

**Downy mildew of spinach –  
Are we making progress?**

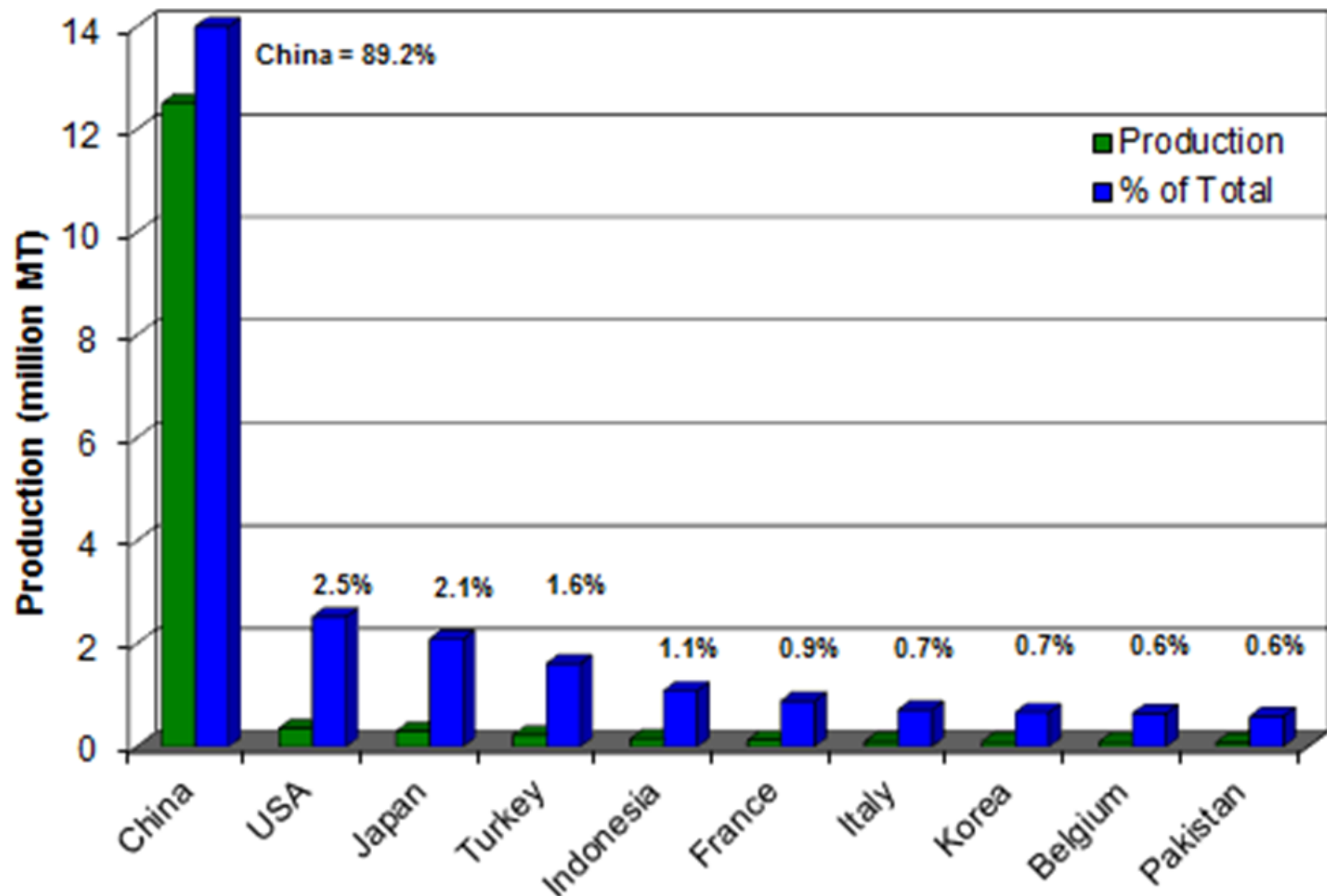
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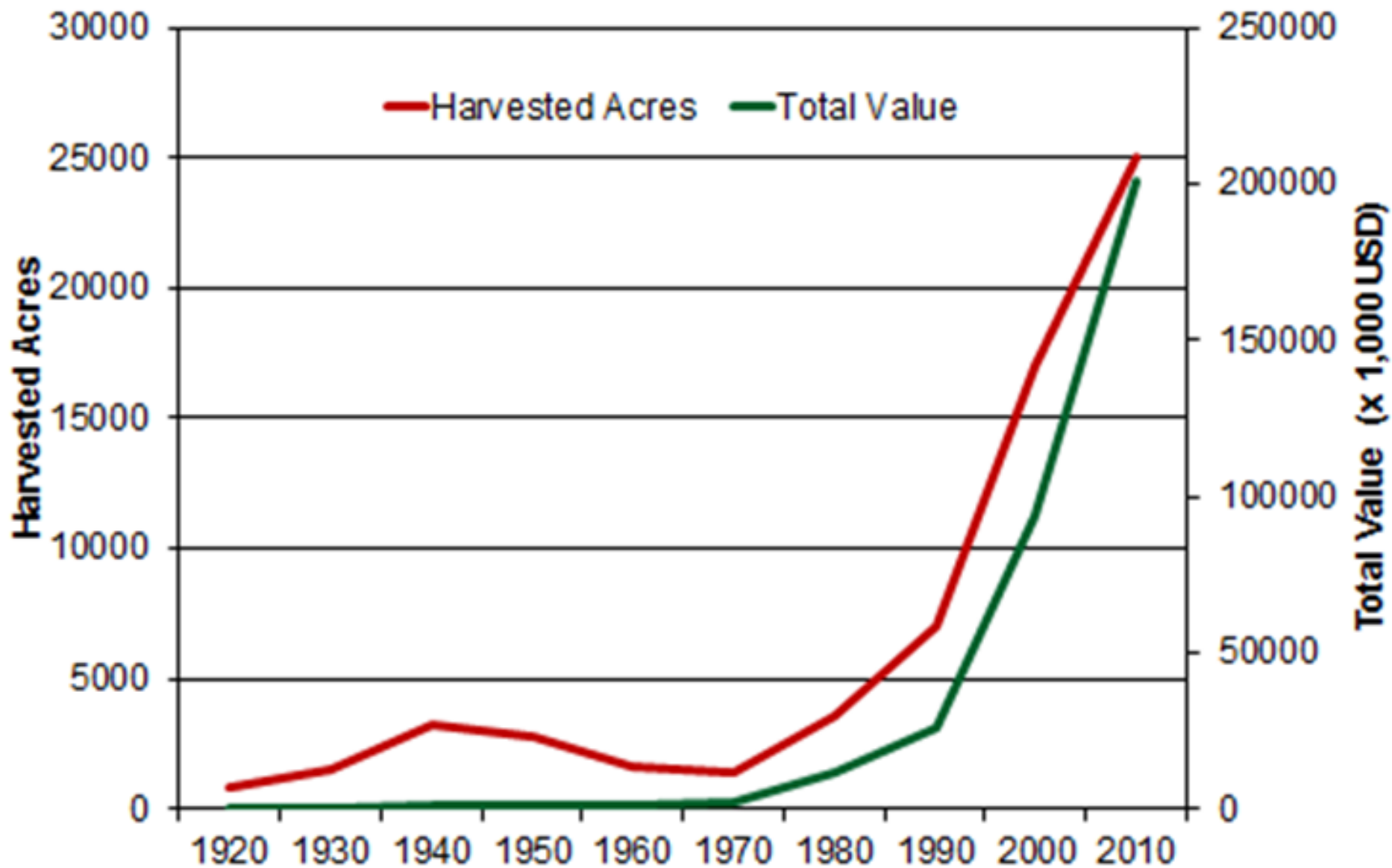




# Top ten spinach producing countries



# Fresh Market Spinach in California



USDA-NASS, 2011



# Intensive – Spinach Harvest

















# Downy Mildew - Before 1990

- 3 races
- No standard differentials
- No IWGP
- Little information available on resistance and genetic control
- One gene/locus controls 1 race
- **Vertical (major gene) resistance**
- Horizontal (minor gene) resistance



# Downy Mildew - 2011

- 13 races plus UA4410
- Standard differentials
- NILs by 2013
- Coordinated IWGP
- Genetics of resistance – 6 hypothesized loci
  - Dominant resistance
  - Each locus controls a few to many races
  - Horizontal (minor gene) resistance



Table 1. Disease reactions of spinach differentials for race identification of the spinach downy mildew pathogen *Peronospora farinosa* f. sp. *spinaciae*.

Differential cultivar	Race <sup>1</sup>													4410
	1	2	3	4	5	6	7	8	9	10	11	12	13	
<b>Viroflay</b>	+	+	+	+	+	+	+	+	+	+	+	+	+	+
<b>Resistoflay</b>	-	-	+	+	+	+	+	+	+	+	+	+	+	+
<b>Califlay</b>	-	+	-	+	-	+	+	-	-	+	-	-	+	-
<b>Polka</b>	-	-	-	+	-	+	+	-	-	+	-	-	+	-
<b>Clermont</b>	-	-	-	-	+	+	+	+	+	+	+	+	+	+
<b>Campania</b>	-	-	-	-	-	+	-	+	+	+	-	+	+/-	+
<b>Dolphin</b>	-	-	-	-	-	-	-	+	-	+	-	+	-	+
<b>Avenger</b>	-	-	-	-	-	-	-	+	-	+	-	+	-	+
<b>Lion</b>	-	-	-	-	-	-	-	-	-	+	-	-	-	-
<b>Lazio</b>	-	-	-	-	-	-	-	-	-	-	+	+	+	+
<b>Whale</b>	-	-	-	(-)	-	(-)	(-)	-	-	+	-	+	+	+
<b>Pigeon</b>	-	-	-	-	-	-	-	-	-	-	-?	-?	-	+



# Announcement of race 13

IWGP and California Cooperative Extension

Benoeming van fysio Pfs: 13, een nieuwe fysio van valse meeldauw in spinazie



The screenshot shows a blog post from the University of California Salinas Valley Agriculture website. The header features the university's logo and name. The post title is "Naming of Another New Race (Race Pfs 13) of the Spinach Downy Mildew Pathogen", posted by Lennis Arriaga on August 5, 2011. The author is identified as Jim Correll, University of Arkansas Steven Koike, University of California Cooperative Extension. The page includes navigation links, a subscribe section with an RSS icon, and social media sharing options.

University of California  
Salinas Valley Agriculture

SUN, OCT 2 2011 4:49:05

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Naming of Another New Race (Race Pfs 13) of the Spinach Downy Mildew Pathogen  
Posted By: Lennis Arriaga  
August 5, 2011  
Written by: Jim Correll, University of Arkansas Steven Koike, University of California Cooperative Extension

# Identification of DM races

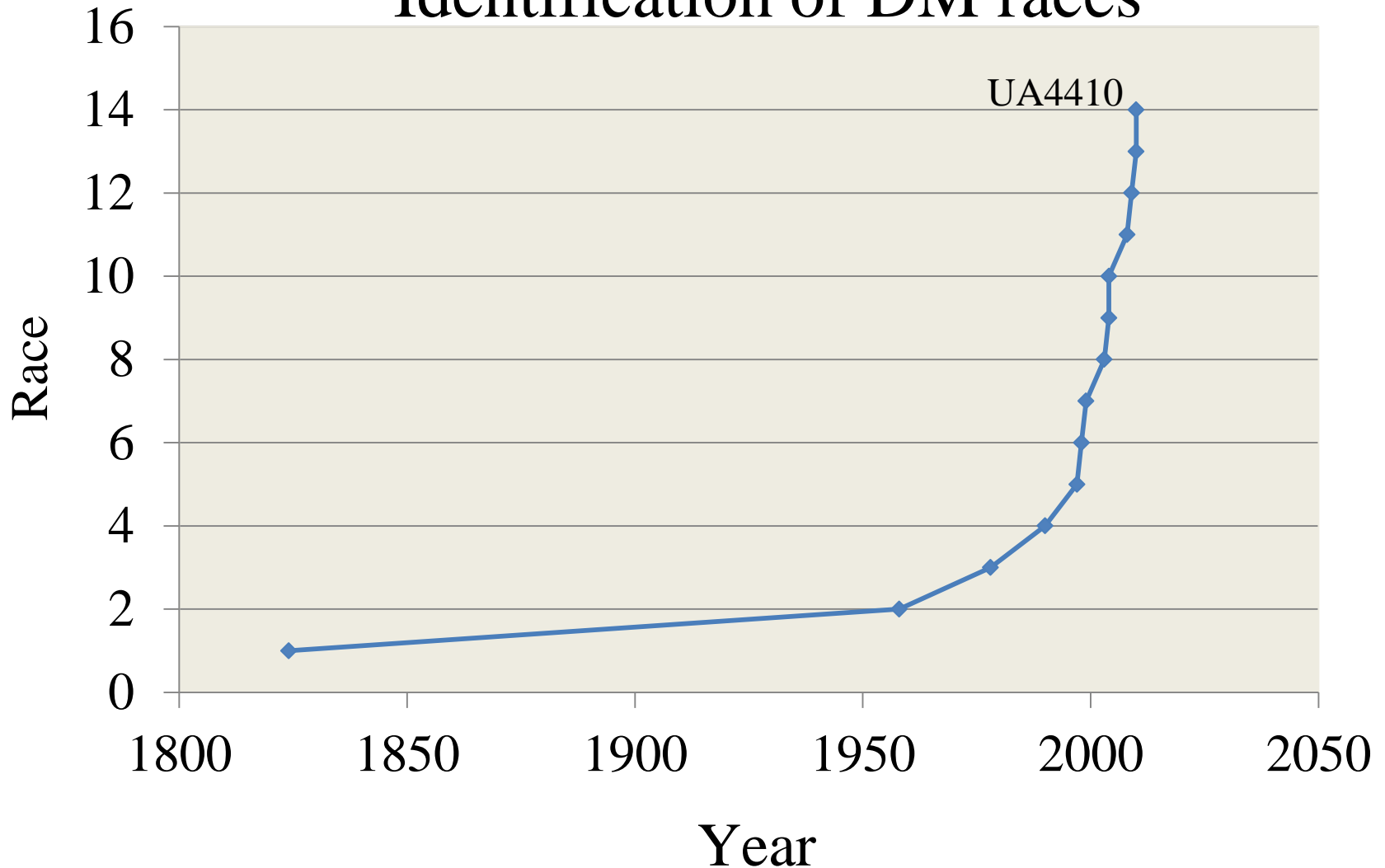
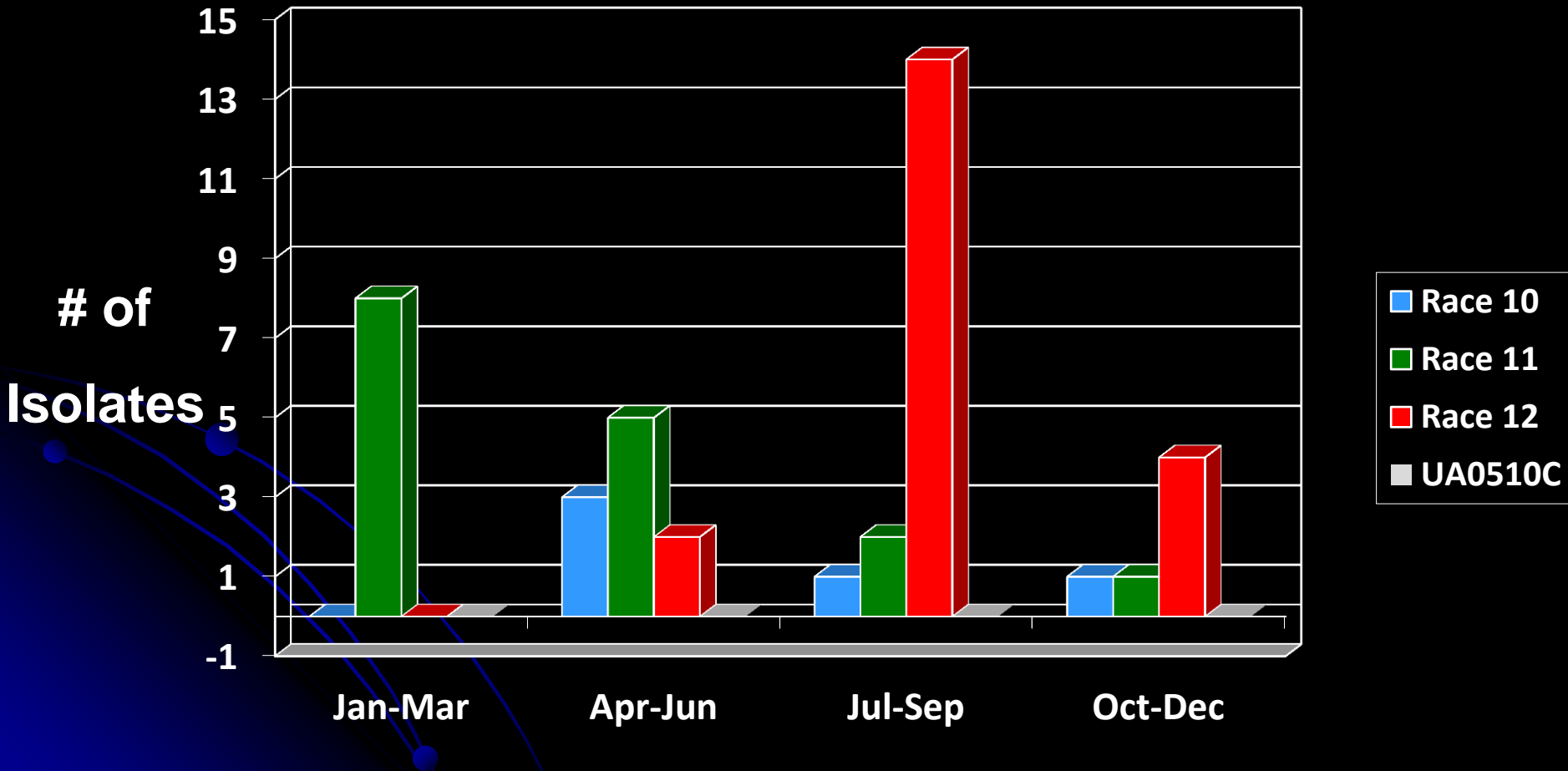


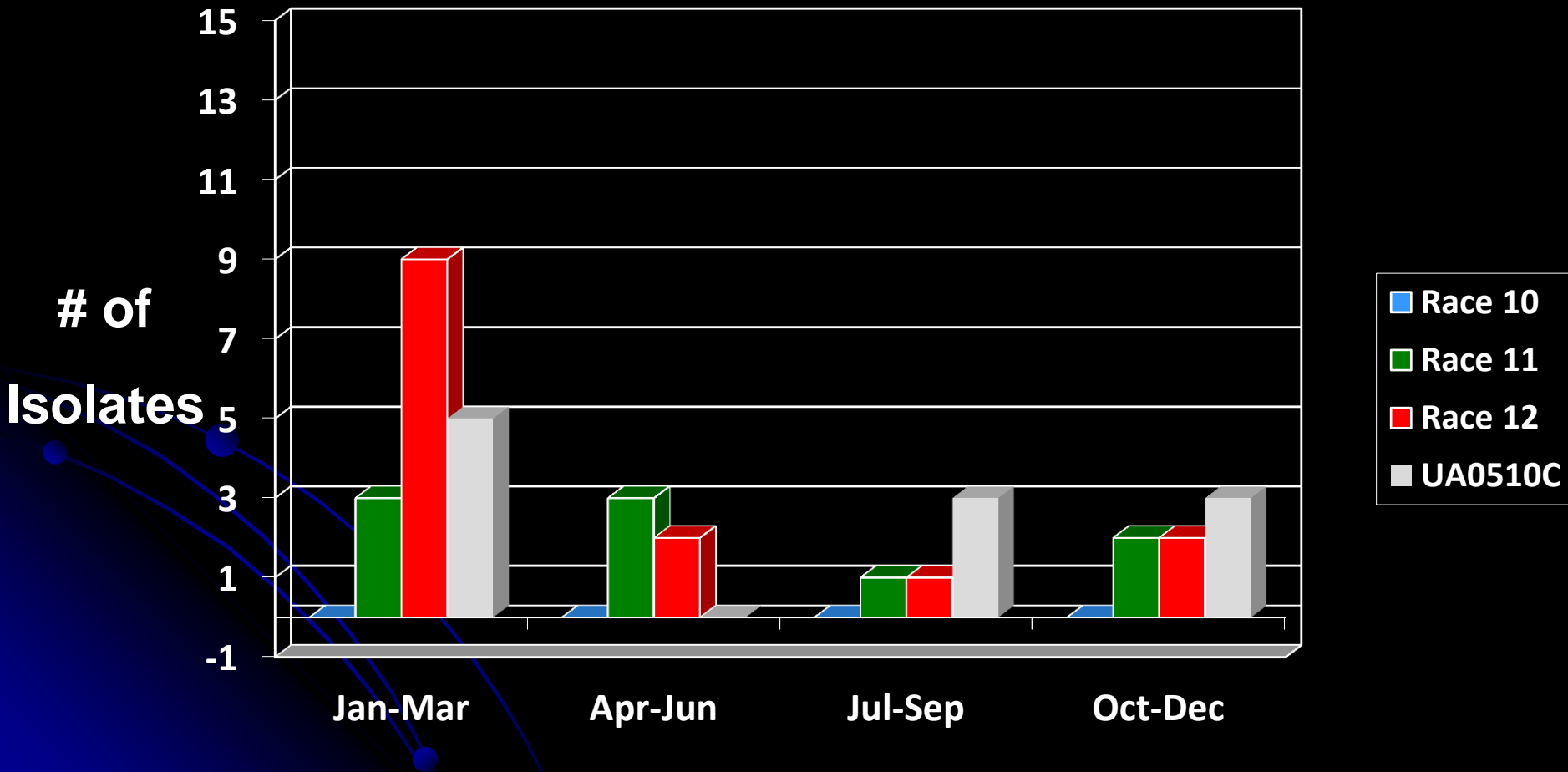
Fig.3 The discovery of spinach downy mildew races by years. New races have been emerged dramatically in the last decade.



# Mildew Races Identified 2009

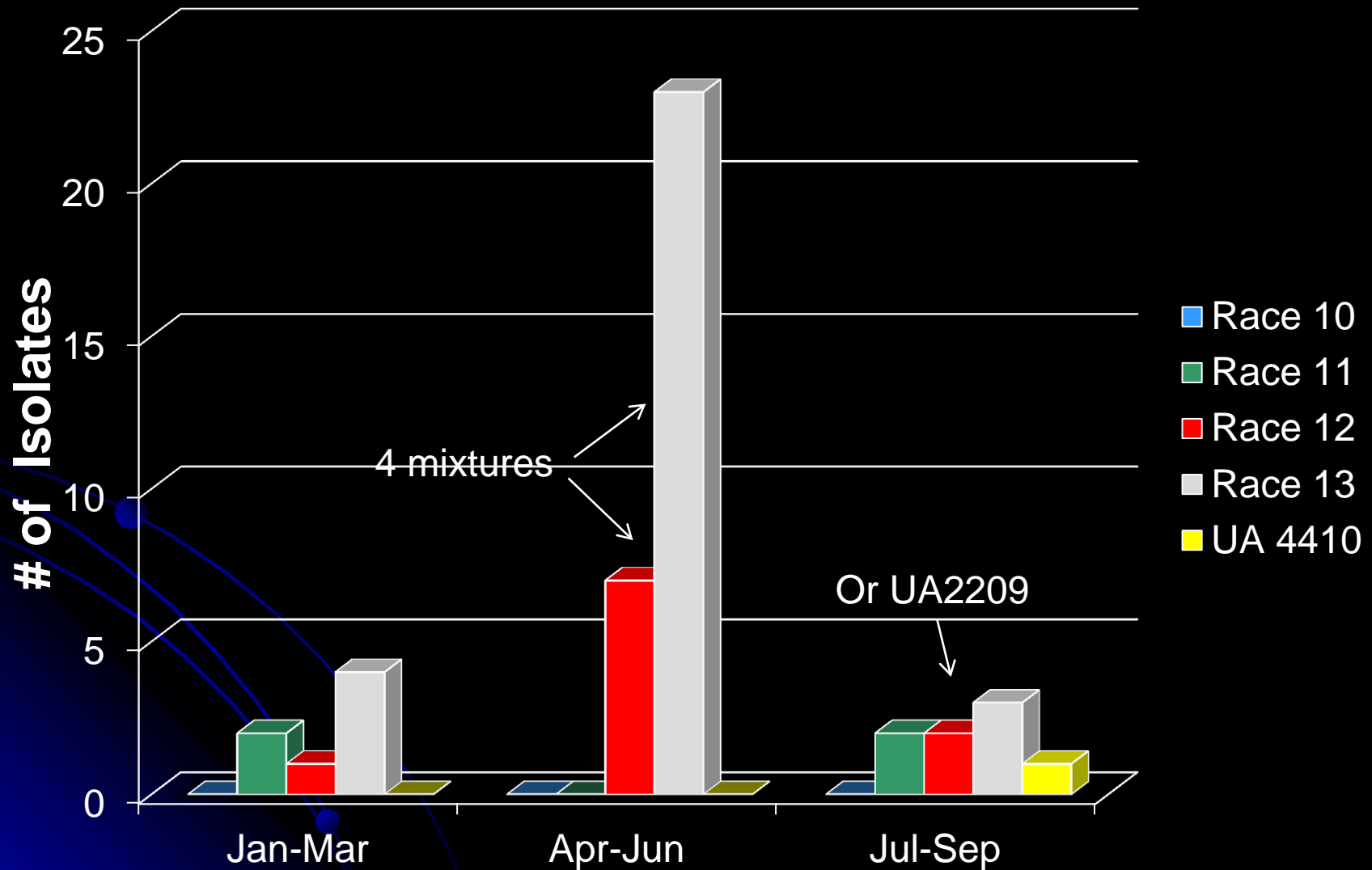


# Mildew Races Identified 2010





# Mildew Races Identified 2011



**UA2511A (Pigeon isolate)**

**All differentials  
Susceptible  
Except Lion**

**UA2511APL(Purified on NIL1)**

**UA2511APC(Purified on Califlay)**

Differential	Disease Response
Viroflay	+
Resistoflay	+
Califlay	-
Bolero	+
Compania	+
Avenger	+
Lion	-
Lazio	+
Dolphin	+
Polka	-

Race 12

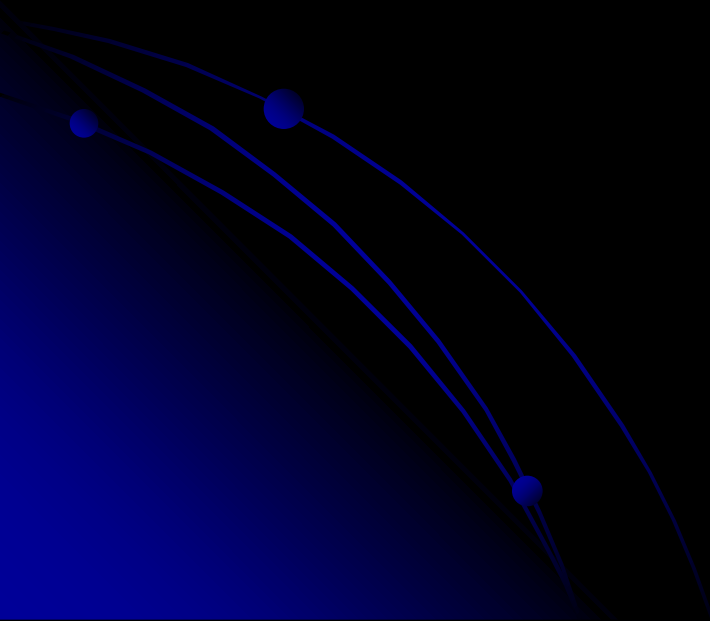
Differential	Disease Response
Viroflay	+
Resistoflay	+
Califlay	+
Bolero	+
Compania	+
Avenger	-
Lion	-
Lazio	+
Dolphin	-
Polka	+

Race 13



# How do you build “durable” resistance?

- Vertical, or qualitative, resistance
- Horizontal, or quantitative, resistance



# Vertical Resistance



# Vertical Resistance Breached





# Horizontal Resistance



# Horizontal Resistance Breached



# Tsunami !





# Spinach Downy Mildew Vertical Resistance Loci

Locus	1	2	3	4	5	6	7	8	9	10	11	12	13	4410
none	S	S	S	S	S	S	S	S	S	S	S	S	S	S
<i>RPF-1</i>								S		S		S		S
<i>RPF-2</i>											S	S	S	S

- Can “build” resistance into hybrids

Use of molecular markers linked to loci of interest

SCALE 0

1

2

3

4



# Horizontal Resistance

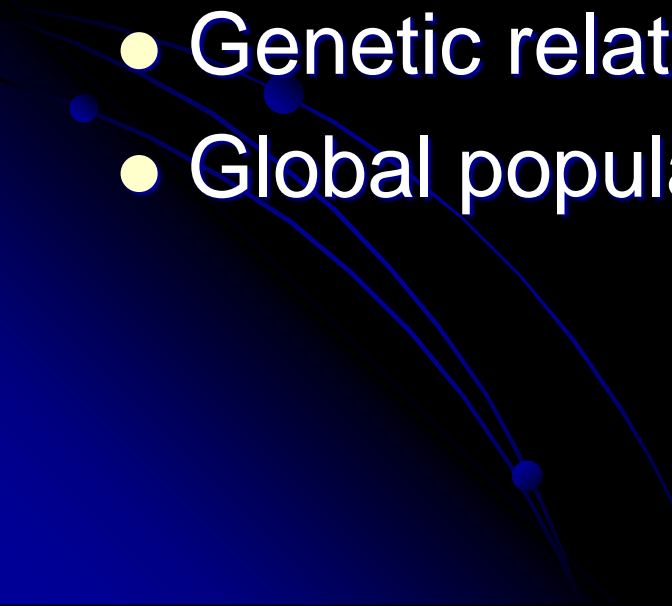
- Varying levels
- All levels can be overcome
- Race specific
- Difficult to phenotype
- Difficult to select for
- Difficult to combine vertical and horizontal



# Downy Mildew – 2030 ???

- More than 14 races
- Approaching Bremia complexity?
- NILs and genetics of resistance improved
- Additional resistance loci identified
- Pyramiding of major genes (molecular markers and phenotyping)
- Combine major and minor resistance – more durability?
- Sequence information of resistance loci

# Downy Mildew – 2030 ???

- Genetics of the pathogen
  - Sexual recombination
  - Seedborne nature of the pathogen
  - Long distance movement
  - Genetic relationships among races
  - Global population diversity
- 

2011





Dank u wel !

