Basil Downy Mildew

An Emerging Disease Challenging Basil production in the US

Zelalem Mersha
State Plant Pathology Specialist
900 Chestnut St., 214 Allen Hall
Jefferson City, MO 65101
E-mail: mershaz@lincolnu.edu; Phone: 573-681-5634

1866 LINCOLN University

Basil Production (*Ocimum sp.*)

- ✓ Basil, a popular annual herb grown for its aromatic leaves. Basil requires full sun, prefers moist well-drained soil.

- ✓ Lamiaceae – the mint family, square stem and opposite leaf orientation

- ✓ *Ocimum basilicum* L.
  - ✓ *Ocimum* from the Greek Okimon = Smell
  - ✓ *basilicum* from the Latin basilikon = Kingly/royal

- ✓ Economic importance
  - Culinary (fresh and dry)
  - source of oil, perfumes, aromatherapeutic products

Basil Production in Greenhouses

Basil Field Production

Basil Varieties

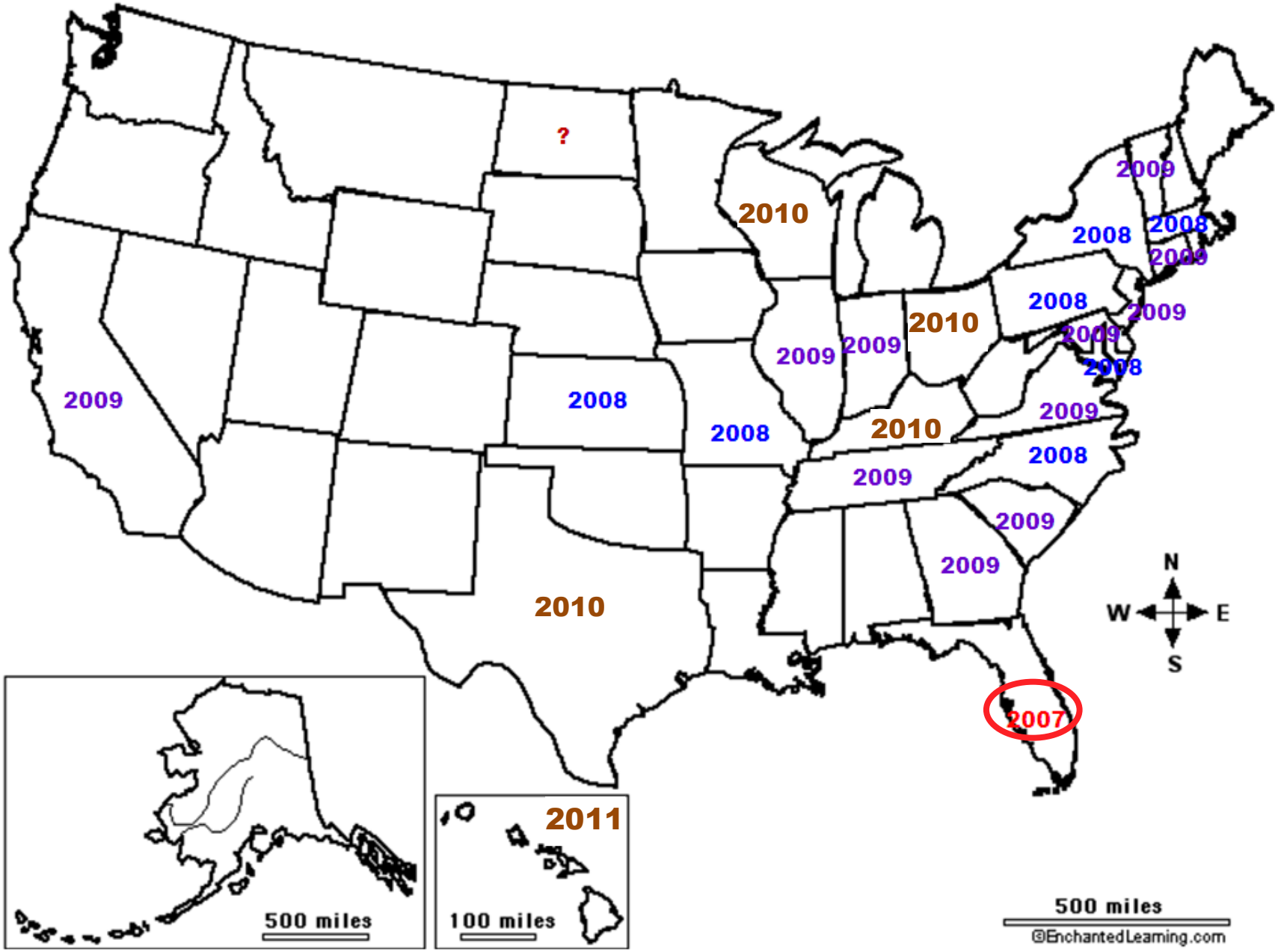
Different species of *Ocimum*

- *O. basilicum* 'Anise' – Iran
- *O. basilicum* 'Cinnamon' – Mexican
- *O. basilicum* var. Citriodorum
- *O. basilicum var.* Thyrsiflora 'True Thai' – Thailand

Basil Downy Mildew

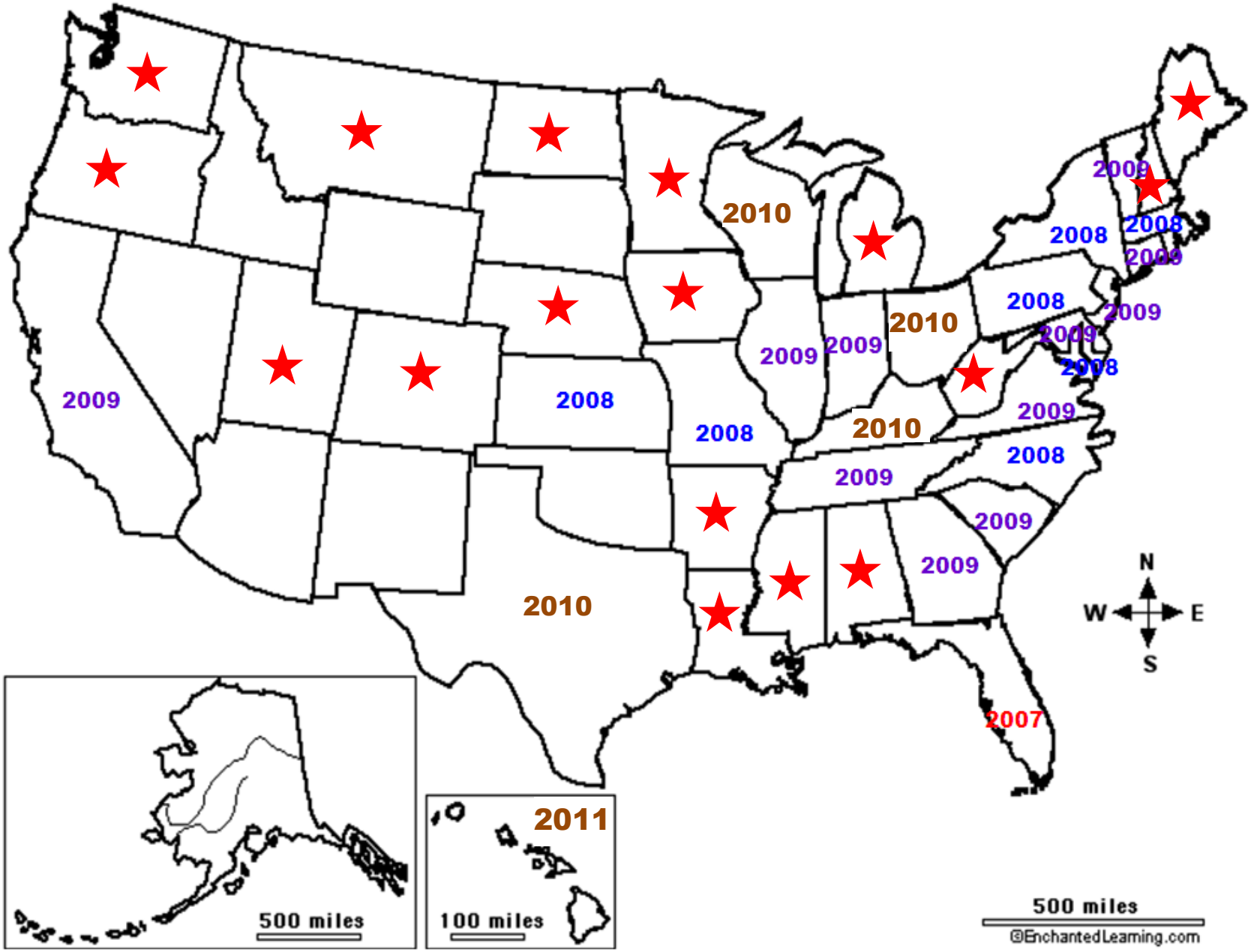
Worldwide Reports of Basil Downy Mildew

Disease reports in the US (2011)



Alarming disease spread … 2014

(Mc Grath, Cornell)



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ND	X
MN	X
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WI	X
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KY	X
TN	
AR	X
AK	X
AL	X
AZ	X
CA	X
CO	
CT	X
DC	X
DE	X
FL	X
GA	
HI	42

Basil Downy Mildew in Midwest USA

Sentinel Plot at Lincoln University's George Carver Farm

- Early detection and report to nearby extension office or plant diagnostic clinics
- Report to Cornell's Vegetable MD Hotline (http://vegetablemdonline.ppath.cornell.edu/NewsArticles/BasilDowny.html)

Basil downy mildew: Symptoms

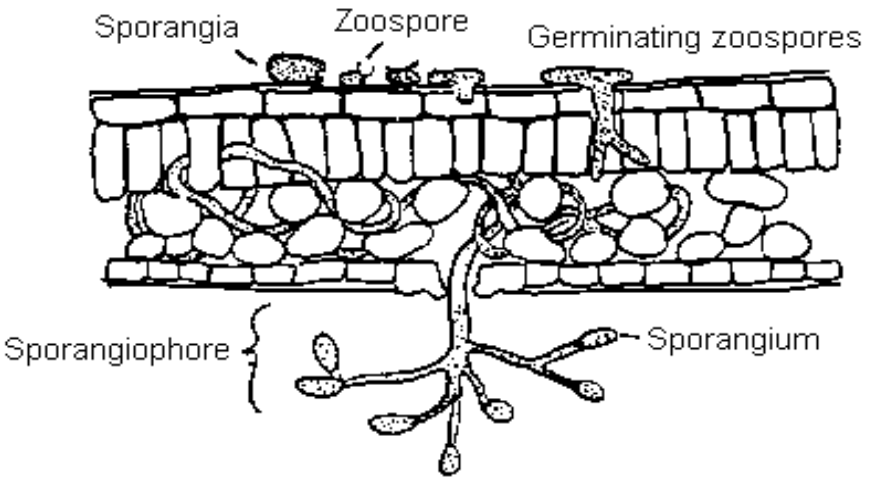
Basil downy mildew: Signs and Symptoms

The Pathogen: *Peronospora belbahrii*

The Downy Mildews (Peronosporales)

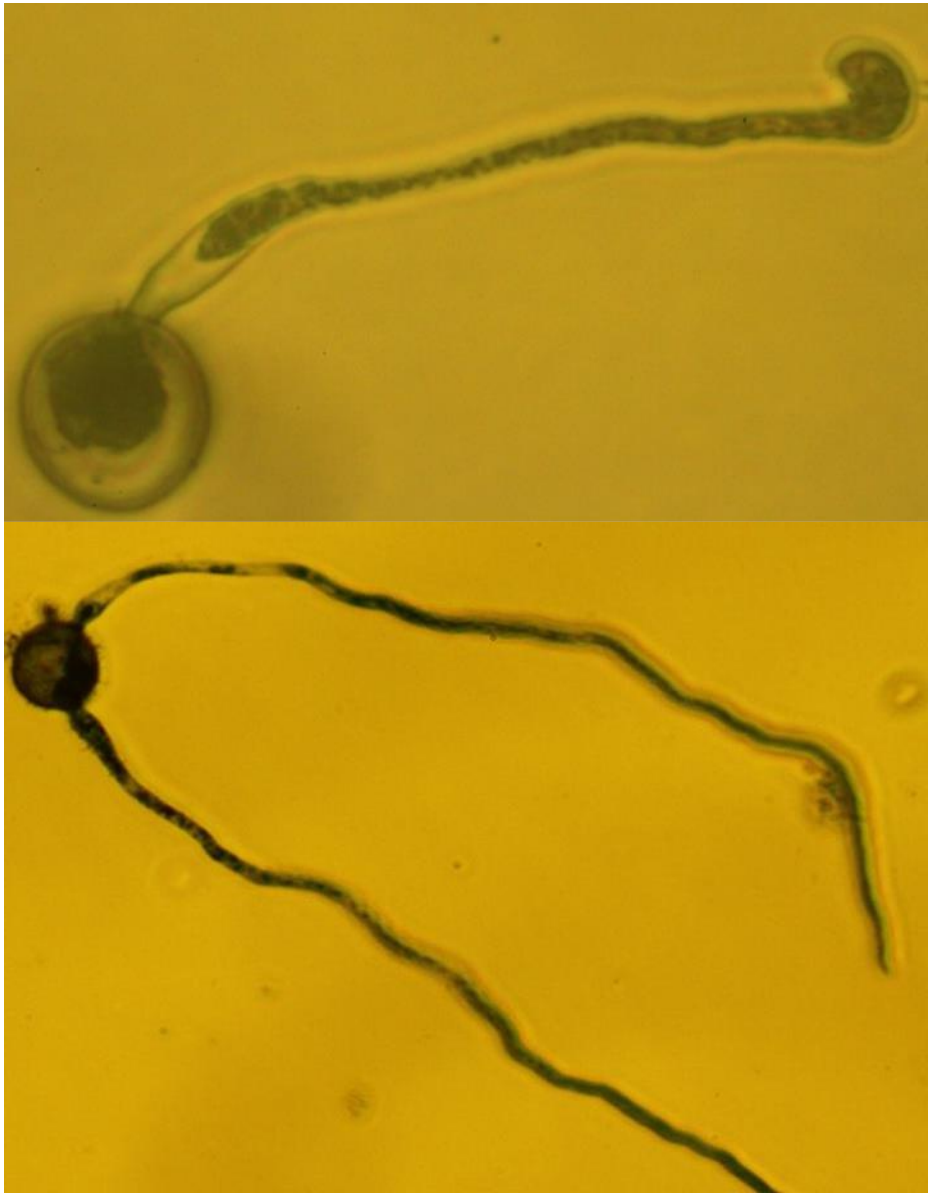
- **Mode of nutrition:**
  - **Obligate biotroph: it needs a live host plant to feed and survive**

- **Epidemiology:**
  - **Cool to warm temperature, high humidity & leaf wetness**



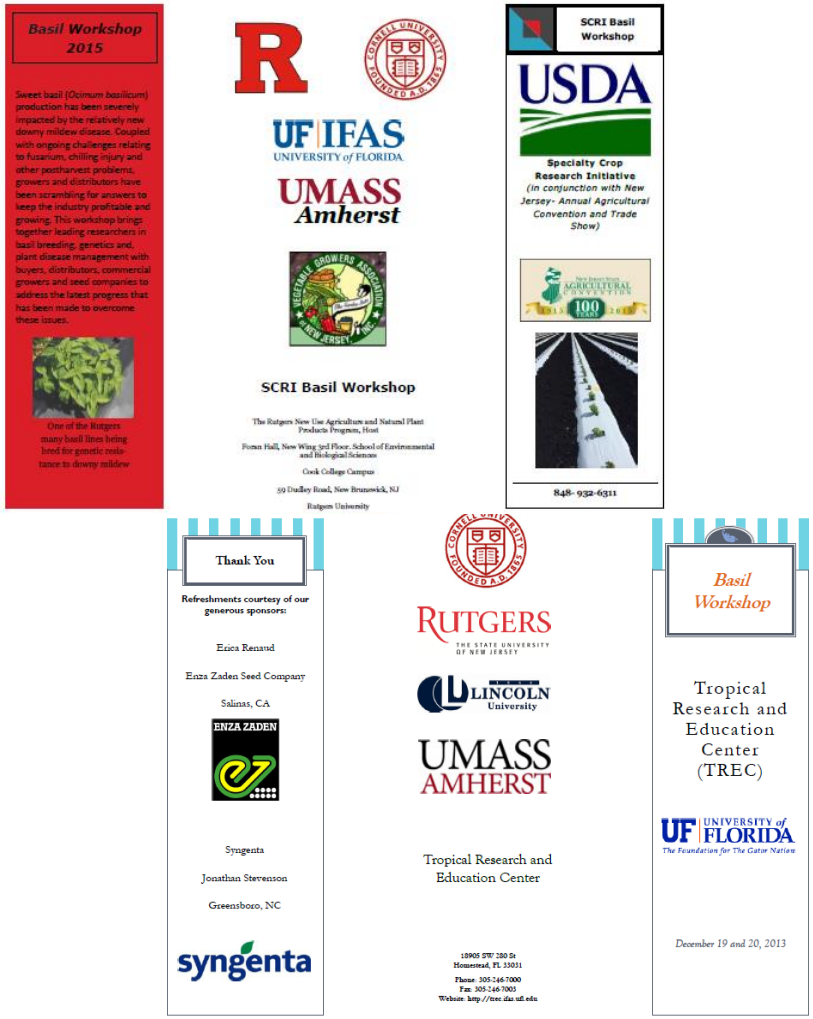
http://kentsimmons.uwinnipeg.ca/2152/fungi1a.htm

Microscopic observation of pathogen structure



What can be done to manage Basil Downy Mildew?

USDA Specialty Crop Research Initiative program



Basil Workshop 2015

Sweet basil (*Ocimum basilicum*) production has been severely impacted by the relatively new downy mildew disease. Coupled with ongoing challenges relating to fusarium, chilling injury and other postharvest problems, growers and distributors have been scrambling for answers to keep the industry profitable and growing. This workshop brings together leading researchers in basil breeding, genetics and, plant disease management with buyers, distributors, commercial growers and seed companies to address the latest progress that has been made to overcome these issues.

One of the Rutgers many basil lines being bred for genetic resistance to downy mildew

UF IFAS UNIVERSITY of FLORIDA

UMASS Amherst

VEGETABLE GROWERS ASSOCIATION OF NEW JERSEY

SCRI Basil Workshop

The Rutgers New Use Agriculture and Natural Plant Products Program, Host

Foran Hall, New Wing 3rd Floor, School of Environmental and Biological Sciences

Cook College Campus

59 Dudley Road, New Brunswick, NJ

Rutgers University

SCRI Basil Workshop

USDA

Specialty Crop Research Initiative

(In conjunction with New Jersey- Annual Agricultural Convention and Trade Show)

New Jersey Agricultural Convention 100 Years

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Tropical Research and Education Center

18905 SW 280 St
Homestead, FL 33031
Phone: 305-246-7000
Fax: 305-246-7003
Website: http://trec.ifas.ufl.edu

Basil Workshop

Tropical Research and Education Center (TREC)

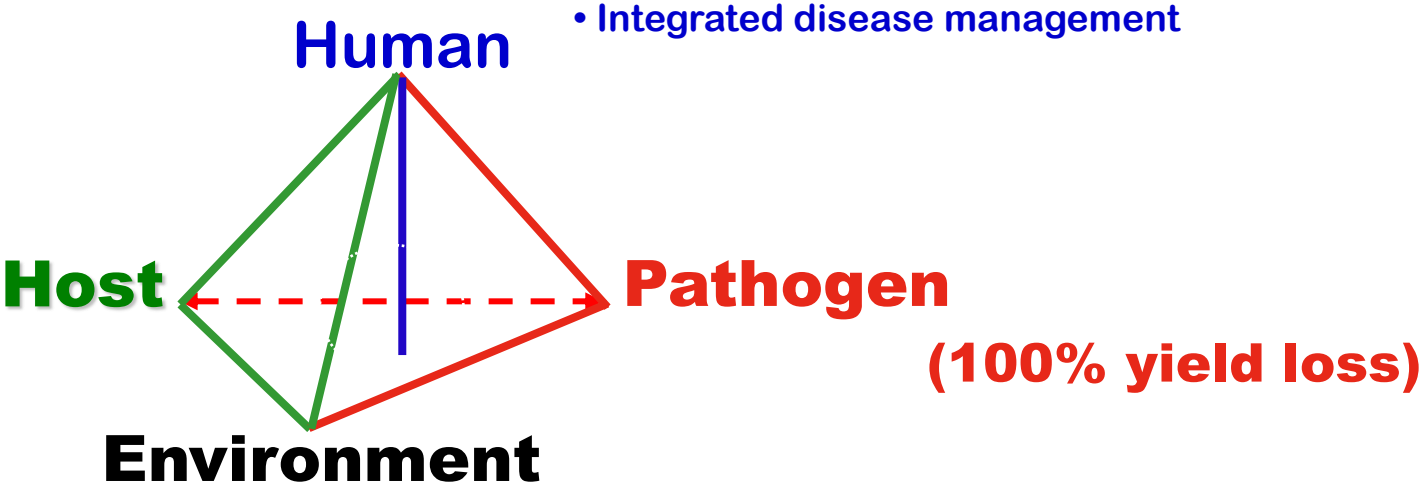
UF UNIVERSITY of FLORIDA
The Foundation for The Gator Nation

December 19 and 20, 2013

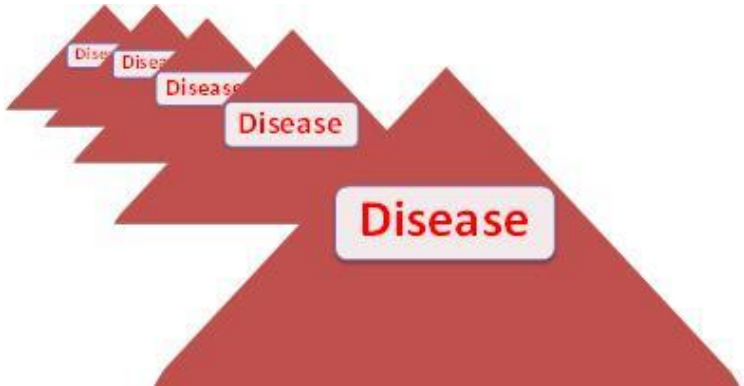
Basil downy mildew management

- Host resistance and Clean seed
- Monitor, Anticipate and Act
- Phytosanitation, reduce humidity
- SAR inducers, biologicals/biorationals
- Fungicides (alternation & tank mix)
- Integrated disease management

Resistant varieties, induced resistance



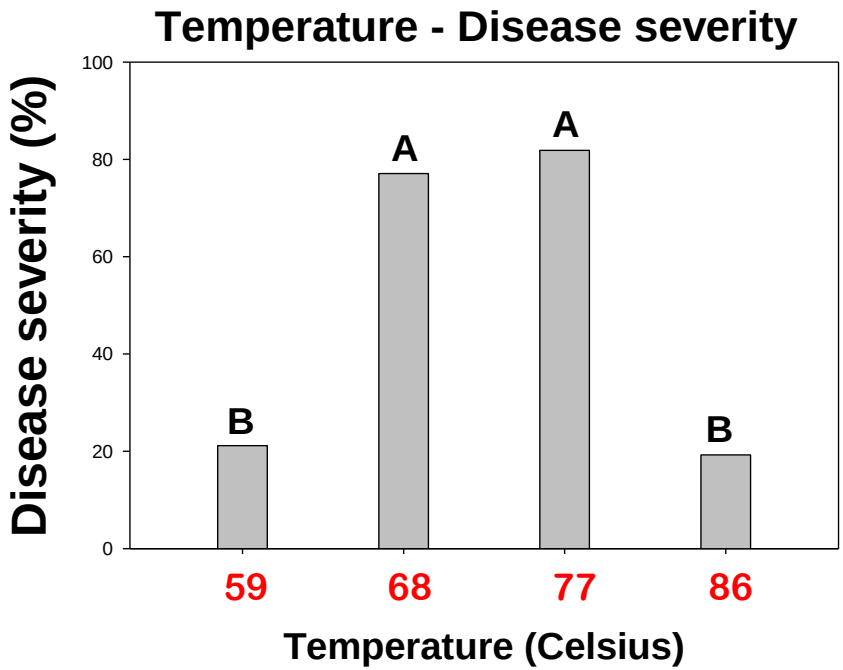
Keep it dry, ventilation, avoid long wetness

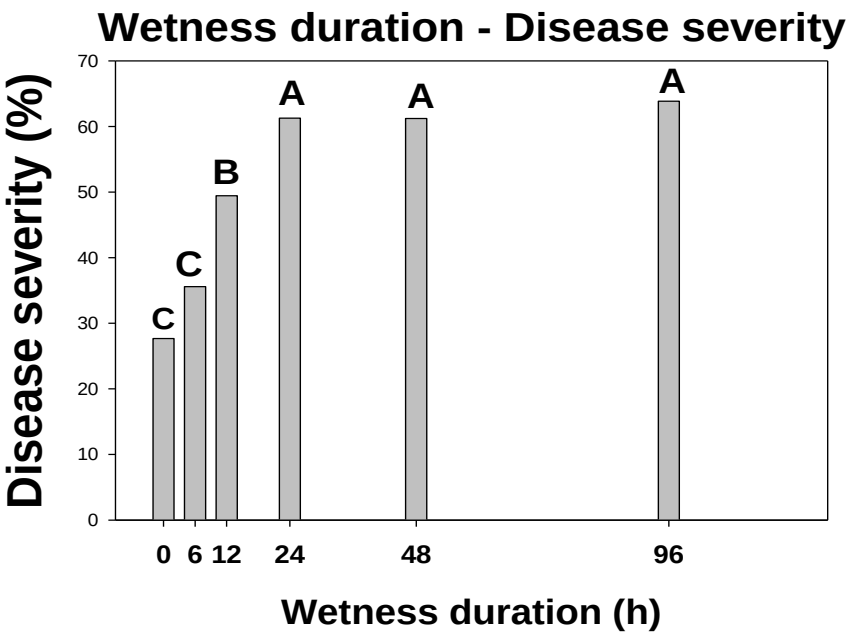


What does the downy mildew organism like most?

Sporulation 20 days after inoculation

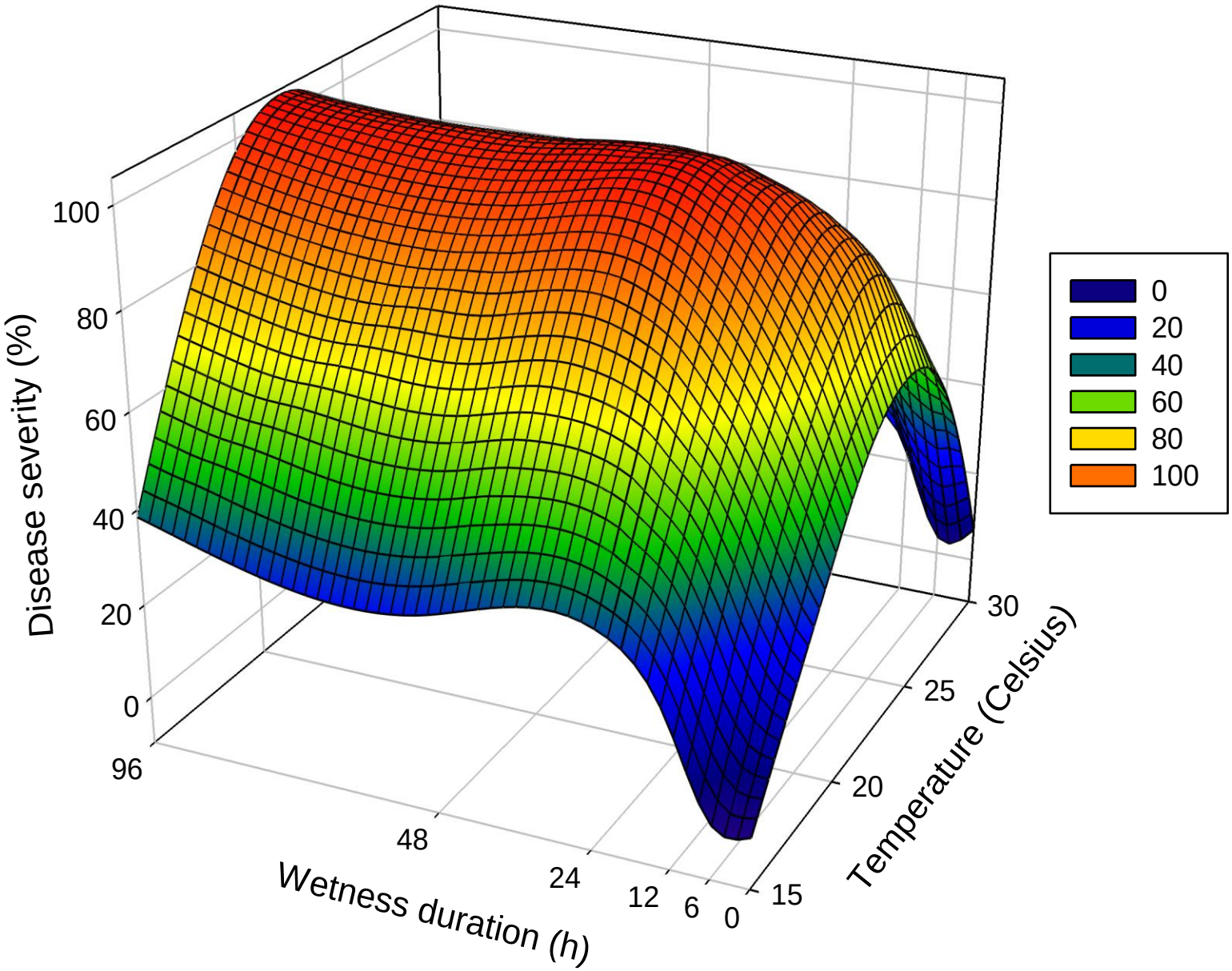
Temperature and Leaf Wetness





Disease severity (%) rated 20 days after inoculation

Temperature-Wetness Duration - Disease

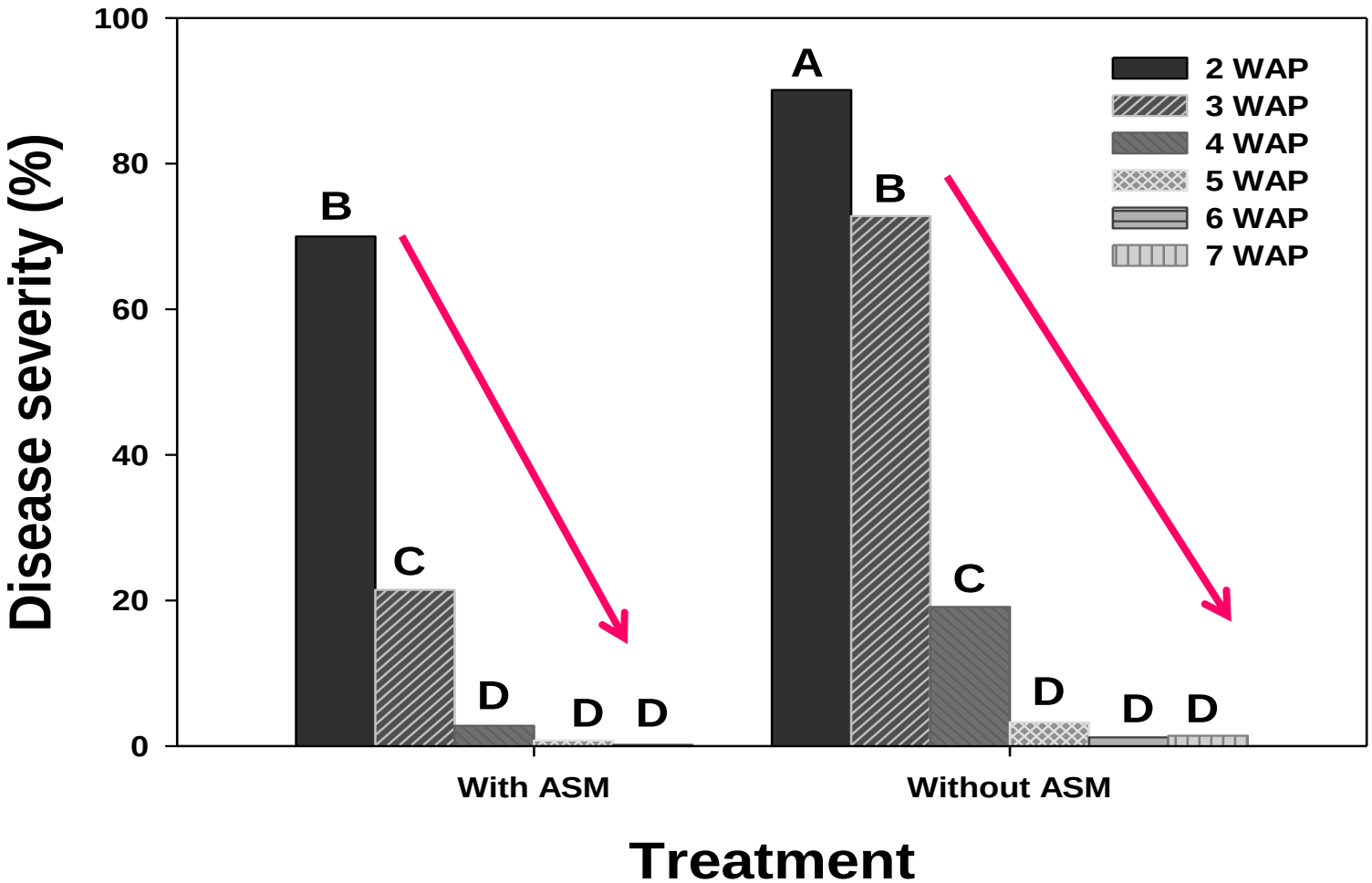


At which age is basil highly susceptible?

7 WAP | 6 WAP | 5 WAP | 4 WAP | 3 WAP | 2 WAP

Result – effect of leaf/plant age

Type III Tests of Fixed Effects			
Effect	Num DF	F Value	Pr > F
WAP	5	289.68	<.0001
ASM	1	115.59	<.0001
WAP*ASM	5	30.49	<.0001



Field Planting at Homestead, Florida

Field Trial 4

Management – seed and crop residue

Seed	Soilless medium (Fafard)	Disease incidence (%) of symptomatic plants											
		Dec. 3'11	Dec. 6'11	Dec. 9'11	Dec. 12'11	Dec. 13'11	Dec. 14'11	Dec. 15'11	Dec. 16'11	Dec. 17'11	Dec. 18'11	Dec. 19'11	Dec. 20'11
Clean	Clean	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
	+ dis. leaves	0	0	0	0	0	0	0	0	0	4.25	19.1	19.1
	+ spor. drench	0	0	0	0	0	0	0	0	0	5.1	10.2	10.2
Cont. seed (Sporangia drench)	Clean	0	0	0	6.3	6.3	12.5	12.5	100	100	100	100	100
	+ dis. leaves	0	0	0	0	4.8	27.2	27.2	100	100	100	100	100
	+ spor. drench	0	0	0	10.0	23.5	100	100	100	100	100	100	100
Cont. seed (Sporangia rub)	Clean	0	0	0	0	0	0	0	0	0	0	4.5	4.5
	+ dis. leaves	0	0	0	0	0	0	0	0	0	4.8	4.8	23.8
	+ spor. drench	0	0	0	0	0	0	0	0	0	4.8	23.9	42.8
Seeds from field trial	Clean	0	0	0	2.2	2.2	2.2	2.2	12.5	12.5	12.5	19.2	19.2
	+ dis. leaves	0	0	0	20	23.9	23.9	23.9	23.9	23.9	23.9	45.6	100
	+ spor. drench	0	0	0	4.8	9.5	14.3	14.3	14.3	14.3	14.3	20.0	20.0

Inducing resistance to basil plants at early growth stages

Since March 2010

- Greenhouse
  - ASM
  - BABA
  - NaSA
  - SA
  - INA

Since January 2011

- Field
  - ASM
  - BABA

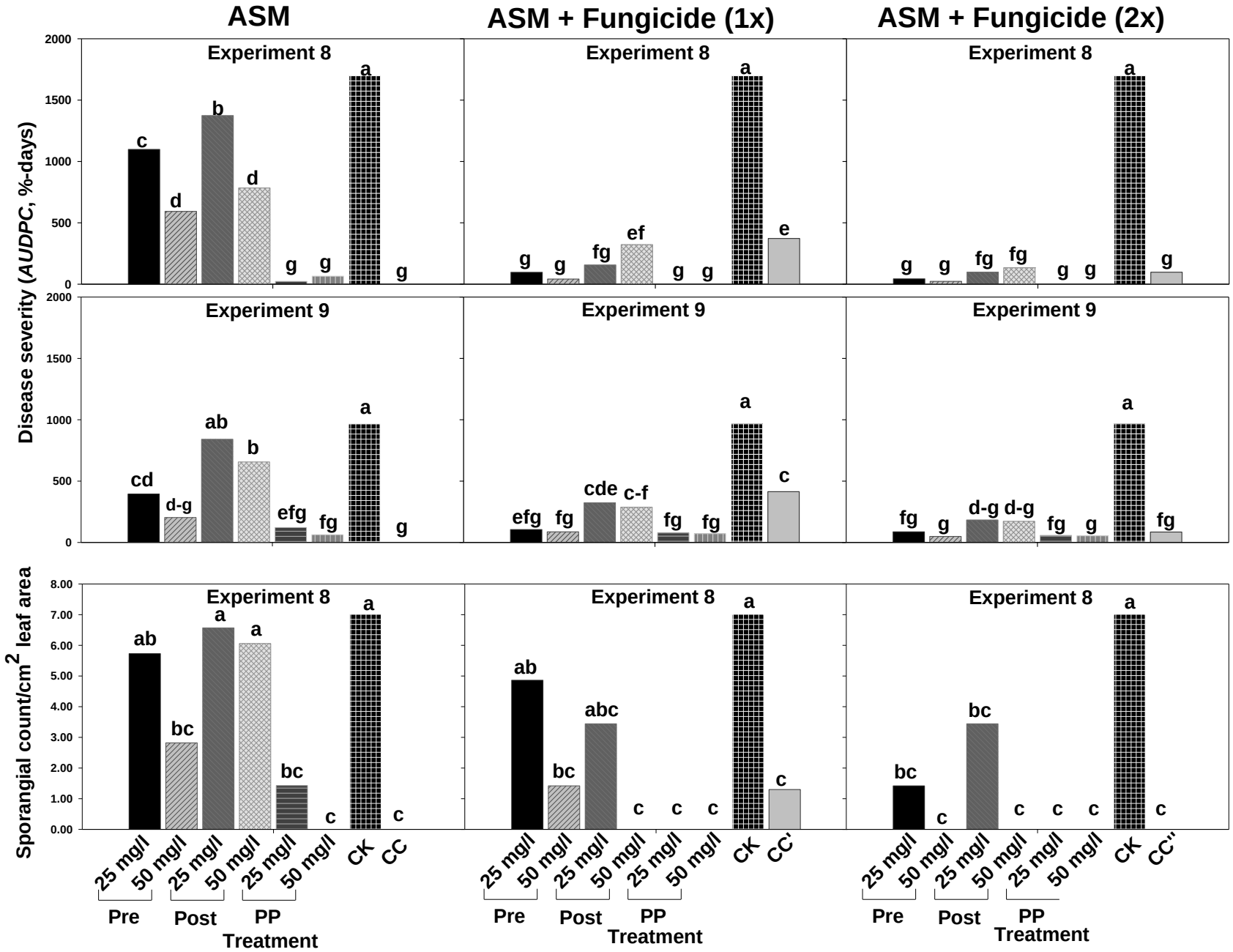
Start Actigard® 50 WP spray at 2-4 true leaf stages and continue the application every week (follow label)

- Compounds
- Rate
- Method
- Timing
- Combination

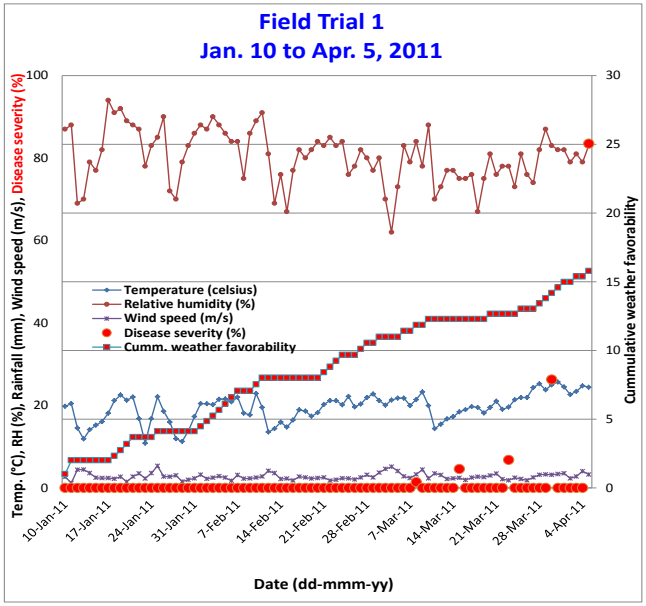
+

P. belbahrii

Actigard with or without fungicides (greenhouse)

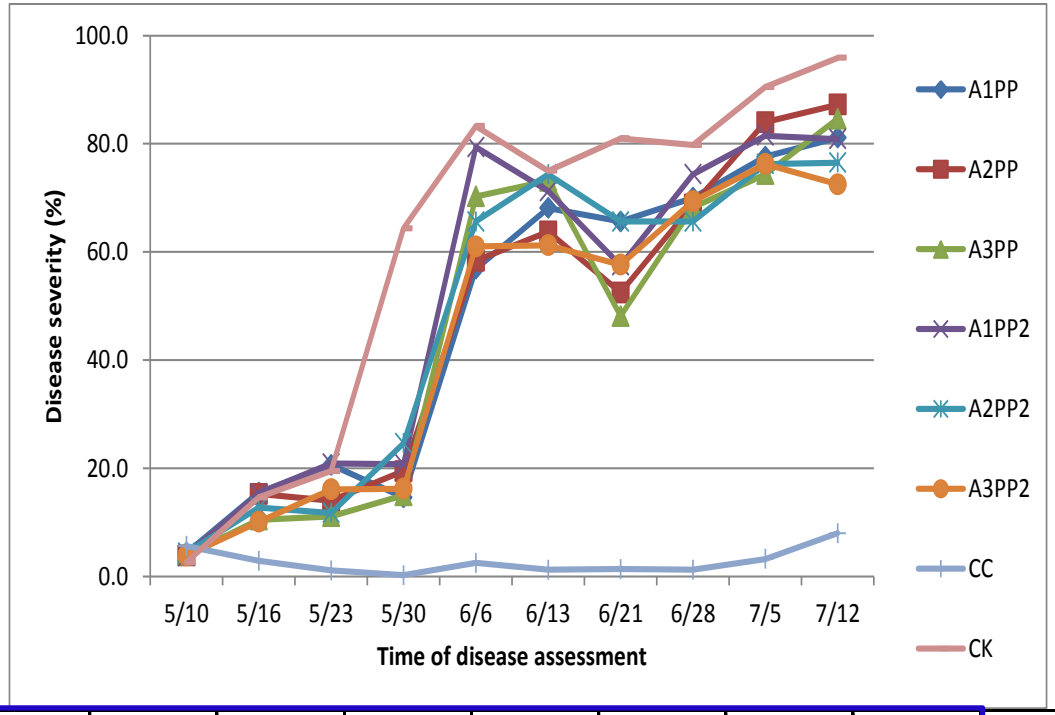


Actigard or BABA alone under field conditions??



Treatment (rate), frequency	Disease severity 05-Apr (%)	Disease severity *AUDPC* [y] (%-days)	Plant height infected with BDM (%)
BABA (125 mg/L), 3 ×	75.9 ab	504.2 a	89.9 ab
BABA (250 mg/L), 3 ×	74.8 ab	514.4 a	90.8 ab
BABA (125 mg/L), 6 ×	72.5 ab	451.0 a	93.1 a
BABA (250 mg/L), 6 ×	70.6 b	452.7 a	84.9 b
BABA (125 mg/L), 3 × + Prophyt-Quadris mix	22.5 c	295.6 b	78.5 c
BABA (250 mg/L), 3 × + Prophyt-Quadris mix	11.5 cd	171.0 bc	29.2 f
BABA (125 mg/L), 6 × + Prophyt-Quadris mix	14.3 cd	109.3 cd	41.7 e
BABA (250 mg/L), 6 × + Prophyt-Quadris mix	9.9 d	101.8 cd	59.0 d
Prophyt (2.5 ml/L) + Quadris (0.7 ml/L), 6 ×	3.4 d	18.7 e	18.1 f
Untreated check	83.5 a	511.3 a	94.2 a

Actigard when combined with fungicides



Trt	5/10	5/16	5/23	5/30	6/6	6/13	6/21	6/28	7/5	7/12	AUDPC
A1PP	4.4	15.5	20.6	14.6	56.9	68.1	65.6	70.0	77.6	81.1	**3196.6**
A2PP	3.9	15.3	14.0	19.5	58.4	63.8	52.5	68.8	84.0	87.3	**3123.4**
A3PP	4.0	10.5	11.1	15.0	70.3	73.1	48.1	68.3	74.4	84.6	**3067.0**
A1PP2	3.8	15.4	20.9	20.8	79.4	71.3	57.5	74.4	81.5	80.9	**3407.1**
A2PP2	4.4	12.8	11.8	24.6	65.6	74.4	65.6	65.6	76.3	76.5	**3223.1**
A3PP2	3.9	10.1	16.1	16.3	61.0	61.3	57.6	69.4	76.3	72.5	**3004.3**
CC	5.6	2.9	1.1	0.3	2.5	1.3	1.4	1.3	3.3	8.0	**148.4**
CK	2.6	14.6	19.5	64.4	83.3	75.0	81.0	79.8	90.5	95.9	**4074.6**

Management – SAR inducers (Greenhouse)

Objectives

- **Sustained efficacy**
- **Cost effectiveness**

How??

- **Rates**
  - **ASM (12.5 – 50 mg/l)**
  - **Quadris and Revus**
    - **Quarter**
    - **Half**
    - **Full**
- **Alternation and tank mix**
- **Frequency**

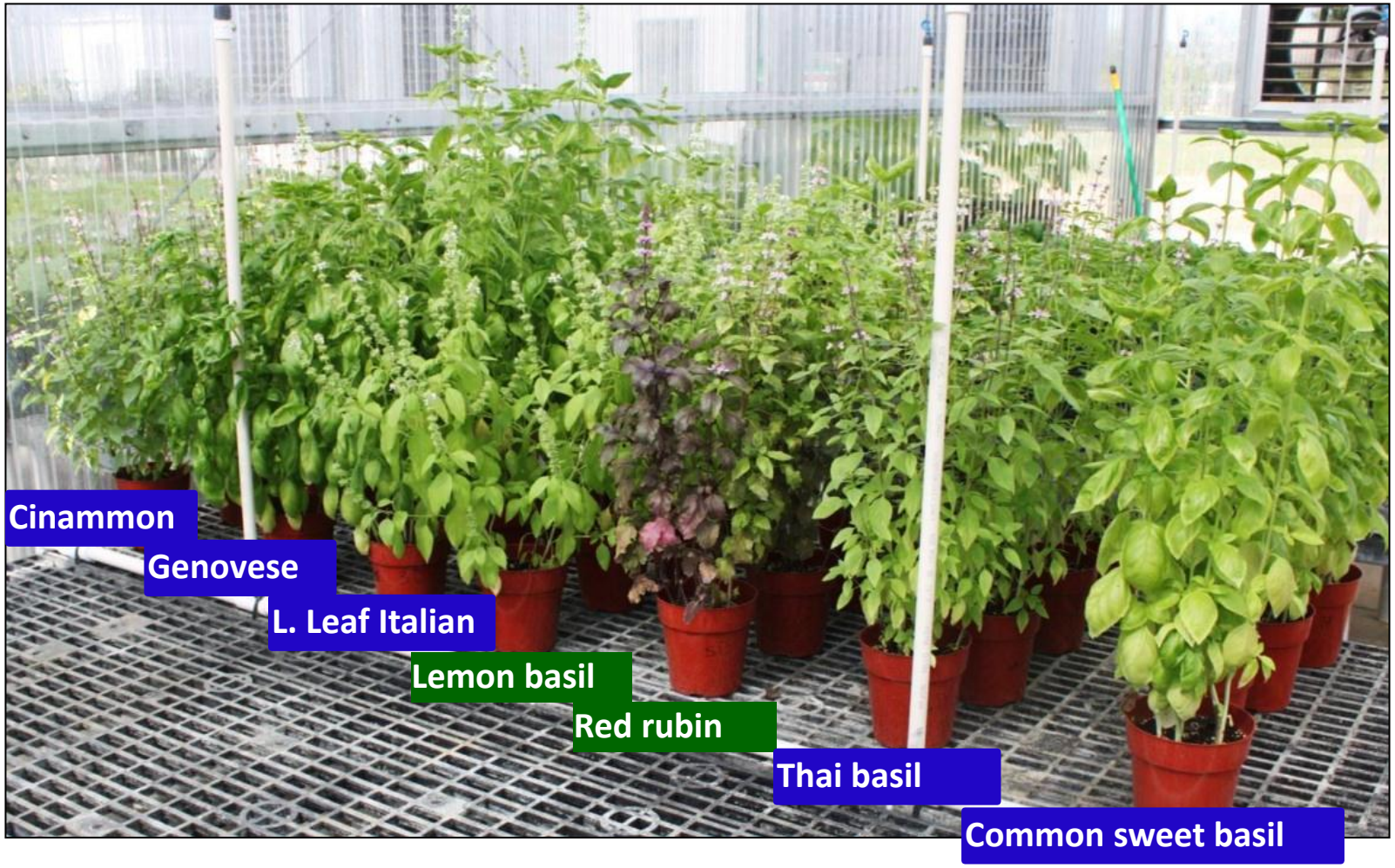
Management – SAR inducers (field)

Objectives
- Efficacy
- Cost effectiveness

Rates
- Actigard (75 and 150 mg/l)
- Quadris (quarter, half or full labelled rate)

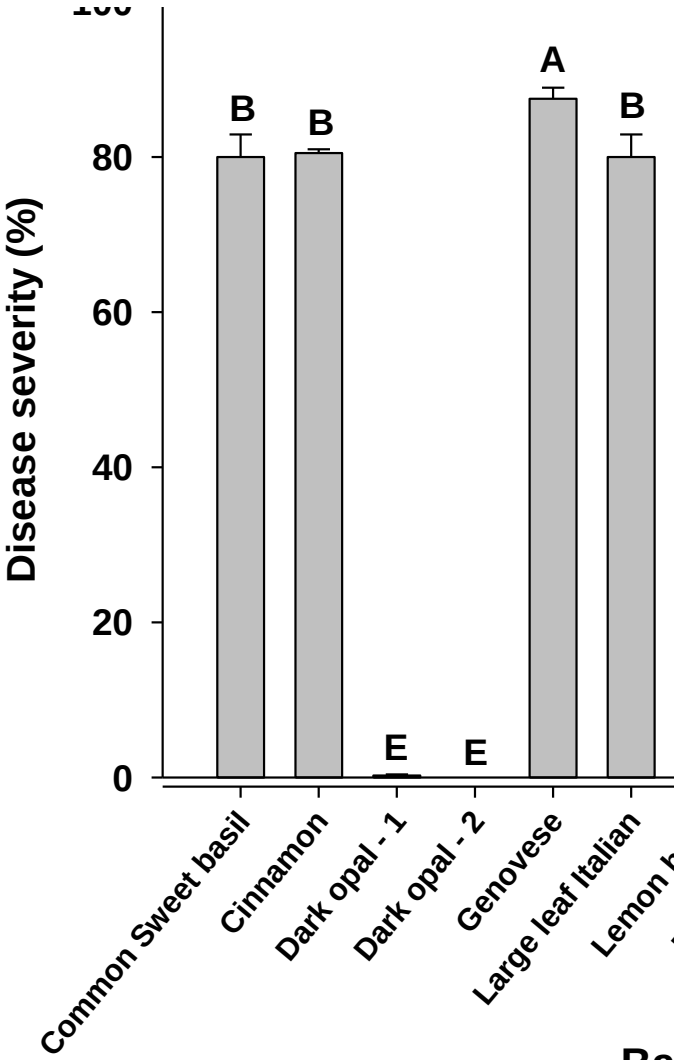
Treatment	Alternation			Tank mix		
	Aug. 17, 2012	AUDPC	% Protection	Aug. 17, 2012	AUDPC	% Protection
ASM_0 Q_0	79.0	623.9		84.5	816.4	
ASM_0 $Q_{1/4}$	30.0	327.3	47.5	21.9	231.4	62.9
ASM_0 $Q_{1/2}$	31.2	255.1	59.1	16.3	170.2	72.7
ASM_0 $Q_{4/4}$	25.4	231.4	62.9	12.3	67.4	89.2
ASM_{75} Q_0	38.1	293.7	52.9	54.4	445.4	28.6
ASM_{75} $Q_{1/4}$	11.9	80.9	87.0	8.9	48.6	92.2
ASM_{75} $Q_{1/2}$	9.3	68.3	89.1	4.9	32.8	94.7
ASM_{75} $Q_{4/4}$	6.0	53.4	91.4	8.2	25.5	95.9
ASM_{150} Q_0	54.4	105.6	83.1	13.3	352.2	43.5
ASM_{150} $Q_{1/4}$	21.9	184.2	70.5	4.4	34.6	94.5
ASM_{150} $Q_{1/2}$	19.0	122.5	80.4	3.1	21.4	96.6
ASM_{150} $Q_{4/4}$	12.3	97.1	84.4	2.3	15.6	97.5

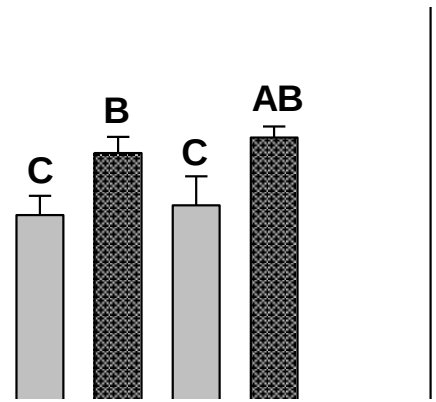
Management –resistance varieties

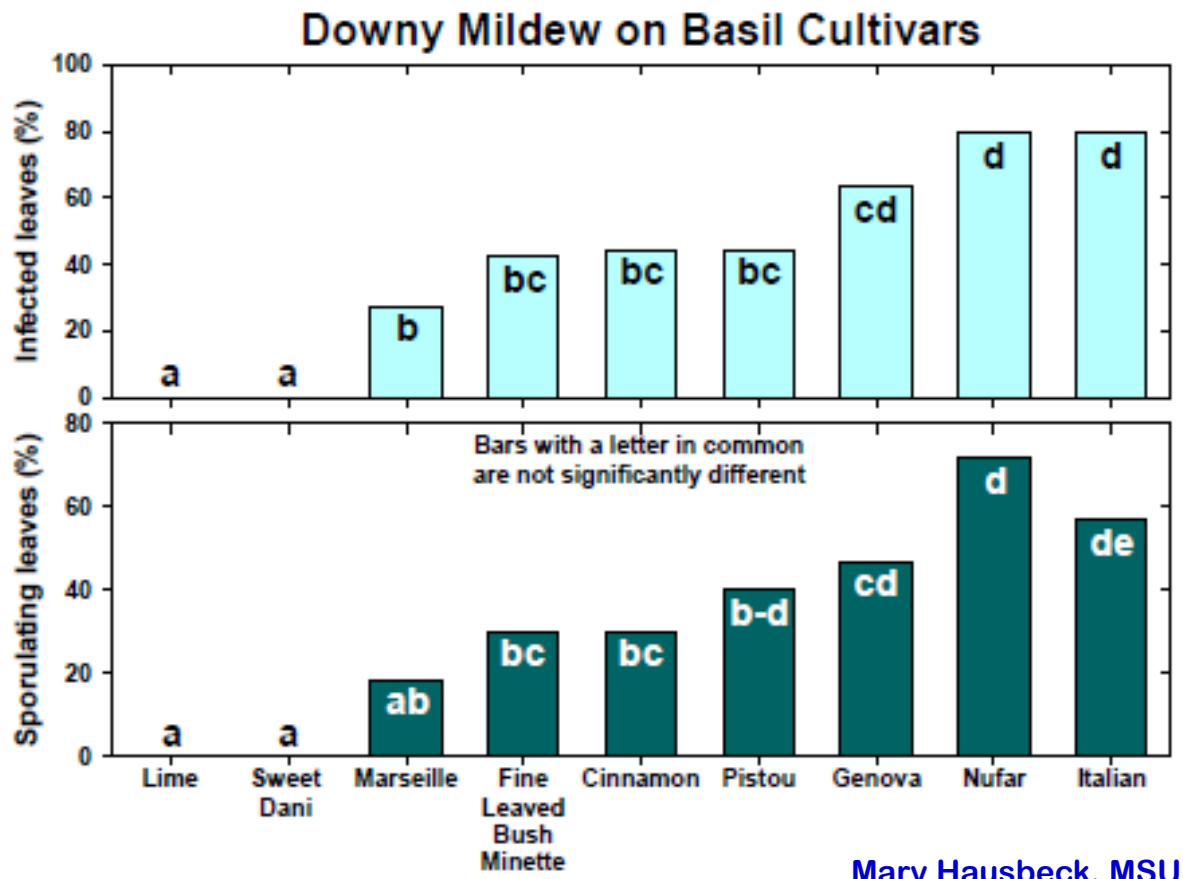


Susceptibility of basil cultivars to downy mildew disease differs significantly

Resistant Varieties







Mary Hausbeck, MSU

Host resistance – field (FL, NJ, NY)

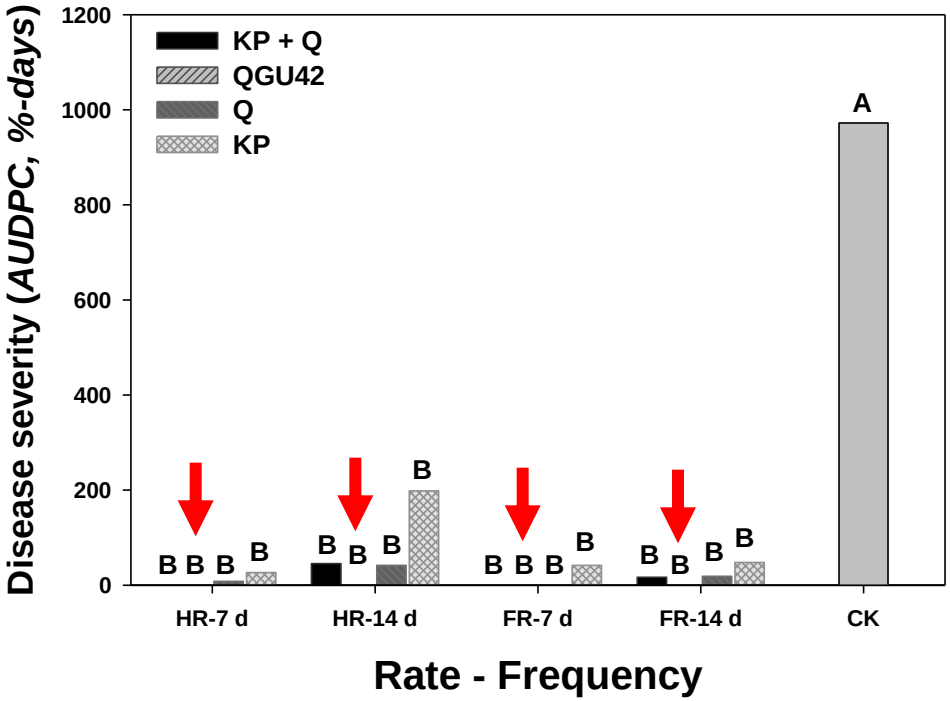
Treatm	Entry name	Downy mildew incidence (% leaves w/ symptoms)[z] 20 Aug	25 Aug	2 Sep	10 Sep	18 Sep		AUDPC[y]		Severity (%)[z] 2 Oct
1. Con	DiGenova (standard)	3.8	32.3	60.3	76.5	66.3	ab	1540.6	abc	57.3
2. Cinn										
3. Darl	Napoletano	5.5	68.3	70.0	70.5	75.3	ab	1827.6	abc	51.8
4. Gen	Jolina	19.0	26.0	49.8	66.0	69.8	ab	1314.1	abc	57.8
5. Larg										
6. Lem	BA101	17.3	45.3	80.8	85.5	84.3	a	1980.3	ab	78.9
7. Lim	BA102	15.8	22.5	44.8	60.0	57.8	ab	1173.1	abc	34.3
8. Purp	BA103	1.0	36.3	58.8	62.0	69.3	ab	1350.6	abc	55.7
9. Spic										
10. Tha	Eleonora (BA104)	0.0	0.0	27.8	57.5	50.5	ab	826.6	bc	57.0
11. Da	BA105	35.0	78.5	88.3	76.5	87.8	a	2256.3	a	77.6
12. Da	BA106	9.3	40.5	57.0	72.5	73.0	ab	1521.0	abc	58.8
13. Ind	BA107	4.0	25.0	48.0	66.3	66.5	ab	1260.3	abc	64.3
14. Pur										
15. Spi	**BA108**	**0.0**	**4.3**	**19.3**	**48.5**	**31.3**	**b**	**676.0**	**c**	**40.3**
16. Tha	P-value (treatment)	0.2920	0.1140	0.0737	0.0641	0.0192		0.0119		0.0511

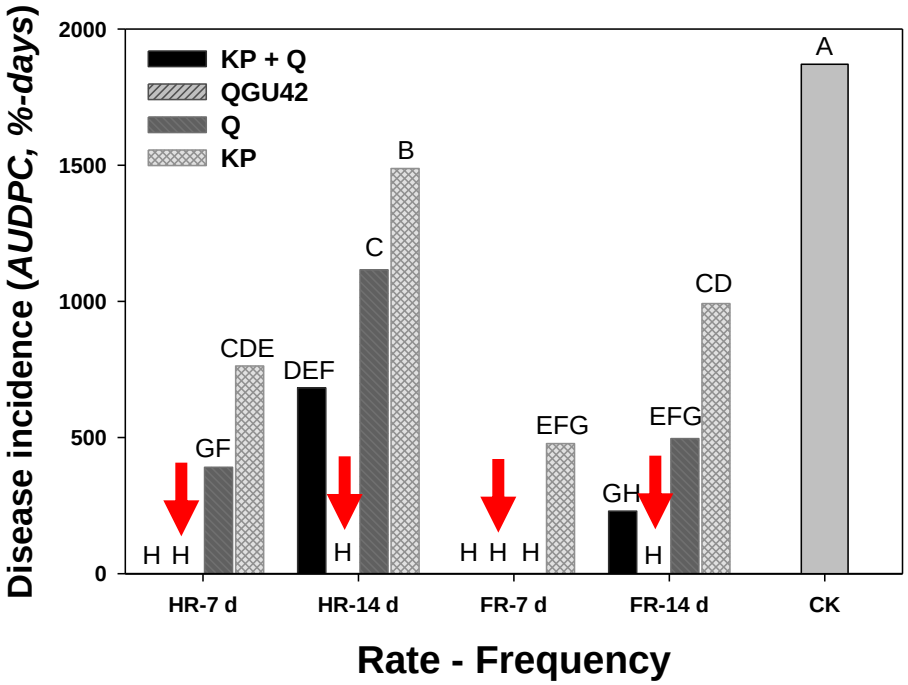
McGrath et al. (2014)

Host resistance vs. customer preference

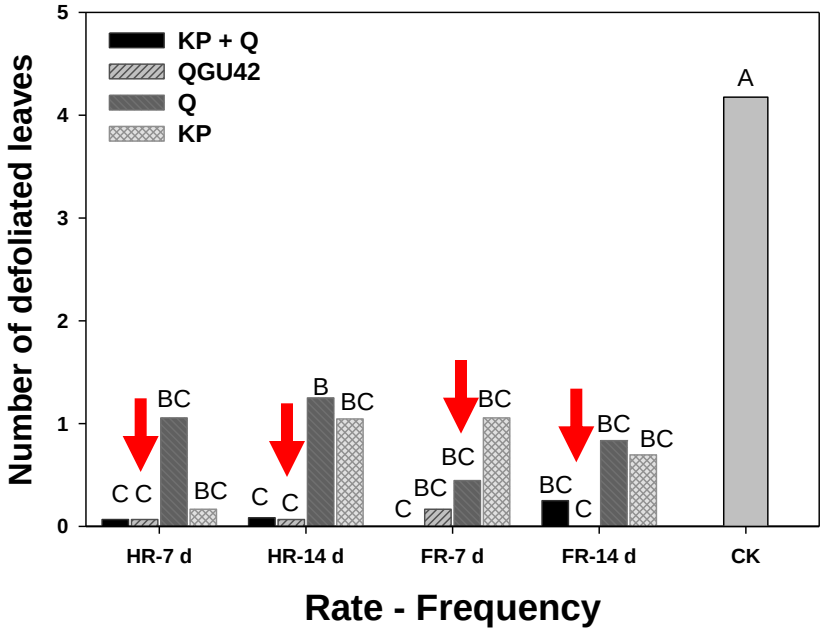
No.	Cultivar	Source	Customer preference (1-10)		Remark
			Home consumption	Gardening	
1	Common sweet basil	Eden Brothers	7	7	Similar to Genovese
2	Cinnamon	Eden Brothers	2	4	OK, taste not so great
3	Dark opal	Eden Brothers	4	6	Wilts fast at market
4	**Genovese**	**Eden Brothers**	**10**	**9**	Preferred vs other Italian
5	Large leaf Italian	Eden Brothers	7	7	Similar to Genovese
6	Lemon basil	Eden Brothers	5	5	Flower spikes great for tea
7	Lime basil	Eden Brothers	9	8	Nice
8	Purple basil	Eden Brothers	6	8	Edible landscaping
9	Spicy globe	Eden Brothers	7	5	NOT a globe!
10	Thai basil	Eden Brothers	4	4	Flavor not as good as 16
11	Dark lemon	Richters	9	9	Nicer than Mrs Burns'
12	**Dark opal**	**Richters**	**4**	9	High variable Landscaping!
13	Indian basil	Richters	4	6	Tulsi (sacred basil) TEA!
14	Purple delight	Richters	4	4	Inconsistent variability
15	Spicy globe	Richters	8	9	Fine-leaf, decorative
16	Thai basil	Richters	9	9	Best flavor, hardy

QGU42, Prophyt and Quadris Results (Florida, Greenhouse)





- QGU42 (oxathiapiprolin)
- potassium phosphite
  - Bimobile
  - Affects growth & penetration
  - Systemic defense boosting?
- azoxystrobin



QGU42 (oxathiapiprolin) Performance

- **QGU42 significantly suppressed and controlled basil downy mildew (*Peronospora belbahrii*) in all greenhouse experiments**
  - ✓ Disease severity
  - ✓ Disease incidence
  - ✓ Less defoliation

- **Detached leaves were clean and no trace of sporulation was detected**

- **Future experiments to verify mode of action and evaluate efficacy under field conditions are recommended**

Management – biologicals

Treatment [z] (rate)	Experiment 1				Experiment 2			
	Disease severity			Total	Disease severity			Total
	17-Sep (%)	02-Oct (%)	AUDPC [y] (%-days)	infected leaves (%)	18-Oct (%)	10-Nov (%)	AUDPC [x] (%-days)	infected leaves (%)
Actinovate (12 oz/A)……	0.30 cd [w]	82.0 ab	664.4 b	84.5 a	3.0 cd	70.7 b	1091.5 d	89.3 a
BU EXP 1216 C (3 lb/A)……..	0.04 c	86.2 ab	733.7 ab	85.1 a	4.0 bc	88.3 a	1381.8 c	90.5 a
BU EXP 1216 S (3 lb/A)……...	3.00 abc	82.0 ab	820.6 ab	86.5 a	7.3 ab	93.0 a	1549.5 ab	92.1 a
Companion (32 fl oz/A).....	3.70 ab	81.0 ab	771.1 ab	87.8 a	4.3 bc	91.7 a	1488.2 bc	90.3 a
HMO 736 (14 oz/A).....	1.02 abc	83.6 ab	672.0 b	83.7 a	6.0 abc	91.7 a	1544.0 abc	88.8 a
Regalia SC (1% v/v).....	0.22 bc	83.2 ab	659.1 b	86.1 a	7.0 ab	95.0 a	1595.2 ab	80.4 a
Serenade (3 lb/A).....	4.20 a	80.0 ab	758.6 ab	85.8 a	7.7 ab	93.0 a	1606.5 ab	84.3 a
Sonata (4 qt/A).....	0.56 bc	74.0 b	631.6 b	83.3 a	5.7 abc	92.3 b	1615.2 ab	80.4 a
Prophyt (4 pt/A).....	0.20 bc	21.6 c	70.3 c	41.3 b	0.00 d	10.3 c	175.8 e	40.4 b
Prophyt (2 pt/A) + Quadris (9 fl oz/A) [v]...	0.00 c	15.0 c	33.7 c	45.6 b	0.00 d	0.3 d	1.3 f	5.2 c
Untreated check……..…...	2.50 abc	92.7 a	890.7 a	85.4 a	8.0 a	94.0 a	1698.5 a	89.6 a

Recent Field Trial Results (NJ and NY)

	Treatment and Rate/A	Downy mildew incidence (% leaves w/ symptoms)[z]										Severity	
Cultivar	(application dates) [y]	2 Sep	8 Sep		18 Sep		2 Oct		AUDPC[x]			3 Oct	
Italian Large Leaf	Untreated control	25.4	48.6	a	62.8	a	85.9	a	1797.1	a		63.8	a
Italian Large Leaf	Regalia 3 qt (1,2) Actinovate 6 oz (4,6,8,10,12,14,16,18) Trilogy 1 % v/v (5,7,9,11,13,15,17,19)	29.2	50.0	a	48.3	a	88.6	a	1649.0	a		30.0	bc
Italian Large Leaf	Ridomil 1 qt (2) Quadris 15.5 fl oz (3) Ranman[w] 3 fl oz (5,9,13,17) Revus[w] 8 fl oz (7,11,15,19) K-Phite 1 qt (7,9,11,13,15,17,19)	0.3	0.5	b	0.0	b	6.5	b	37.3	b		0.0	d
Italian Large Leaf	Quadris 15.5 fl oz (3) Zorvec[w] 2.4 fl oz (5,11,17) Ranman[w] 3 fl oz (7,13,19) Revus[w] 8 fl oz (9,15)	0.3	2.5	b	3.5	b	21.8	b	185.1	b		7.3	cd
Eleonora	Untreated control	5.5	22.3	ab	40.6	a	76.2	a	1204.3	a		29.0	bc
Eleonora	Regalia 3 qt (1,2) Actinovate 6 oz (4,6,8,10,12,14,16,18) Trilogy 1 % v/v (5,7,9,11,13,15,17,19)	10.2	24.0	ab	45.5	a	79.8	a	1287.9	a		32.0	b
Eleonora	Ridomil 1 qt (2) Quadris 15.5 fl oz (3) Ranman[w] 3 fl oz (5,9,13,17) Revus[w] 8 fl oz (7,11,15,19) K-Phite 1 qt (7,9,11,13,15,17,19)	0.5	1.1	b	4.1	b	7.8	b	74.7	b		2.0	d
Eleonora	Quadris 15.5 fl oz (3) Zorvec[w] 2.4 fl oz (5,11,17) Ranman[w] 3 fl oz (7,13,19) Revus[w] 8 fl oz (9,15)	0.3	0.0	b	0.9	b	10.4	b	74.4	b		0.0	d
P-value (treatment)		0.0797	0.0001		0.0001		0.0001		0.0001			0.0001	

Integrated BDM management

Planting and harvesting

- Seed transmission
  - Use certified seeds
  - Seed treatment
- Crop residue management
  - Sanitize and pre-treat greenhouses, shed houses etc.
  - Thorough tilling and disking field soil
  - Crop rotation – avoid Lamiaceae
- Planting time (escape), sunny weather good for basil
- Optimal fertigation
  - Avoid excessive nitrogen – susceptible tissues for biotrophs
  - Drip irrigation
- Harvesting (timely and regularly)
  - Economic returns
  - Increased ventilation

Integrated BDM management

SAR inducers

ASM is very effective in greenhouses

- Optimal rate, method and timing
- Combine with fungicide/s for sustained efficacy

- ASM or BABA application alone doesn't guarantee disease control

Integrated BDM management

Biologicals

- Tested biologicals at TREC highlighted that disease reductions by applying only biologicals are non-significant
- For some oily compounds, appearance on basil may affect marketability

Fungicides (Chemistries)

- Quadris, Revus, Prophyt and QGU42 effectively controlled downy mildew in greenhouses and under field conditions
- Quadris is registered for use in field grown basil to control other foliar diseases
- How frequent Vs. economic return
- Fungicide field trials at Univ. of Florida, Rutgers, Cornell, Illinois

Integrated BDM management

Resistance cultivars

- Greenhouse (highly resistant)
  - Lemon basil, Dani lemon, Indian basil
  - Red rubin, Dark opal, Purple delight
- Field (moderate to highly resistant)
  - Lemon basil, Dani lemon, Indian basil,
  - Red rubin, Dark opal, Purple delight
- Unfortunately most popular sweet basil cultivars are highly susceptible to downy mildew

- On going efforts of selection/breeding at NJ & NY

Basil Workshop 2015

Sweet basil (*Ocimum basilicum*) production has been severely impacted by the relatively new downy mildew disease. Coupled with ongoing challenges relating to fusarium, chilling injury and other postharvest problems, growers and distributors have been scrambling for answers to keep the industry profitable and growing. This workshop brings together leading researchers in basil breeding, genetics and, plant disease management with buyers, distributors, commercial growers and seed companies to address the latest progress that has been made to overcome these issues.

One of the Rutgers many basil lines being bred for genetic resistance to downy mildew

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VEGETABLE GROWERS ASSOCIATION of NEW JERSEY, INC.

SCRI Basil Workshop

The Rutgers New Use Agriculture and Natural Plant Products Program, Host

Foran Hall, New Wing 3rd Floor, School of Environmental and Biological Sciences

Cook College Campus

59 Dudley Road, New Brunswick, NJ

Rutgers University

aesop.rutgers.edu/~newuseag

SCRI Basil Workshop

USDA

Specialty Crop Research Initiative

(In conjunction with New Jersey- Annual Agricultural Convention and Trade Show)

New Jersey State AGRICULTURAL CONVENTION 100 YEARS 1915 2015

848- 932-6311

Thank You !!