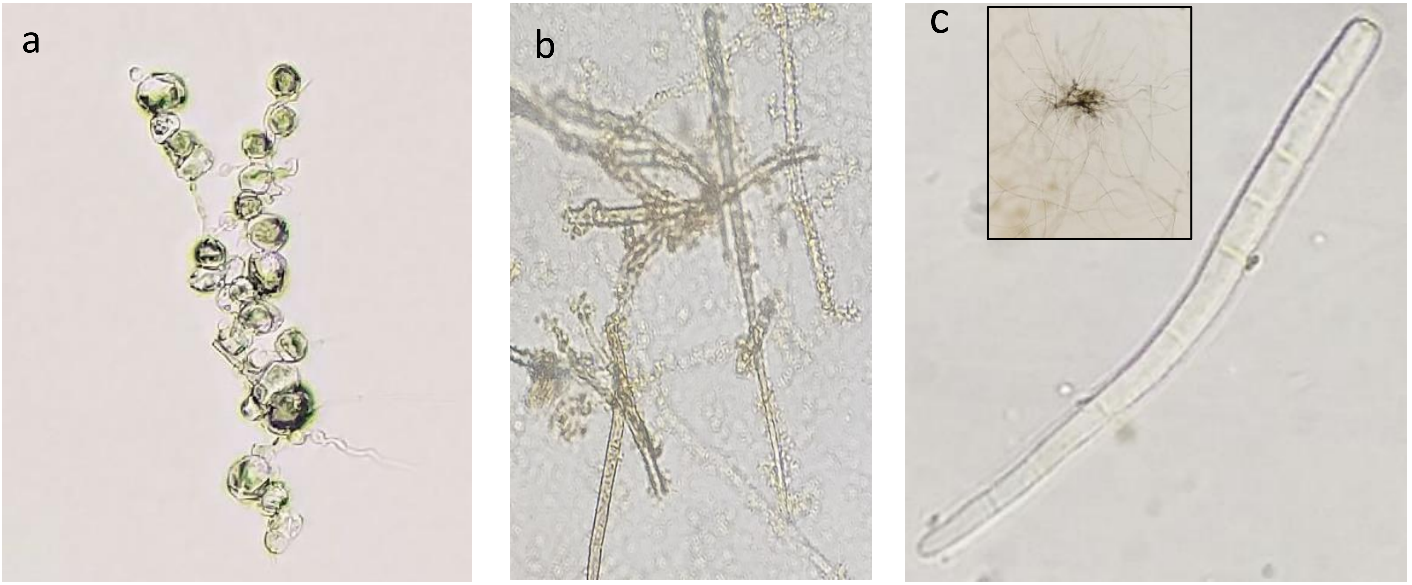
How does it suppress the pathogen?

Antifungal activity of lipopeptide extract of *Ba* PRIN1 against *C. lactucae-sativae & Bacterial pathogen*





Degeneration of conidial (a) and mycelial (b) structure due to the activity of lipopeptide extract of *Ba* PRIN1

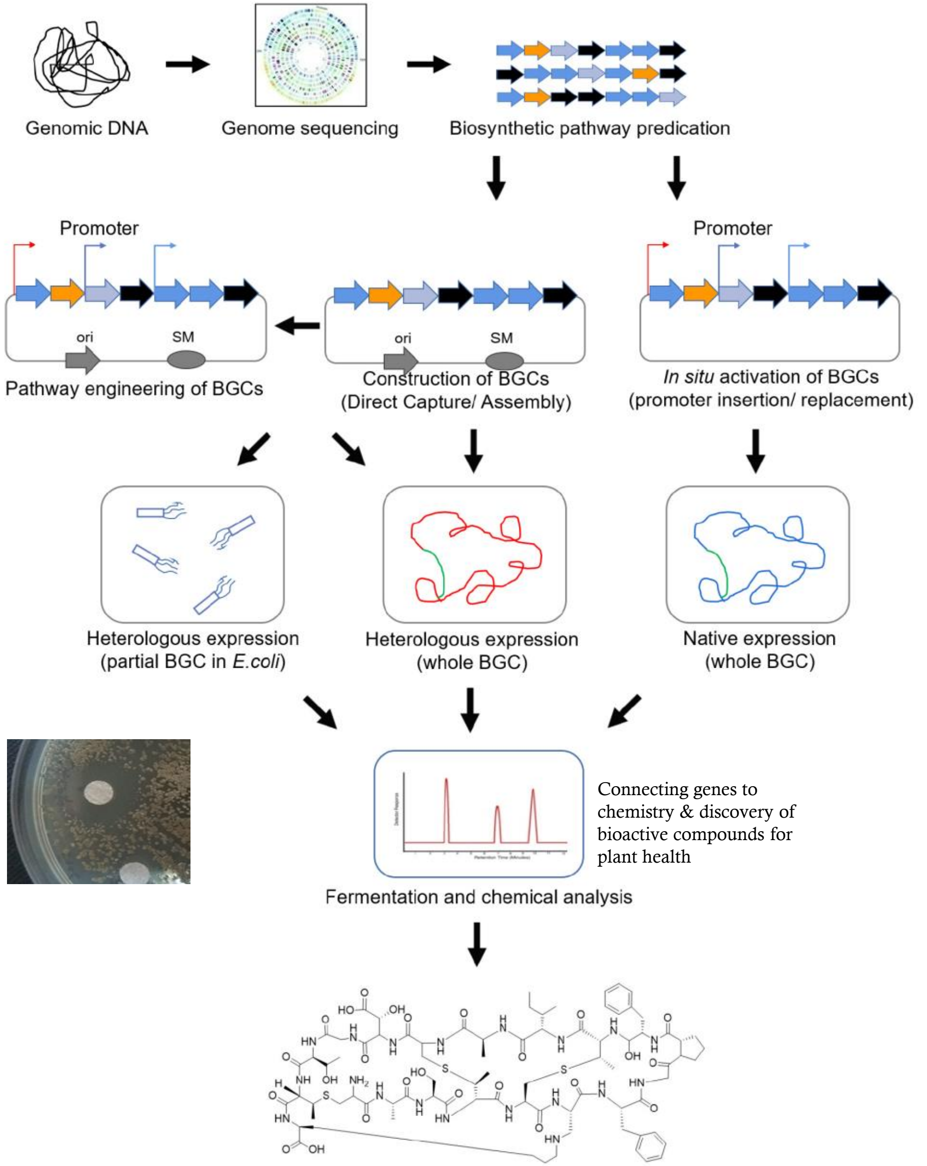


a. Degeneration and lysis of conidia
b. Lysis of mycelium
c. Normal conidia and mycelium (inset) in control

Novel Anti-fungal, anti-bacterial and anti-oomycete compounds discovered using coloumn chromatography, HPLC & 1H NMR

Thomas, A., and Saravanakumar, D. 2022

Genome mining for discovery of novel compounds



DNA sequencing & analysis of 4 *Bacillus* strains

Overview | 1.1 | 1.2 | 1.3 | 1.4 | 1.5 | 1.6 | 2.1 | 2.2 | 3.1 | 4.1 | 4.2 | 5.1 | 5.2 | 5.3 | 5.4 | 10.1 | 11.1 | 12.1 | 13.1 | 16.1

Identified secondary metabolite regions using strictness 'relaxed'

Region	Type	From	To	Most similar known cluster		Similarity
Region 1.1	NRPS, betalactone, transAT-PKS	1	86,616	fengycin	NRP	80%
Region 1.2	transAT-PKS-like, transAT-PKS, NRPS, T3PKS	142,819	251,989	bacillaene	Polyketide + NRP	100%
Region 1.3	transAT-PKS	473,771	561,977	macrolactin H	Polyketide	100%
Region 1.4	lanthipeptide-class-ii	725,813	754,702			
Region 1.5	terpene	875,632	896,372			
Region 1.6	PKS-like	978,386	1,019,630	butirosin A / butirosin B	Saccharide	7%
Region 2.1	NRPS, RiPP-like	73,698	125,490	bacillibactin	NRP	100%
Region 2.2	other	674,148	715,566	bacilysin	Other	100%
Region 3.1	transAT-PKS	1	33,921	difficidin	Polyketide + NRP	46%
Region 4.1	transAT-PKS, NRPS	1	46,583	rhizocticin A	Other	6%
Region 4.2	NRPS	116,656	182,063	surfactin	NRP:Lipopeptide	82%
Region 5.1	transAT-PKS-like	1	45,657	difficidin	Polyketide + NRP	53%
Region 5.2	T3PKS	161,201	202,301			
Region 5.3	terpene	270,928	292,811			
Region 5.4	NRPS	315,381	336,976	plipastatin	NRP	30%
Region 10.1	NRPS	1	22,379	locillomycin	NRP + Polyketide	35%
Region 11.1	transAT-PKS-like	1	22,767	difficidin	Polyketide + NRP	26%
Region 12.1	NRPS	1	12,916	fengycin	NRP	20%
Region 13.1	NRPS	1	9,227	fengycin	NRP	13%
Region 16.1	NRPS	1	6,493			

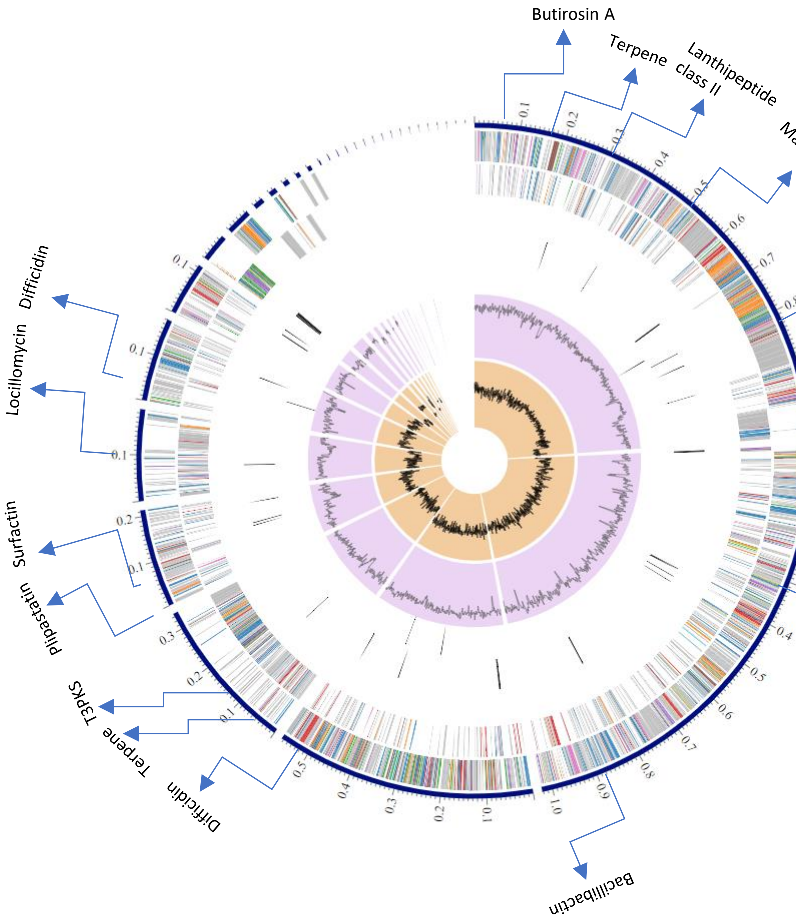
Antifungal
Antibacterial
Antifungal & Antibacterial

Antibacterial and antiviral

Microbes	Size (bp)	Proteins with functional assignments	Secondary metabolites
Ba CHAG 1D	3,920,902	3,281	14 types of antimicrobial compounds present in B. amyloliquefaciens strains , NRPs, RPs, PKs, NRPs-PKS, RiPPs
Ba PRIN1	3,920,153	3,282	Locillomycin (+), Lanthipeptide Class ii
Ba CUN9	3,914,165	3,289	Rhizocticin (+),
B. subtilis OG2	4,087,451	3,604	Subtilosin A (+), subtilomycin (+) Difficidin (-), Macrolactin (-), locillomycin (-), Lanthipeptide Class i

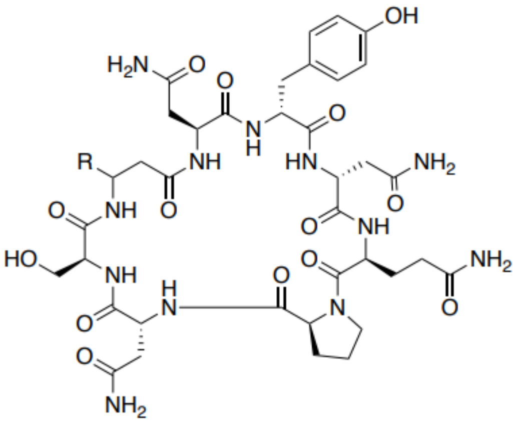
Genome mining for pesticidal & phytohormonal compounds

Whole Genome Sequencing of Ba PRIN1D



Outer to inner rings, the contigs, CDS on the forward strand, CDS on the reverse strand, RNA genes, CDS with homology to known antimicrobial resistance genes, CDS with homology to know virulence factors, GC content and GC skew [AntiSMASH & NaPDoS)

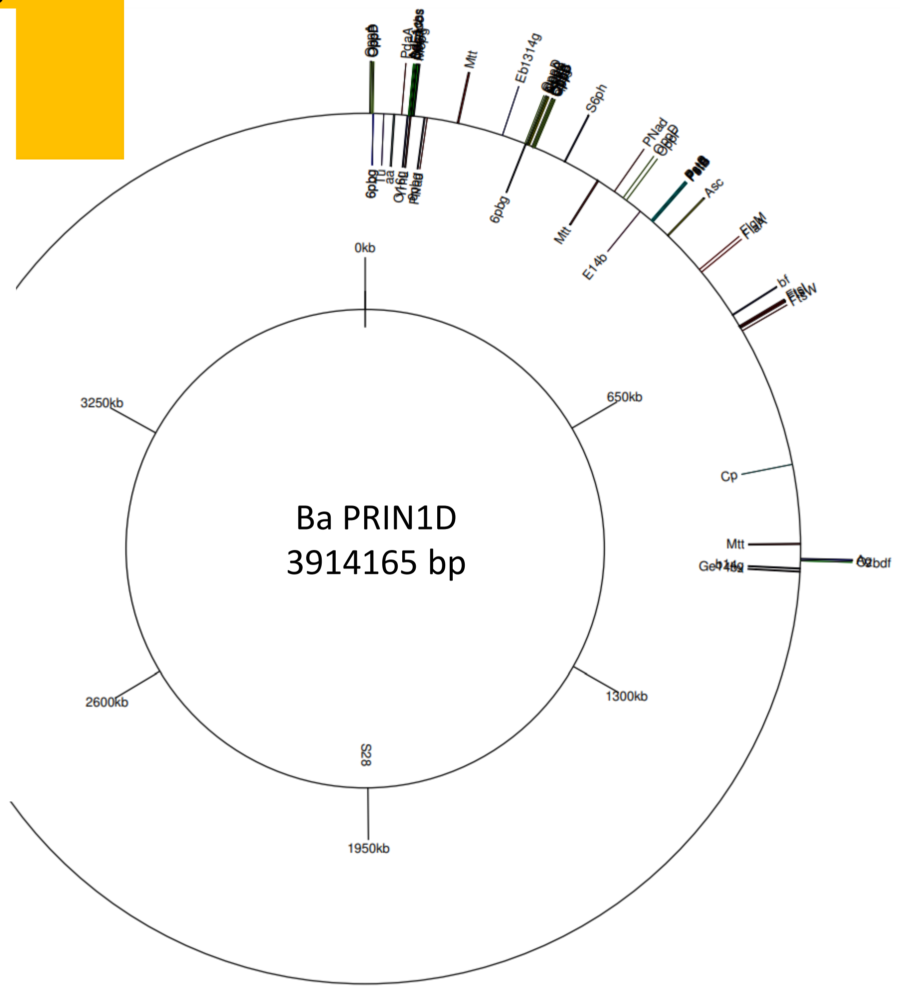
Genomic approach connecting genes to



Iturin A's
P1-LAN-EA-2d-1: R = nC_{11}
$C_{48}H_{74}N_{12}O_{14}$
mw=1042.58
P1-LAN-EA-2d-2: R = aiC_{12}
P1-LAN-EA-2d-3: R = iC_{12}
$C_{49}H_{76}N_{12}O_{14}$
mw=1056.58

Iturin A_L's
P1-LAN-EA-2d-4: R = iC_{13}
P1-LAN-EA-2d-5: R = nC_{13}
$C_{50}H_{78}N_{12}O_{14}$
mw=1070.58

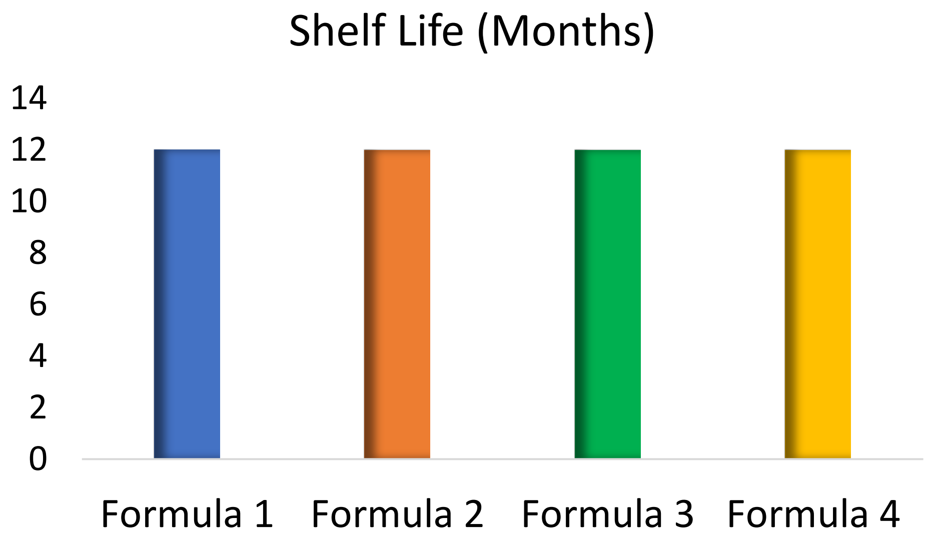
DNA PROCESSING (17, 89)
MEMBRANE TRANSPORT (16, 73)
RNA PROCESSING (13, 51)
CELL ENVELOPE (4, 16)
REGULATION AND CELL SIGNALING (3, 10)
MISCELLANEOUS (3, 10)



Plant colonization & growth-related genes

Development of microbial formulation for plant health management

- Shelf life
- Formulations for different delivery systems
- Efficacy enhancement

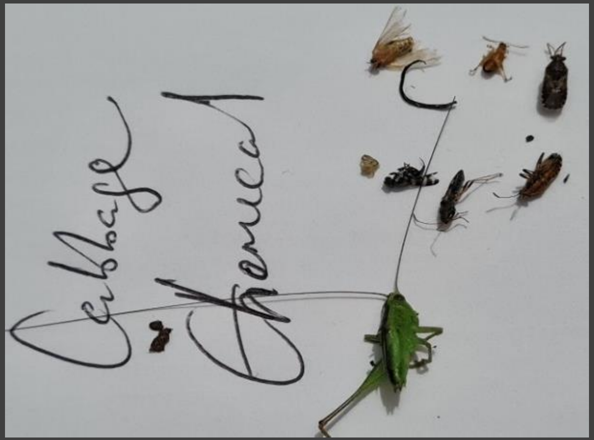


F1 + 2 hrs | F1 + 16 hrs | F2 | F2 + 16 hrs | F3 | F3 + 16 hrs | F4-W | F4-D | Control

Khan M & Saravanakumar D, 2025

Developed the bio-product after series of lab, greenhouse & field experiments - Biophyt 1.0

Could be a potential component of integrated disease management practices in the region!

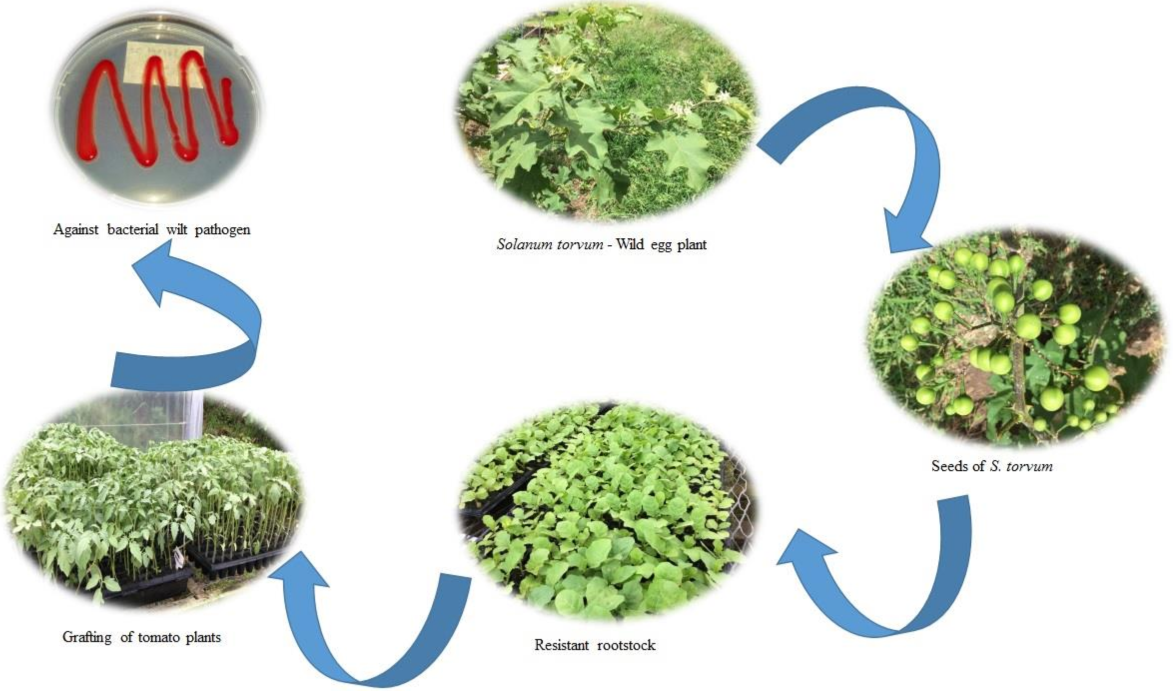


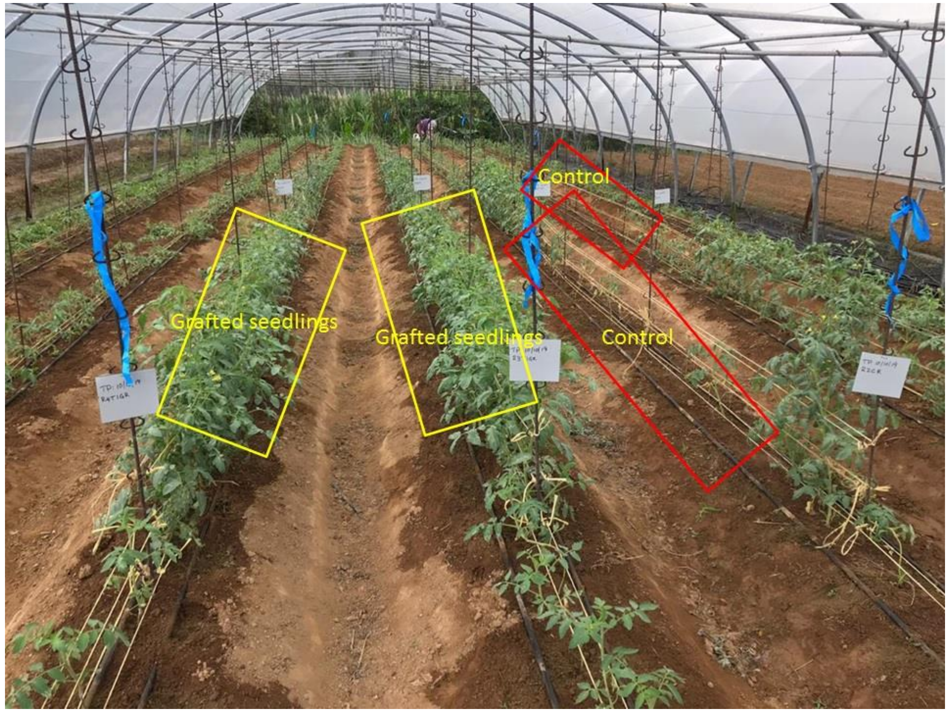
Khan M & Saravanakumar D, 2025

Crop Resistance against Bacterial wilt in tomato - St Lucia

- Tropical condition – high disease severity
- No crop rotation – limited land
- No effective chemical
- No resistant variety
- Semi-protected cultivation

Grafting as technique for enhancing disease resistance





Grafting procedure utilized to prepare planting material for compatibility study
A. Preparation of rootstock (*S. torvum*) by cutting the stem horizontally, B. V-shaped incision with 5 mm depth, C. Preparation of scion (tomato seedling with similar stem diameter) with V shaped wedge, D. Placement of scion wedge into V shaped incision of the rootstock, E. Union of scion and rootstock

DAP	Disease incidence (%)	
	Grafted on ST	Non-Grafted
7	0.00^{f}	35.00^{de}
14	0.00^{f}	51.67^{cd}
21	0.00^{f}	51.67^{cd}
28	0.00^{f}	61.67^{bcd}
35	0.00^{f}	83.34^{abc}
56	6.67^{ef}	98.33^{a}
63	6.67^{ef}	100.00^{a}
77	10.00^{ef}	100.00^{a}
Fruit yield / plant (kg)		
	4.5	0.0*

Performance of grafted and non-grafted tomato plants in semi-protected trials against naturally infected bacterial wilt pathogen

[Smith, J & Saravanakumar, D, 2022 Journal of Plant Disease Protection]

How to reduce the risk of pesticides?

- Replace the hazardous pesticides
- Reduce the use of pesticides

Is that simple?
Need evidence based data - Health, Food, Environment

Ban Registration/De-registration

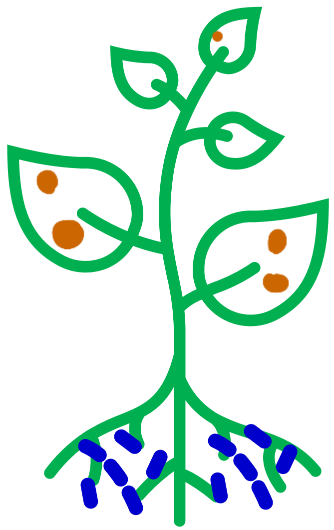
How to replace or reduce the risk of pesticides?

Regional Perspectives:

Food Safety: Lack of pesticide residue data
Environment: Lack of environmental assessment
Registration: No expedited or provision for registration of biopesticides
Trainings: Extension officers / ICTs
Farmers: Knowledge transfer and information

Alternatives
(i) Integrated management practices
- Cultural
- **Biologicals**
- **Genetic approaches**
- Low risk pesticides/mitigate risk

Summary



- Pesticide Risk Reduction
- Ongoing Projects – CPSP & UNEP/FAO
- Pesticide Suicide Prevention
- Tool to determine Pesticide Risk
- Integration of efforts to reduce pesticide risks in the region