Nematode detection and Management in Vegetable Crops (Georgia Perspective)

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Economic importance of plant-parasitic nematodes

- Out of 20,000 described species, more than 4,000 are parasites of plants

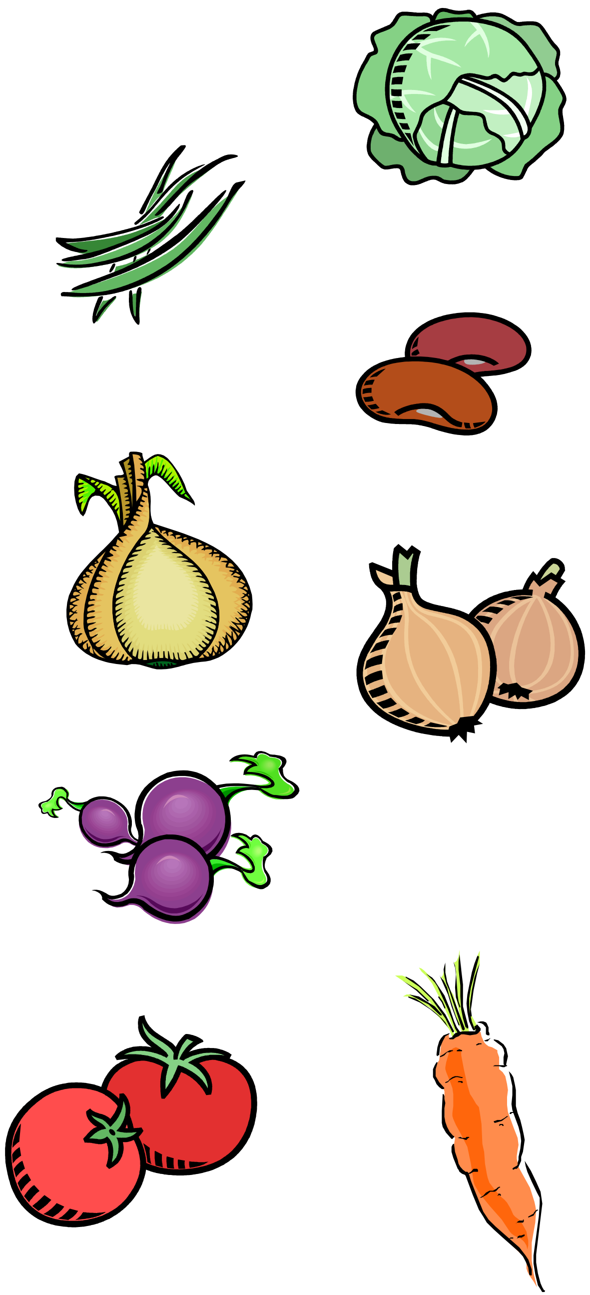
- \$80-100 billion/yr (5%) yield loss worldwide

- \$6-8 billion/yr in USA

- 11% annual yield loss in 24 vegetable crops in USA

Most important nematode pests of vegetable crops

- Root-knot — *Meloidogyne* spp.
- Stubby root — *Paratrichodorus minor* and *P. allius*
- Sting — *Belonolaimus longicaudatus*
- Reniform — *Rotylenchulus reniformis*
- Root lesion — *Pratylenchus* spp.
- Stunt — *Tylenchorhynchus spp.*



Root-knot nematodes (RKN), *Meloidogyne* spp.

- A specified plant pathogen that infects over 2000 plant species.

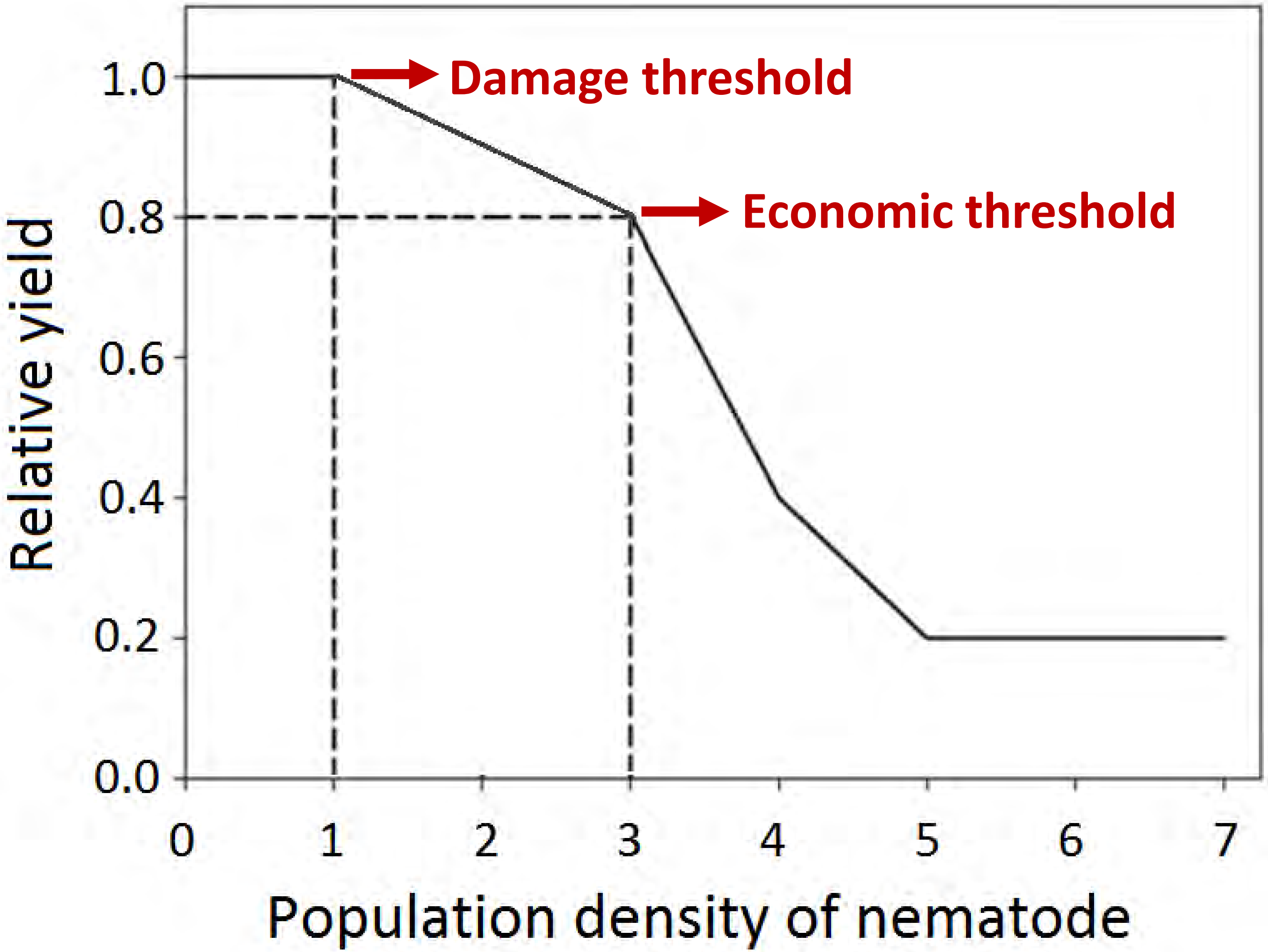
- Annual crop yield losses estimated up to 5% globally.

- Major yield-limiting pathogen of agricultural crops in the US.

- Obligate sedentary endoparasites of plant roots.

- Develop sophisticated interactions with their host.

Typical relationship between RKN numbers in the soil at planting and relative crop yield



Damage thresholds: The initial population density at which a detectable yield loss occurs and control methods should be applied to prevent crop loss

Economic thresholds: The initial population density at which the cost of nematode control is equal to the crop value

Damage thresholds of plant-parasitic nematodes (per 100 cc of soil) in vegetables

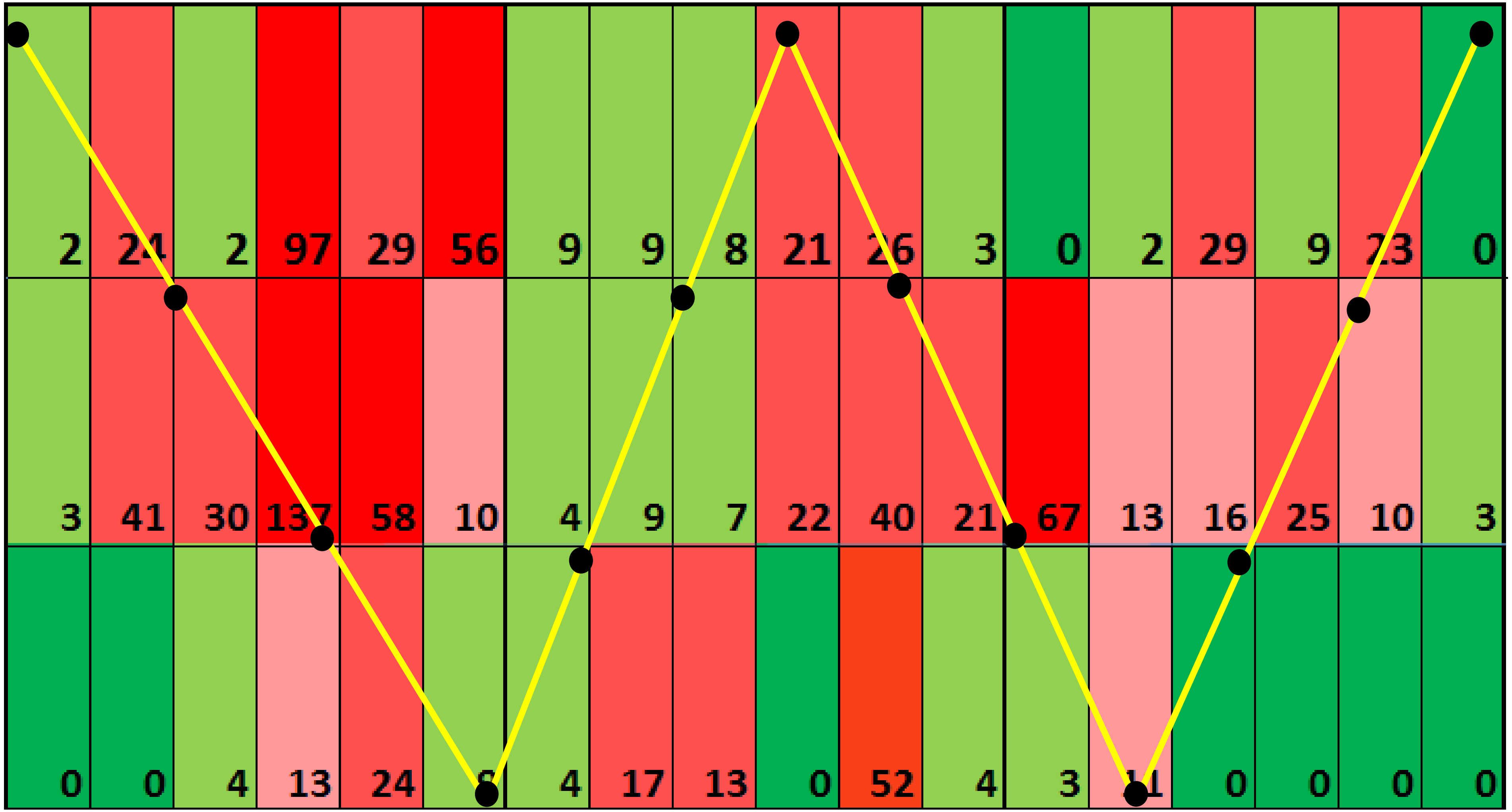
	Root knot	Stubby root	Sting	Lesion	Stunt	Reniform
Cucurbits	1	>1	1			
Crucifers	1	>1	1	>50		
Tomato	1	>1	1	>40		
Eggplant, Okra, Peppers, Squash	1	>1	1	>50	>30	
Potato (sweet)	1	>1				
Carrot	1	>1	1	>10		
Beans/Peas	1	>1	1			>1
Watermelon, Cantaloupe	1	>1				>1
Onion	1	>1				

Soil sampling plays a significant role in detecting damage thresholds and implementing proper management procedures.

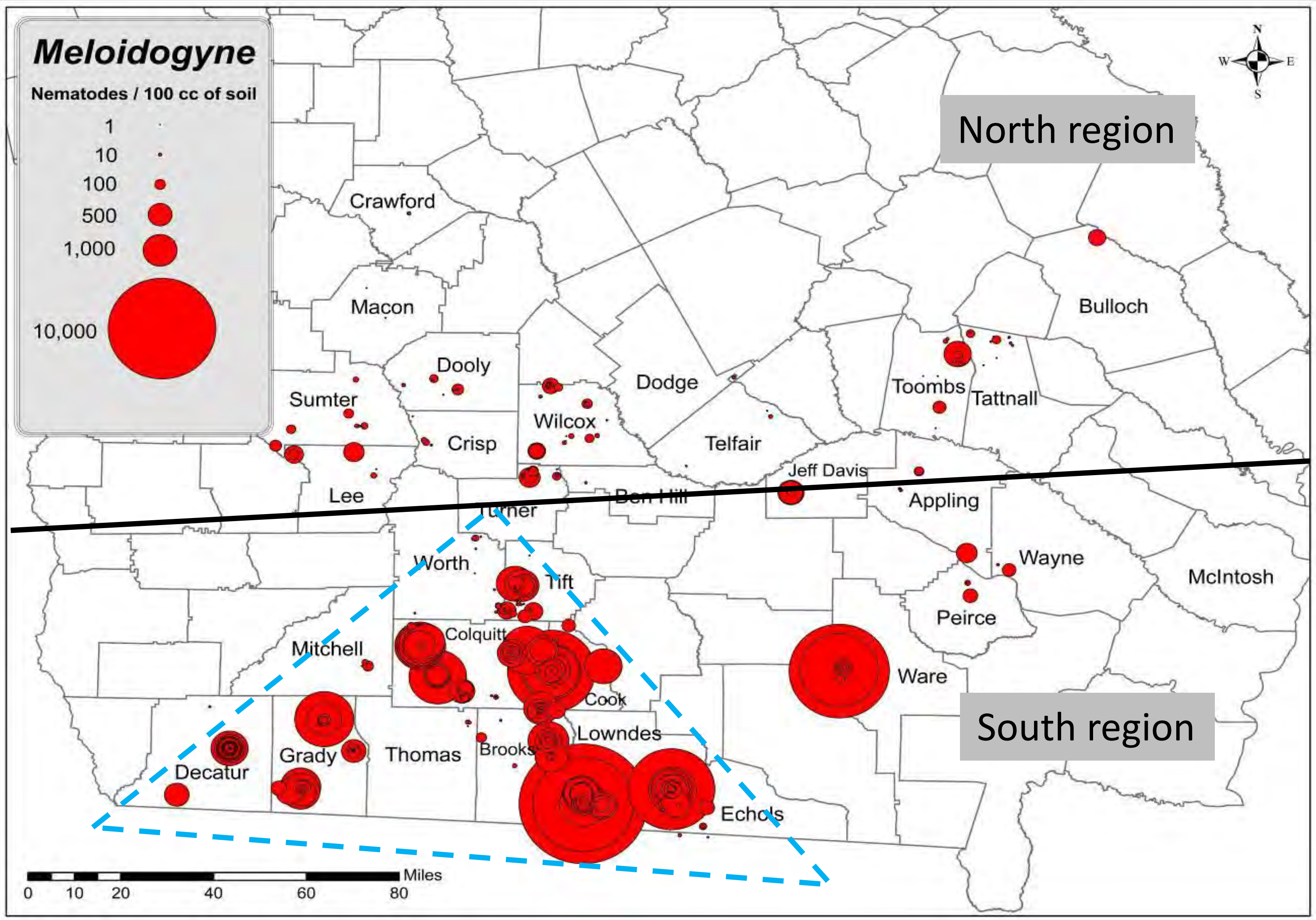
2	24	2	97	29	56	9	9	8	21	26	3	0	2	29	9	23	0
3	41	30	137	58	10	4	9	7	22	40	21	67	13	16	25	10	3
0	0	4	13	24	9	4	17	13	0	52	4	3	11	0	0	0	0

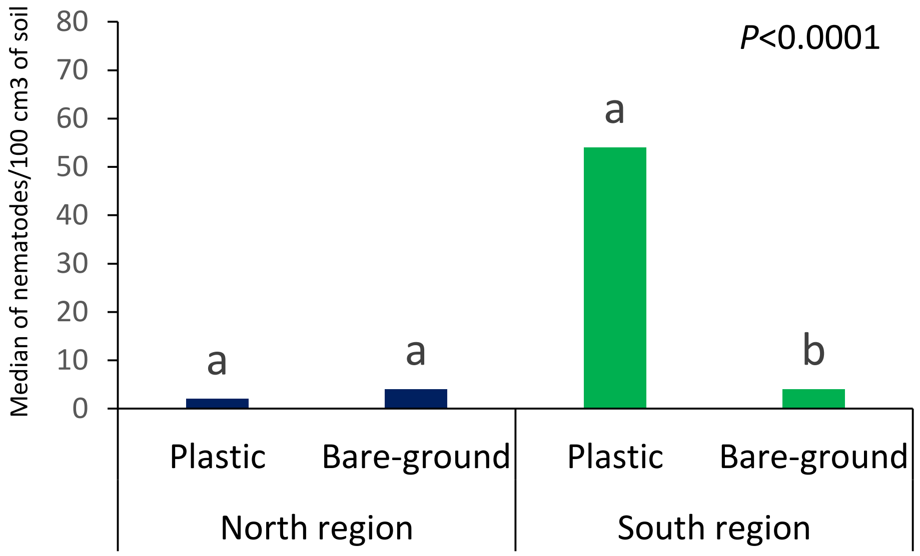
Map of root-knot nematode counts in 100 cc of soil

Soil sampling techniques (ex. zig-zag patterns) need to consider the uneven distribution of nematodes in fields to obtain a truly representative sample.



Do the cropping systems affect the distribution and infestation pressure of root-knot nematodes in vegetable fields in Southern Georgia?





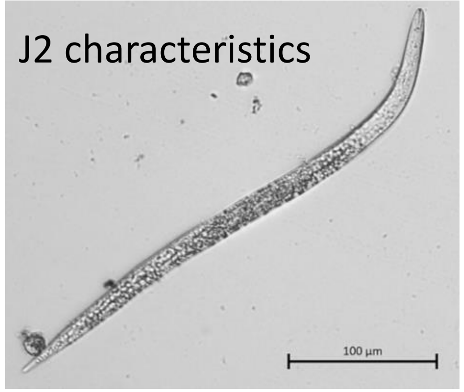
- *Meloidogyne* spp. was the predominant plant-parasitic nematode associated with plastic beds in the South region.
- The South region consisted mainly of commercial fields that rotated multiple vegetable crops through the same plastic beds.

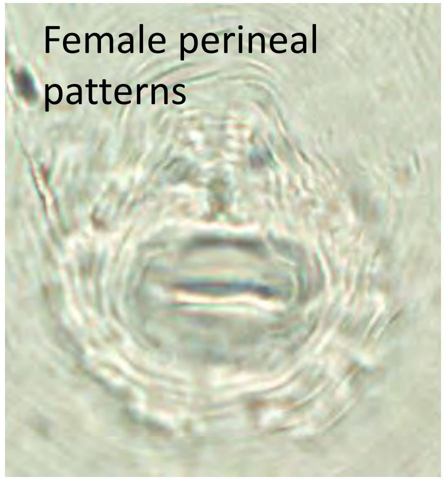
Which RKN species (*Meloidogyne* spp.) are of most significant concern to vegetable growers?

- ***M. incognita***
- ***M. arenaria***
- ***M. javanica***
- ***M. floridensis***
- ***M. haplanaria***
- ***M. enterolobii***

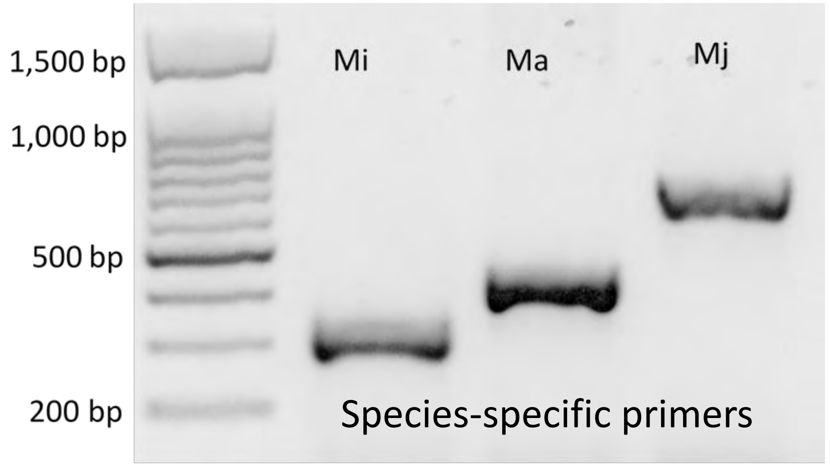
Identification

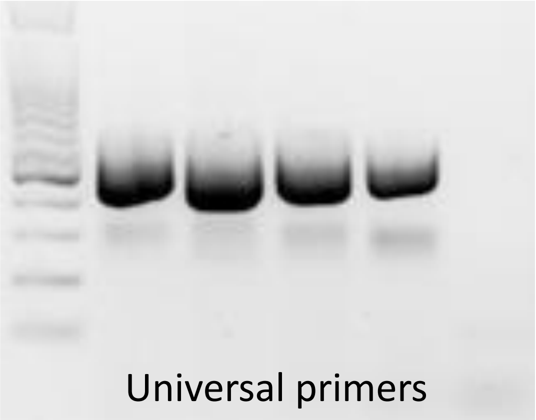
Morphology





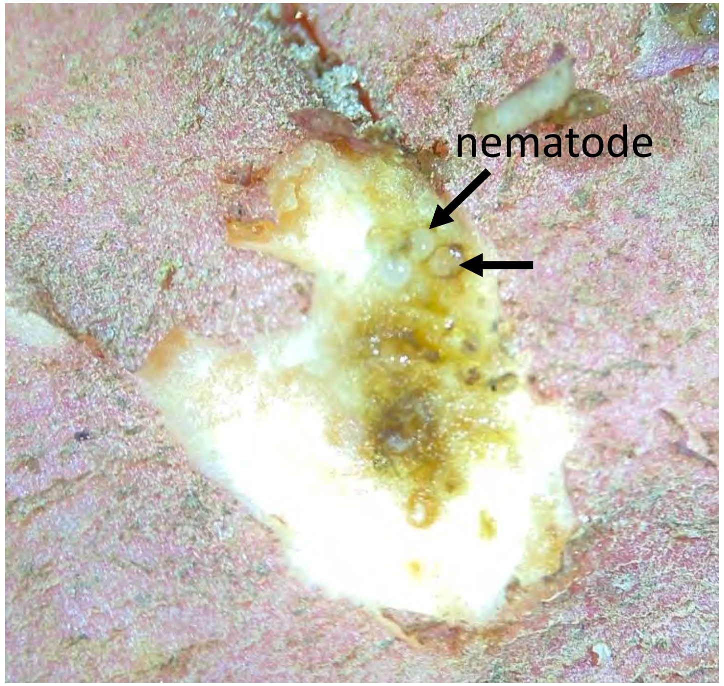
Molecular analyses





Meloidogyne enterolobii

- An emergent problem in the Southeast, USA
- First reported in FL in 2005 on tomato and recent years in NC, SC, LA and GA.
- The nematode seems to be distributed to other regions mainly through infected sweetpotato seed.
- Overcomes the resistance developed against other RKN species in several crops including sweetpotato, tomato, pepper, tobacco, and cotton.

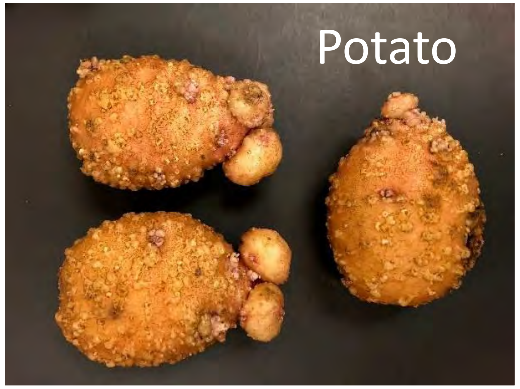


FINDMe

Focused INvestigations on the Distribution and management of *Meloidogyne enterolobii*

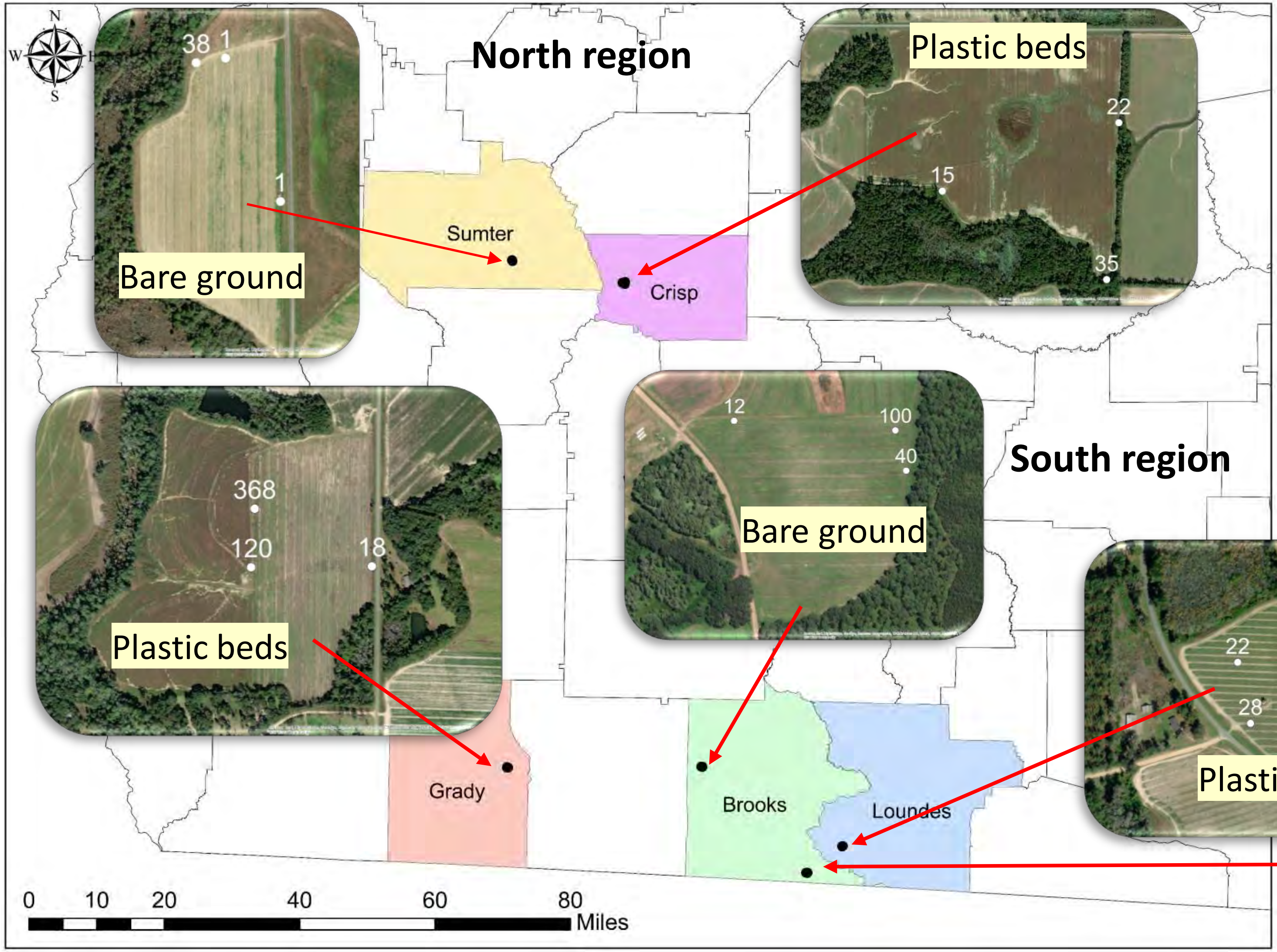
www.findmenematode.org

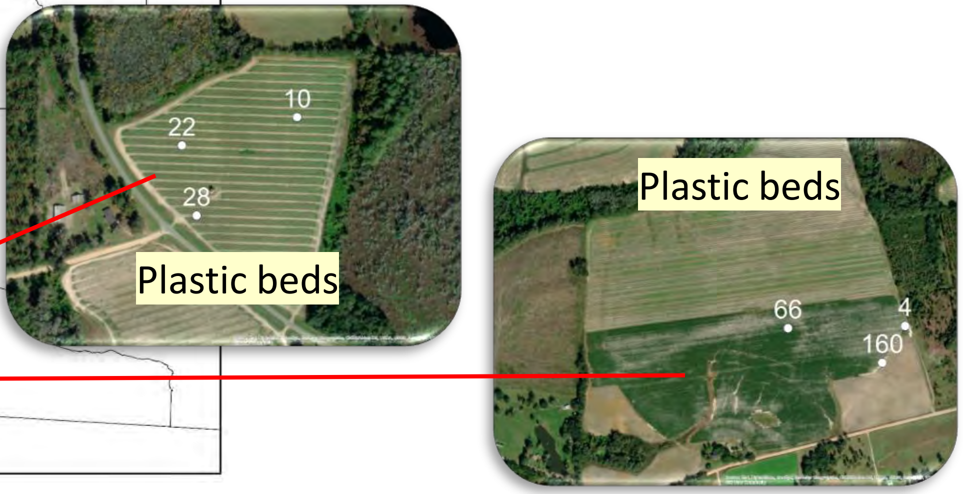
RKN damage symptoms



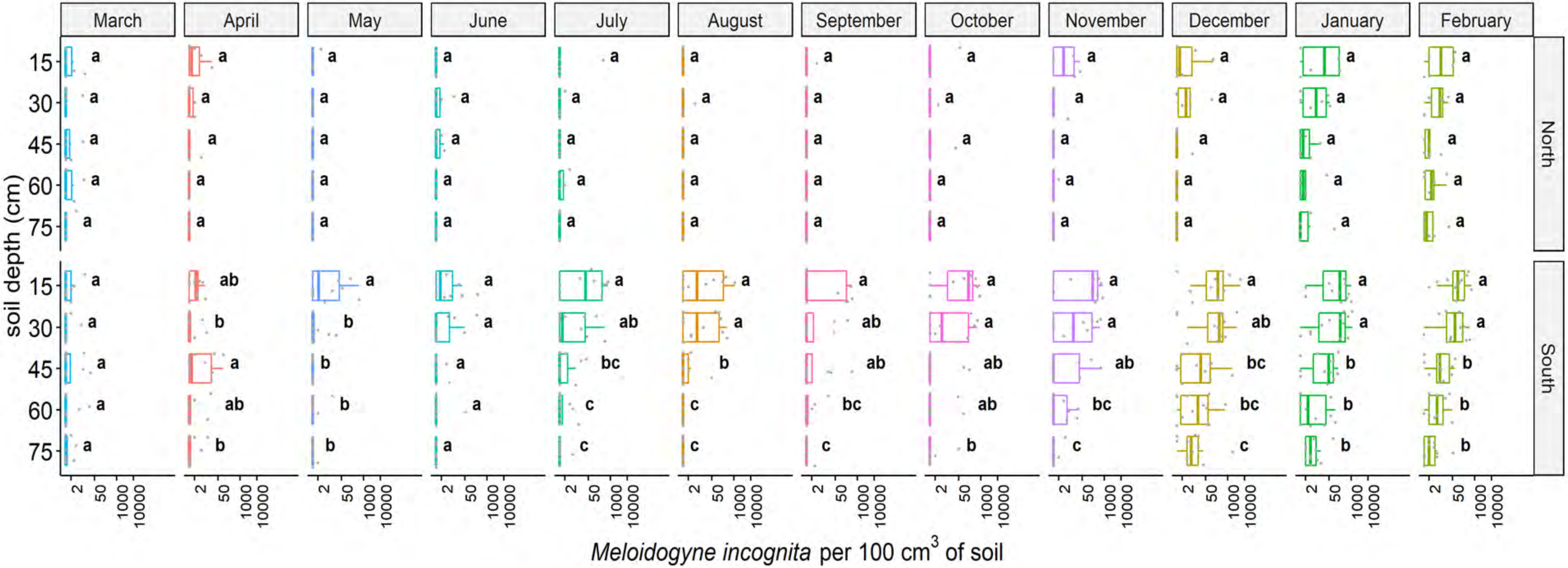
How do root-knot nematodes migrate in the soil and what factors affect their population dynamics?

- Monthly sampling of different vegetable fields from March 2019 to February 2020
- Nematode analysis was conducted in three locations per field at 5 soil depths with 15 cm intervals
- Environmental and edaphic factors measured include soil temperature at 5, 10, and 20 cm, sand, clay, gravimetric soil moisture, volumetric soil moisture bulk density, porosity, water filled porosity and air filled porosity

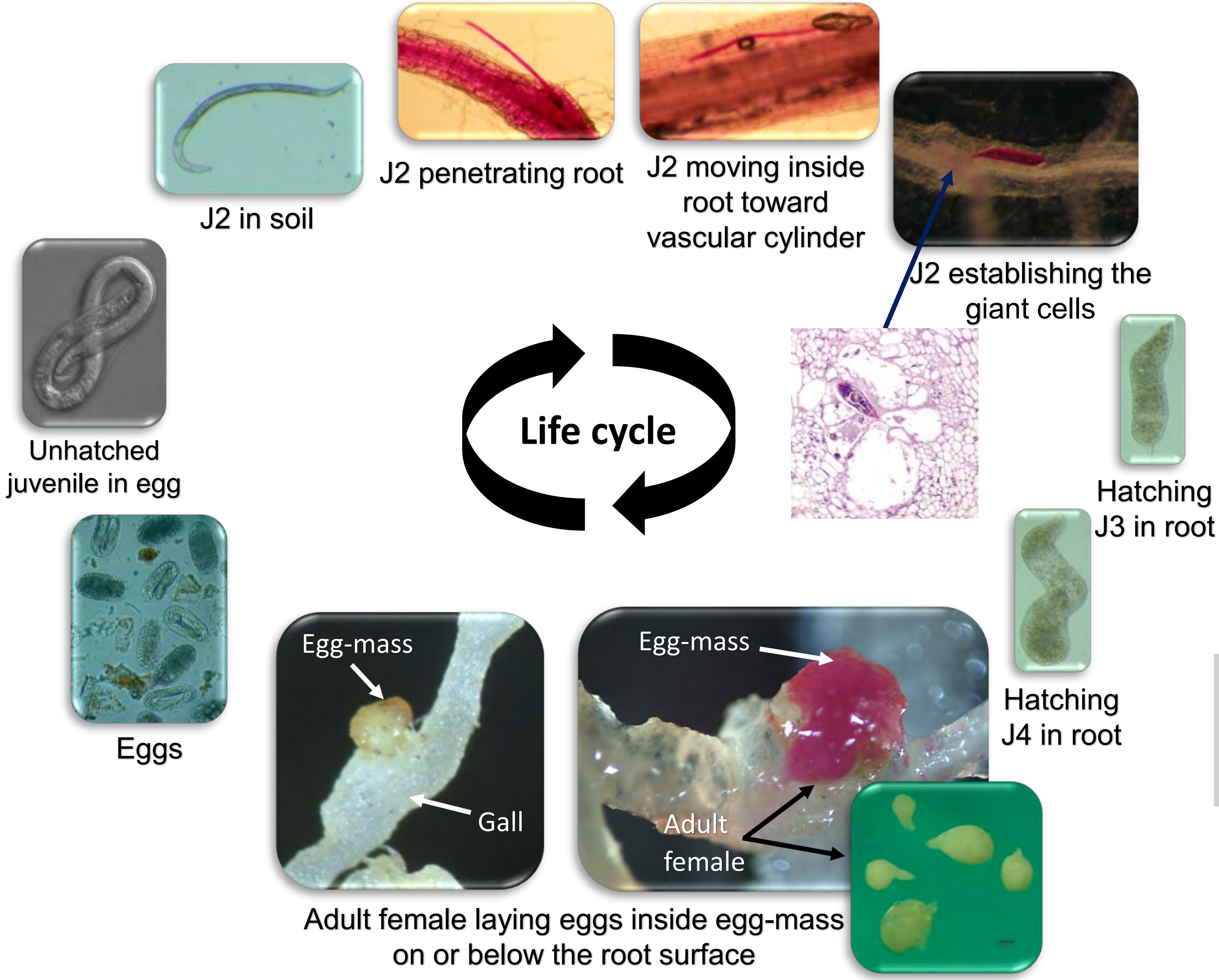




- **Patterns of vertical migration of root-knot nematodes are limited to cold months (December to April) in the south region.**
- **Soil temperature and latitude plays a significant role in nematode migration**



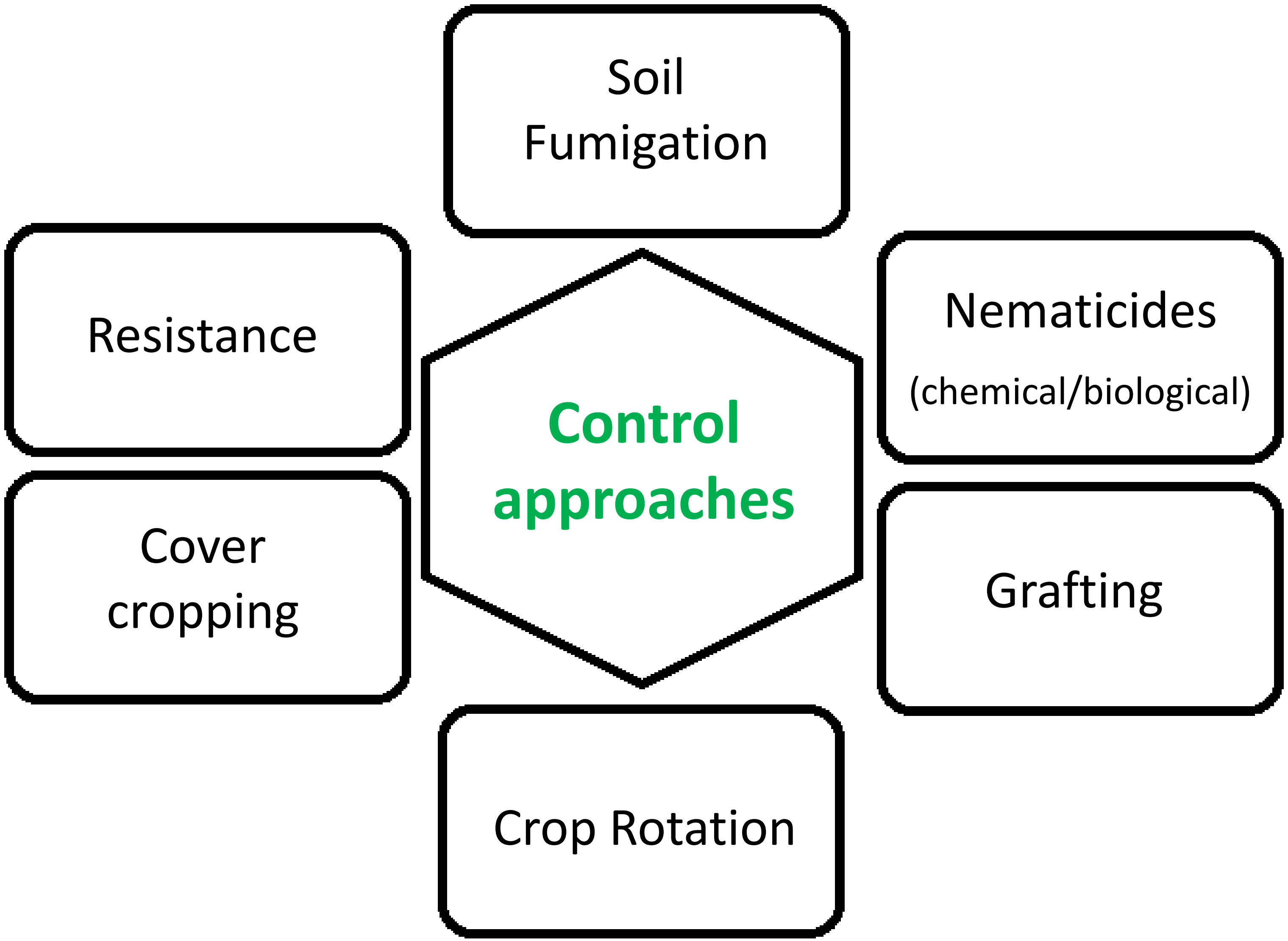
There is a direct relationship between RKN development and soil temperature.



RKN life cycle under the southern Georgia's climate

- 20-25 d (April-October)
  - 2 cycles on cucurbits, beans & peas
  - 3 or 4 cycles on fruiting vegetables
- >8 wks (November-March)
  - 1 or 2 cycles on Brassica crops (crucifers)

Management of root-knot nematodes in vegetable production systems



Available fumigant chemicals for use in vegetable crops

Trade Name	Active Ingredient	Toxic Activity	Producer
Telone II	1,3-dichloropropene	Nematicide	Corteva Agriscience
Chlor-O-Pic	96.5-99% chloropicrin	Nematicide/Fungicide	Corteva Agriscience
Telone C-17	73% 1,3-D, 17% chloropicrin	Nematicide/Fungicide	Corteva Agriscience
Telone C-35	65% 1,3-D, 35% chloropicrin	Nematicide/Fungicide	Corteva Agriscience
InLine	61% 1,3-D, 33% chloropicrin	Nematicide/Fungicide	Corteva Agriscience
Pic-Chlor 60	40% 1,3-D, 60% chloropicrin	Nematicide/Fungicide	Corteva Agriscience
Pic-Chlor 80	20% 1,3-D, 80% chloropicrin	Nematicide/Fungicide	Corteva Agriscience
Vapam	Metam sodium	Broad-spectrum	AMVAC
K-Pam	Metam potassium	Broad-spectrum	AMVAC
Paladin	Dimethyl Disulfide	Broad-spectrum	Arkema Inc.
Dominus	Allyl isothiocyanate	Broad-spectrum	Isagro USA

Not on the market currently

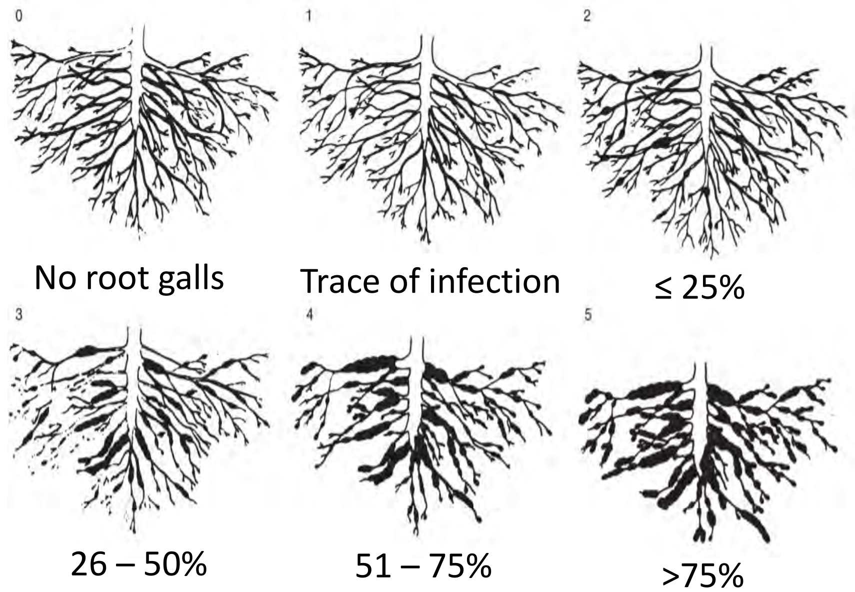
Two field trials (spring 2019 and 2020)

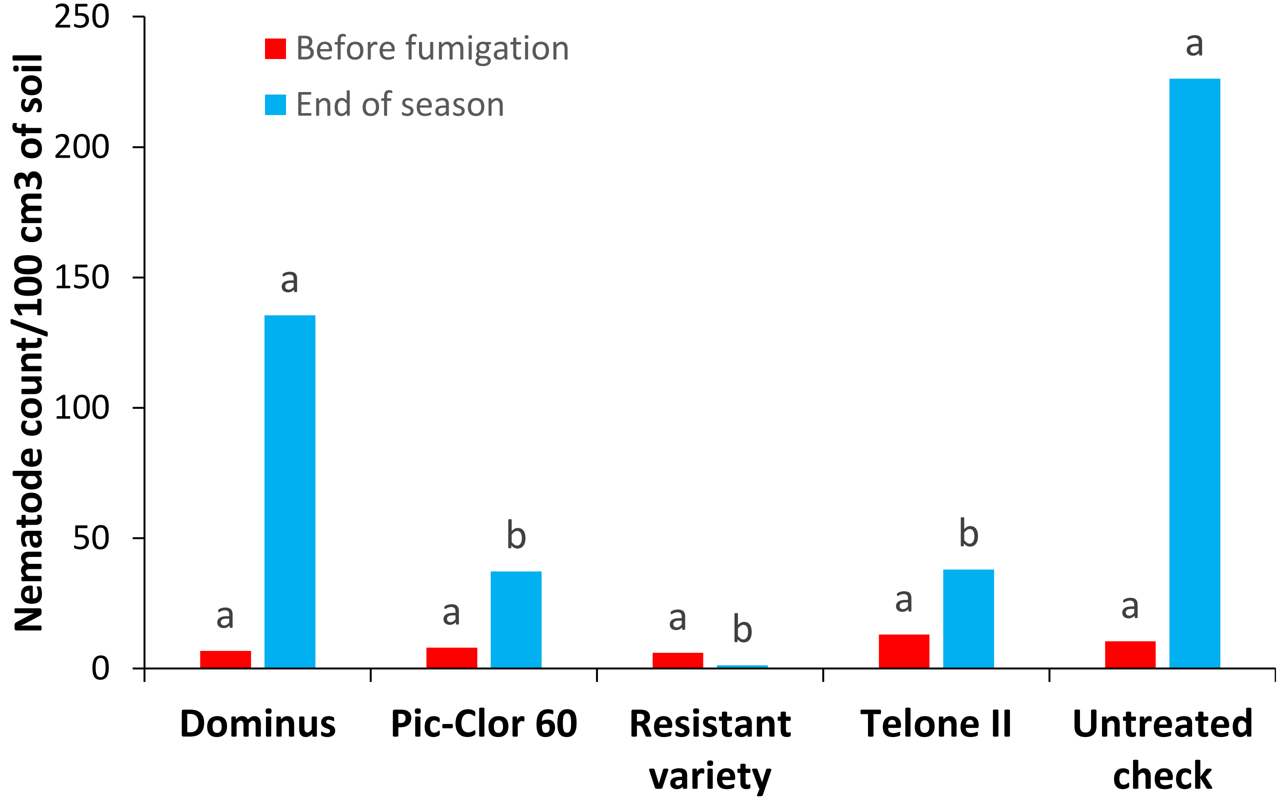
- Experiment site was infected with *M. incognita*
- 5 treatments:
  - ✓ Telone II (1,3-D) – 15 gal/A
  - ✓ Dominus (Ally Isothiocyanate)– 30 gal/A
  - ✓ Pic-Clor 60 (Chloropicrin+1,3-D) – 21 gal/A
  - ✓ Resistant pepper (cv. Carolina Wonder)
  - ✓ Untreated check (cv. Aristotle)

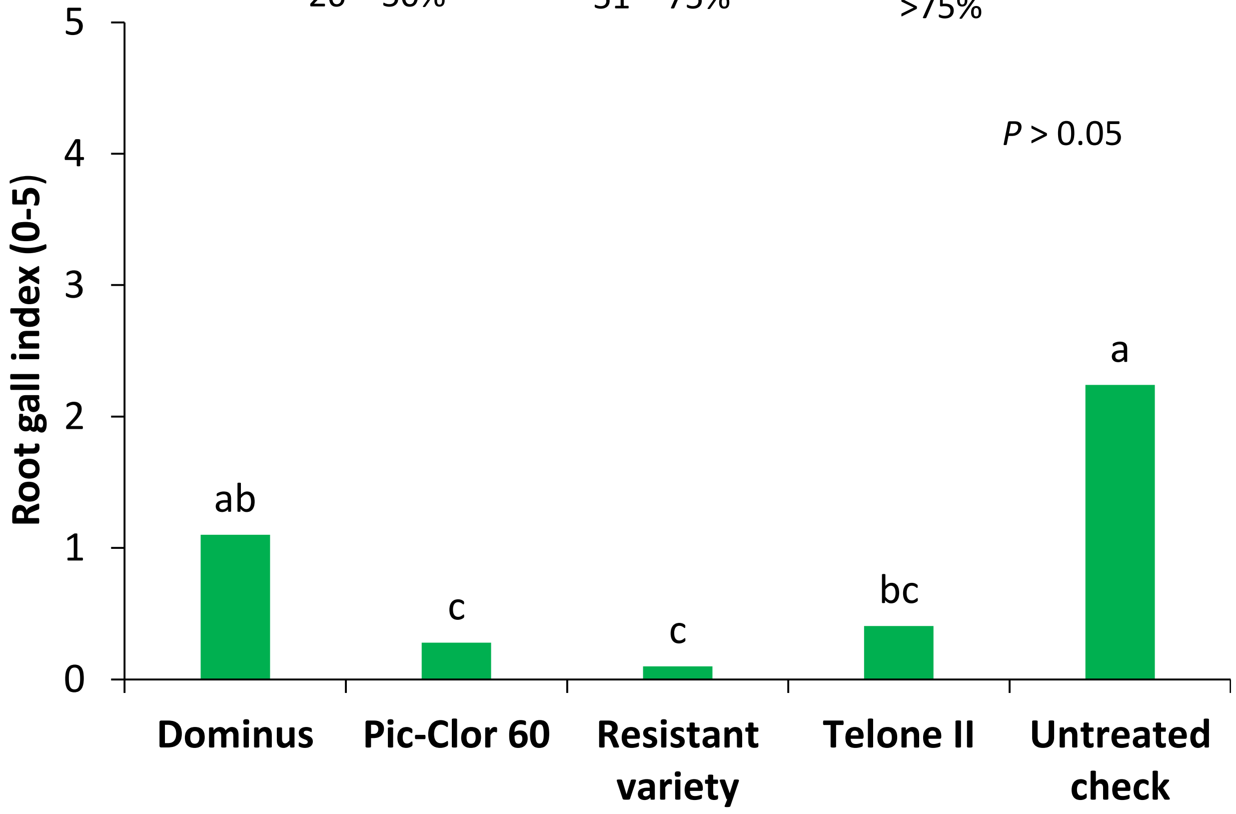
- CRD with 4 replications per treatment
- Each plot size: 170 ft × 3 ft
- Fumigants applied three backswept chisels spaced 25.4 cm apart and attached to a plastic mulch layer

- White-on-black LDPE film mulch was placed over beds
- A single row of drip tape with 12 in. spacing between emitters
- 85 plants per plot

- RKN soil populations at the end of the season was greatly reduced in the resistant cultivar, Pic-Clor 60 and Telone II plots than other treatments.
- Pic-Clor 60, Telone II and the resistant cultivar reduced root galling than the untreated check treatment.

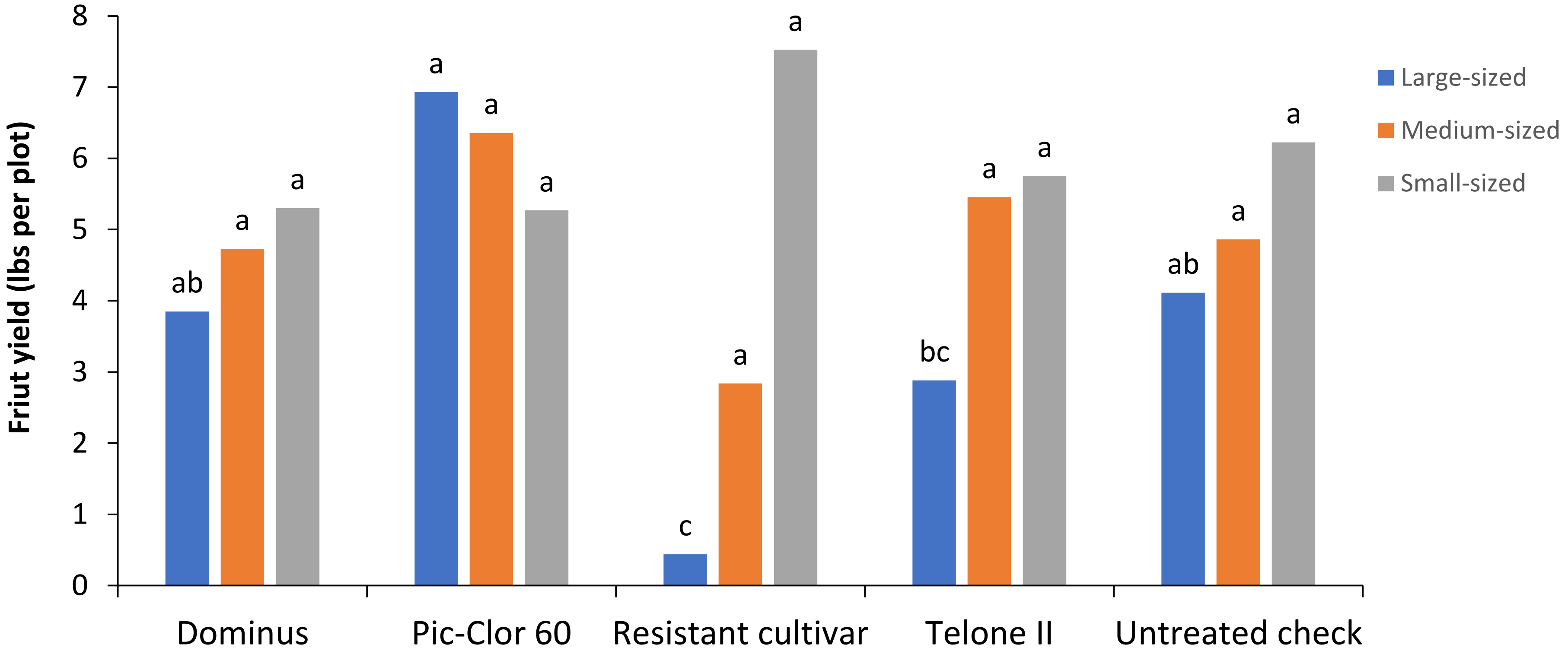






Yield response:

- Pic-Clor 60 showed a greater trend towards increasing crop yield than 1,3-D and the resistant cultivar.
- The resistant pepper had the poorest fruit yield despite significantly reducing the root gall index and *M. incognita* numbers in the soil



Non-fumigant chemical and biological nematicides for use in vegetables

- Newly developed non-fumigant nematicides have great potential to control RKN upon exposure.
- They are crop specific and their efficacy depends on the application method and RKN infestation pressure.

Trade Name	Active Ingredient	Toxic Activity	Manufacturer
Vydate	Oxamyl	Nematicide and Insecticide	Corteva
Nimitz	Fluensulfone	Nematicide	Adama
Velum Prime	Fluopyram	Nematicide/Fungicide	Bayer CropScience
Movento	Spirotetramat	Nematicide/Fungicide	Bayer CropScience
Majestene	Heat-killed cells of *Burkholderia rinojensis* strain A396	Nematicide	Marrone Bio Innovations, Inc.
MeloCon WG	Live conidia of *Paecilomyces lilacinus*	Nematicide	Certis, USA
****A couple of contact (ex. Salibro) and seed treatment nematicides are currently in the development process****			

2-year field study:

Effect of fluensulfone, fluazaindolizine, and fluopyram applied by:

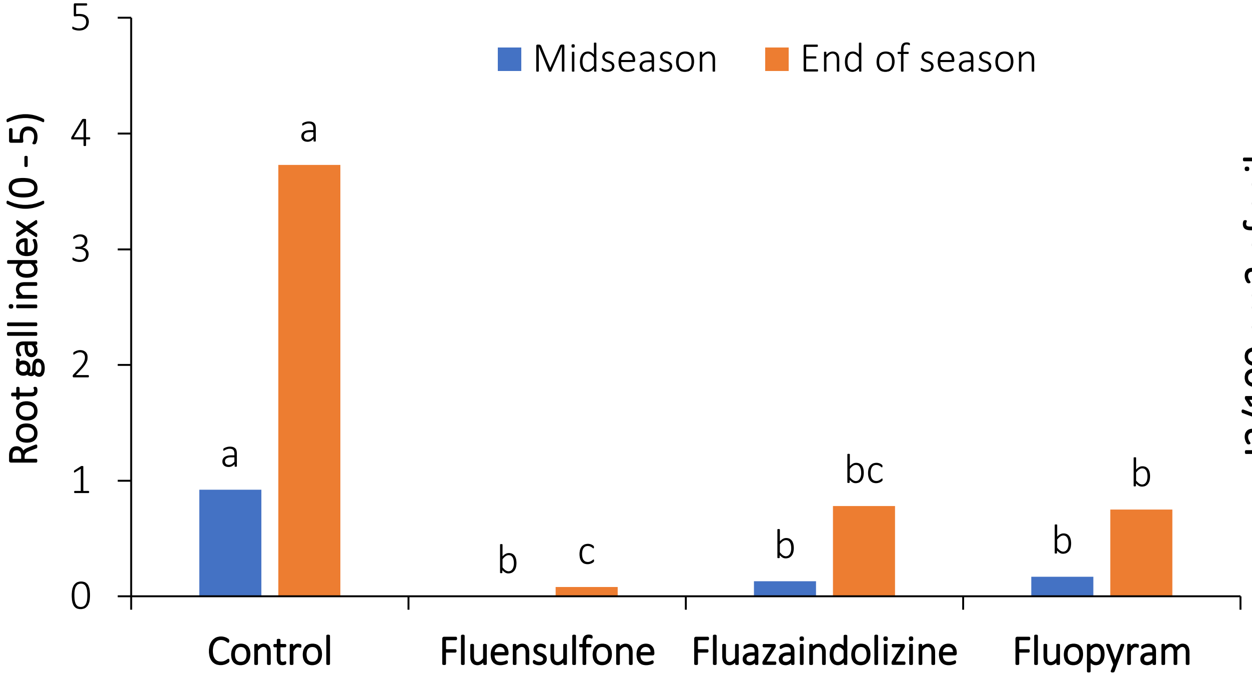
- Surface and sub-surface drip tapes vs. only surface drip tape on RKN populations and tomato yield.

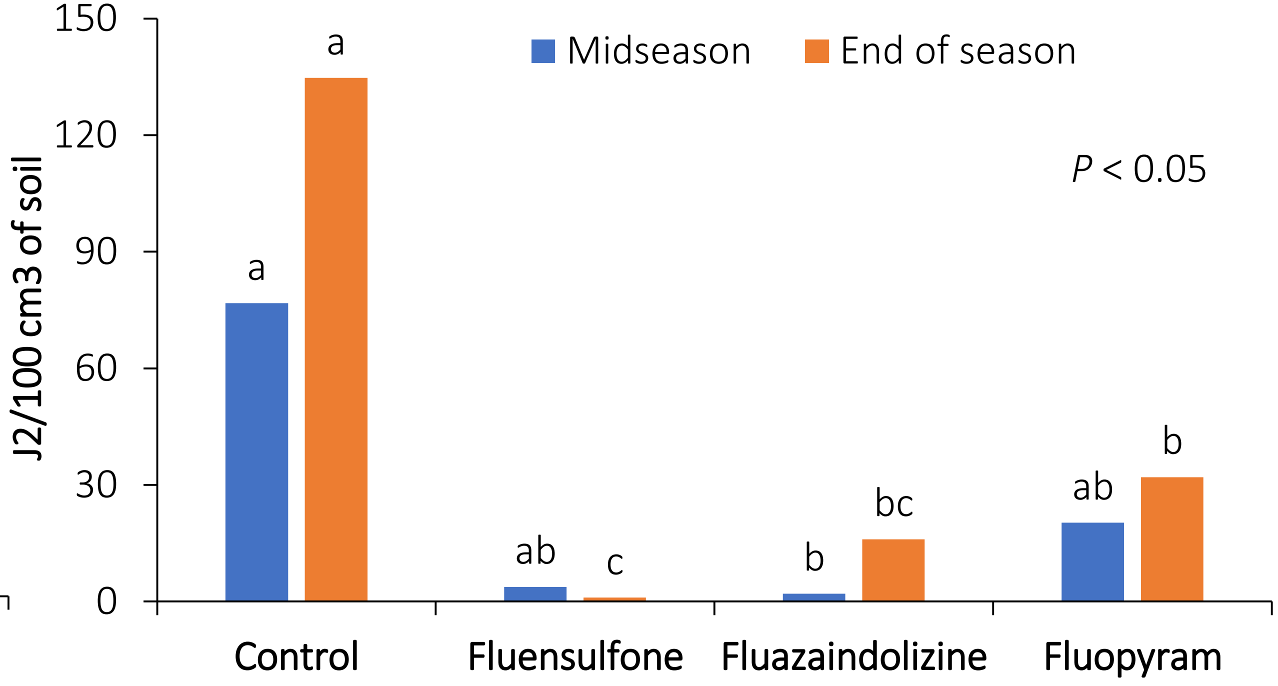
- Split-plot RCBD trials conducted in 2019 and 2020
- LDPE mulch was laid on raised beds
- A CO_2 pressurized tank used in injecting each nematicide to a drip irrigation manifold.
- Three non-fumigant nematicides used:
  - Fluensulfone – 5 pt/A
  - Fluopyram – 6.5 fl oz/A
  - Fluazaindolizine – 30.1 fl oz/A

Treatment	Fruit weight (kg/plot)	Root gall index (0-5)		*M. incognita*/100 cm^3	
		At midseason	End of season	At midseason	End of season
Surface drip tape	11.17 a	0.15 a	0.6 a	15.25 a	21.19 a
Surface and sub-surface drip tapes	9.68 a	0.18 a	0.89 a	11.81 a	27.38 a

- No drip tape × nematicide interactions on nematode and tomato variables was observed.

- A significant effect for nematicides on nematode reproduction factors was observed.





- Drip tape placement depth (surface + subsurface vs. surface) plays no role in RKN control in a single crop plasticulture system.

- Injection of non-fumigant nematicides at the upper soil surface needs to be improved.

Resistant crops

- Reduce damage to the current crop
- Reduce nematode population densities for succeeding crops
- Some damage to the seedlings may occur with high nematode numbers
- Commercially available cultivars of some vegetable crops are mainly resistant to three common RKN species (*M. incognita*, *M. javanica* and *M. arenaria*) and not aggressive species such as *M. enterolobii*

Example:

- Sweetpotato cultivars Covington and Evangeline
- Pepper cultivars Charleston Belle and Carolina Wonder
- Tomato varieties carrying the *Mi*-1 gene

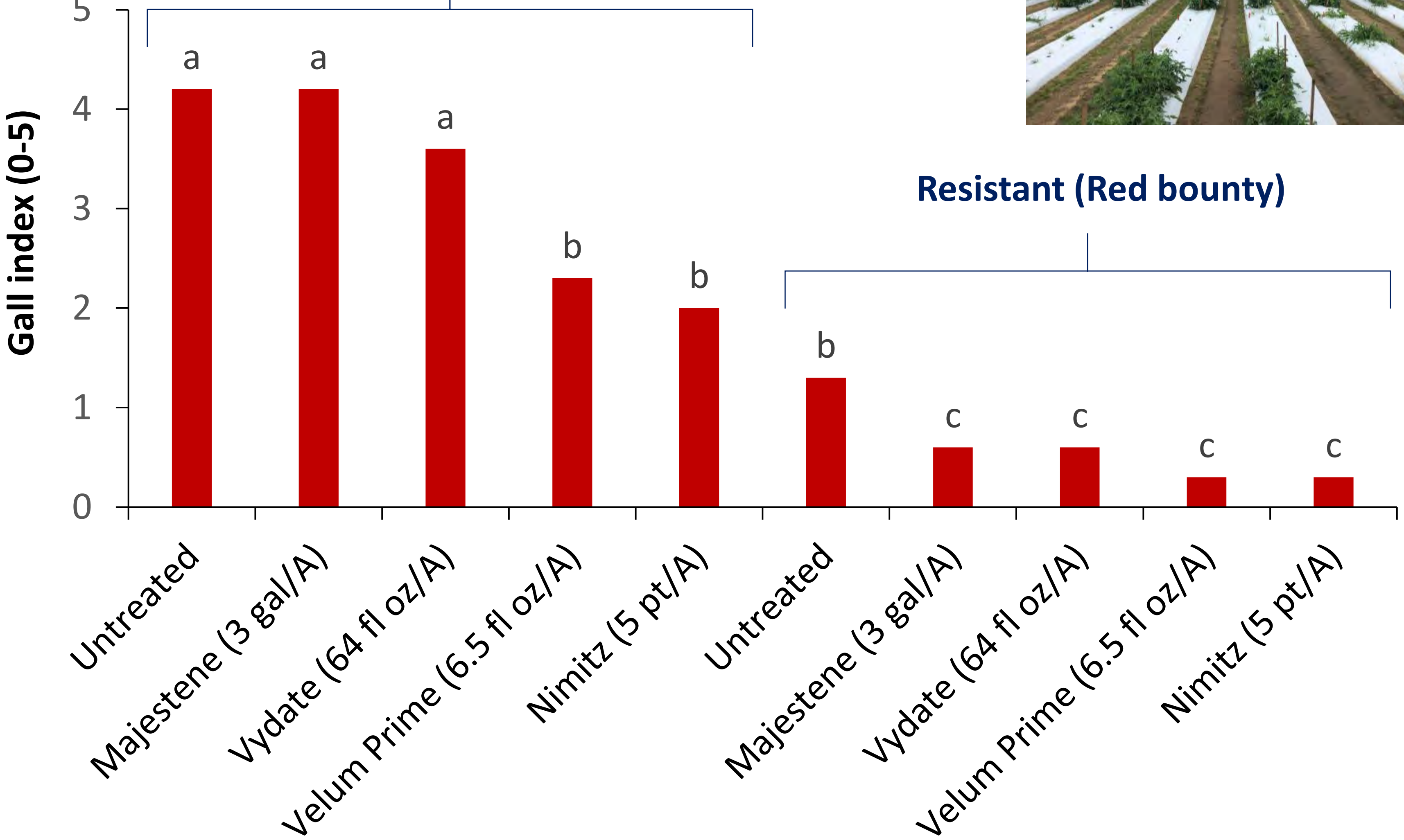
Use of tomato resistant cultivars to control root-knot nematodes:

- The *Mi*-1 gene was introgressed into the cultivated tomato from the wild tomato (*Lycopersicon peruvianum*) in the early 1940s.
- Commercially available varieties have the resistance gene (*Mi*-1.2 gene) to combat three common species of *M. incognita*, *M. arenaria* and *M. javanica.*
- Not a common growing practice in the Southeast!

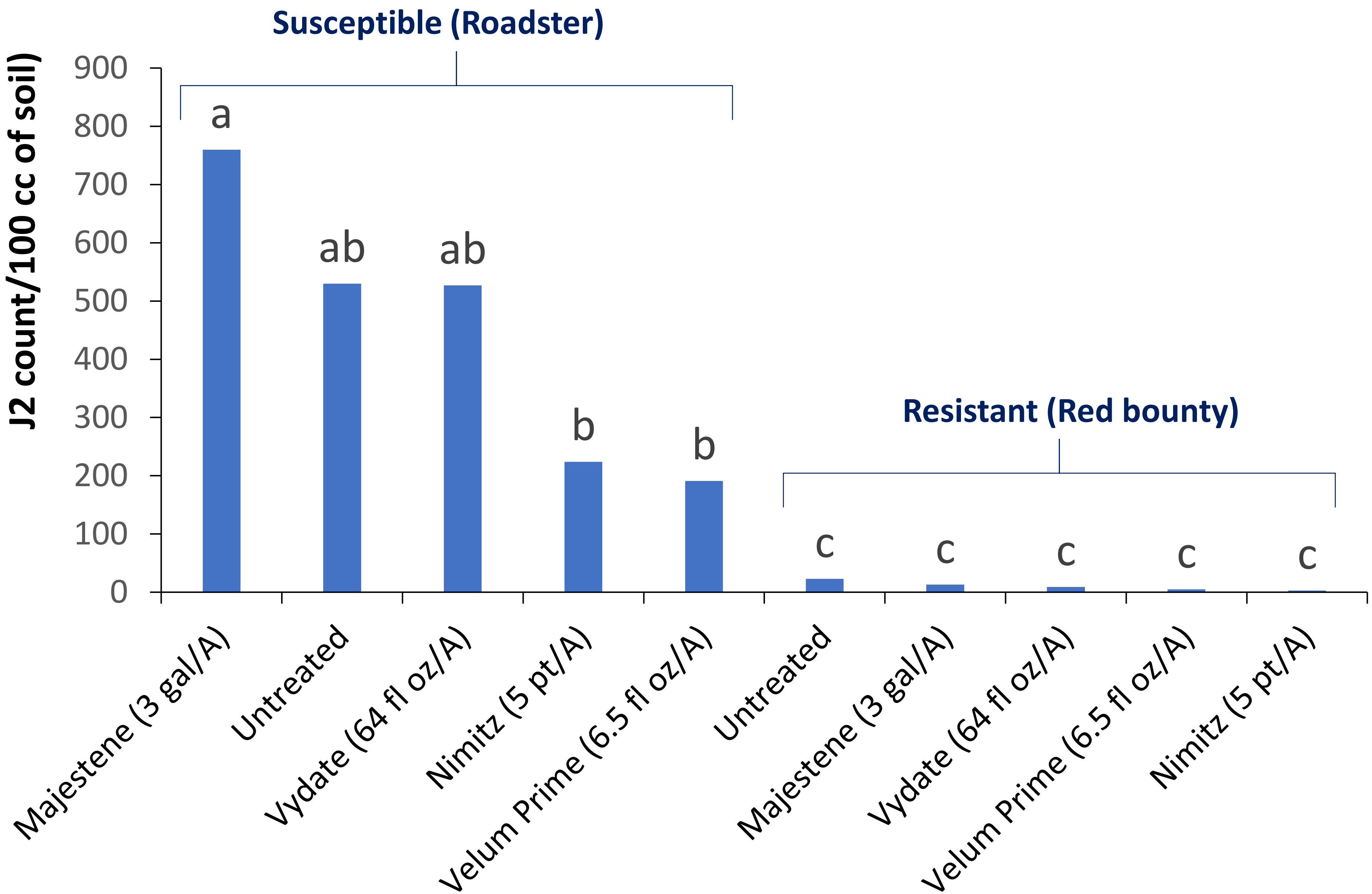
Examples of commercially available varieties with resistance to common RKN species

Tomato type	Level of resistance
Round	
Red Bounty	Moderately resistance
Amelia	Resistance
Myrtle	Moderately resistance
Skyway 687	Moderately resistance
DRI-0319	Moderately resistance
YAQUI	Moderately resistance
SV7631	Highly resistance
Resolute	Highly Resistance
Dixie Red	Moderately resistance
BHN 968	Highly resistance
Heatmaster	Moderately resistance
Saybrook	Moderately resistance
Cherry	
Chocolate Sprinkles	Highly resistance
Shiren	Moderately resistance
Pulm	
Mariana F1	Resistance

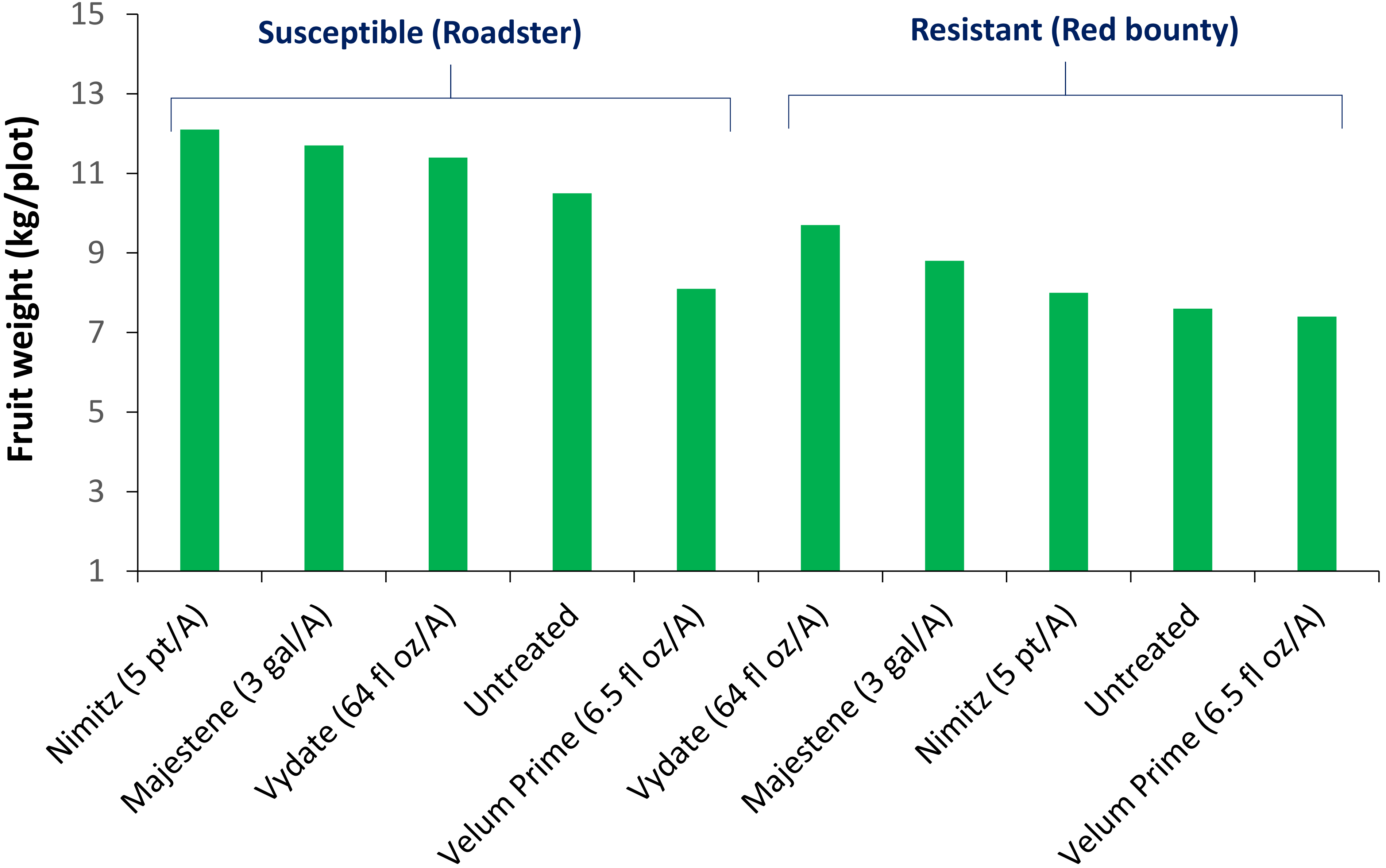
M. incognita control using a resistant tomato cultivar and non-fumigant nematicides applied through the drip irrigation system



RKN soil counts were fewer in plots grown with the resistant tomato and treated with nematicides



Efficacy of non-fumigant nematicides on tomato yield between susceptible and resistant cultivars



Potential limiting factors of implementing RKN-resistant tomato cultivars

- Sensitivity of tomatoes carrying *Mi*-1 gene to high (> 28°C) soil temperatures

Conflicting data have been reported

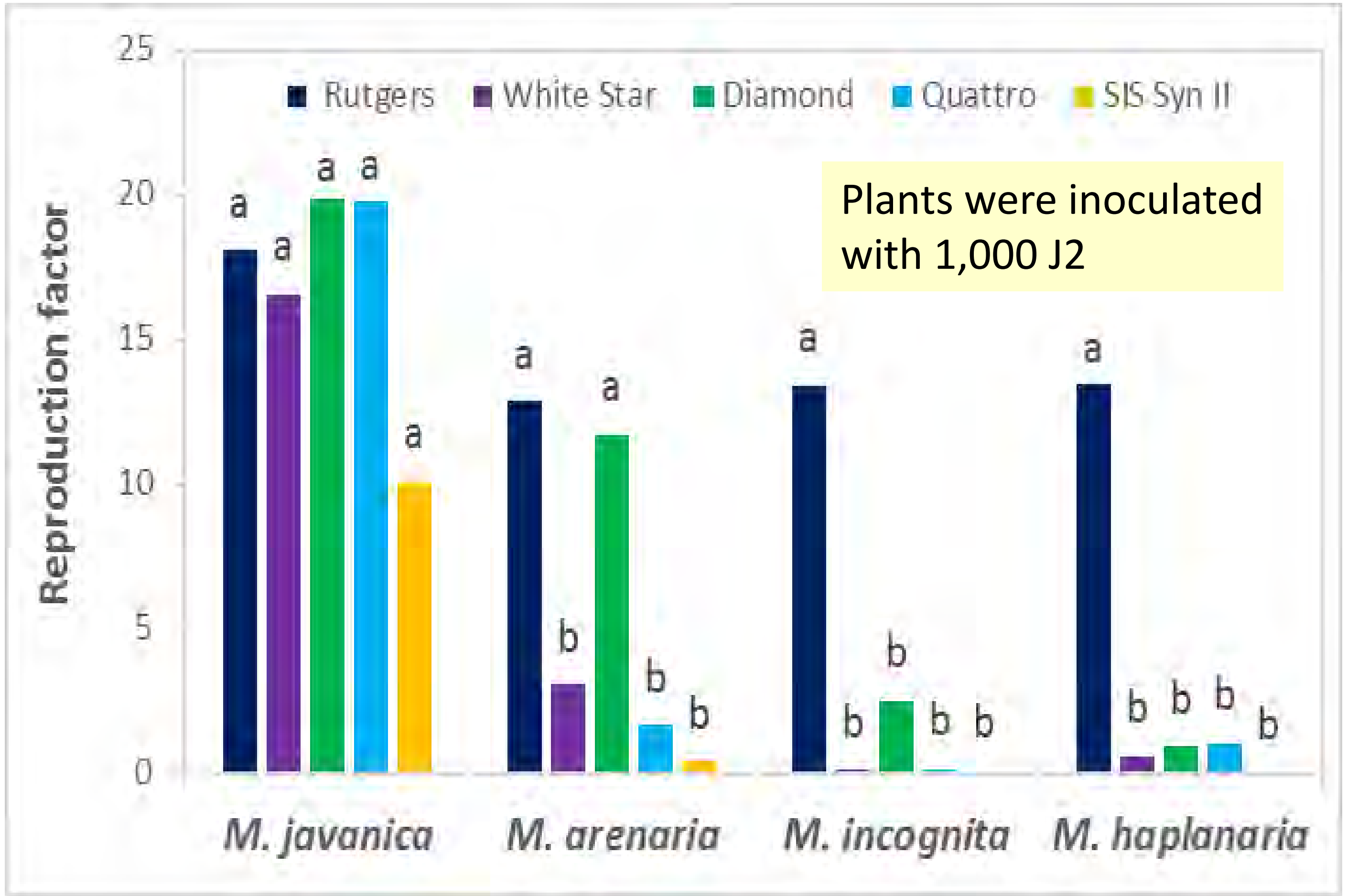
- Incidence of resistance-breaking RKN species (i.e. *M. haplanaria, M. floridensis* and *M. enterolobii*).

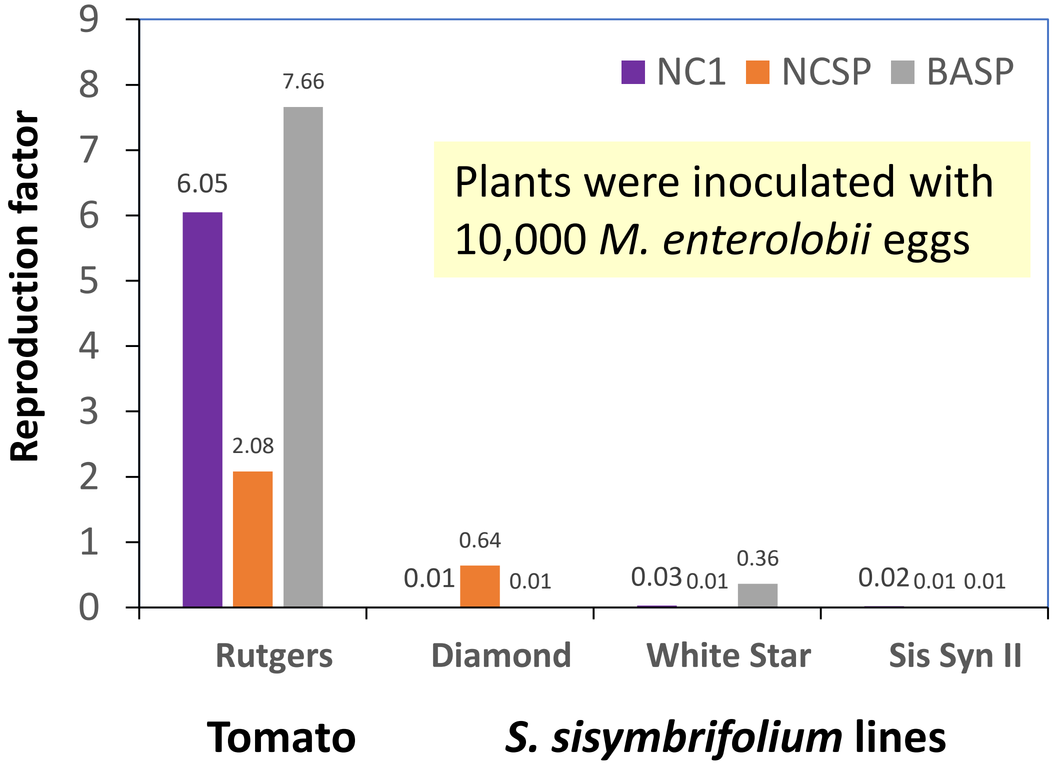
- Virulent populations of *M. incognita* and *M. javanica* are able to break down the resistance conferred by *Mi*-1.2.

- Resistant breaking RKN were detected in California and Georgia.

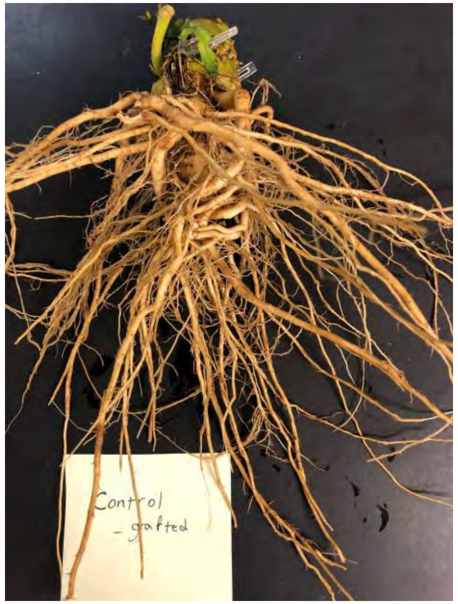
Need for new source(s) of resistance

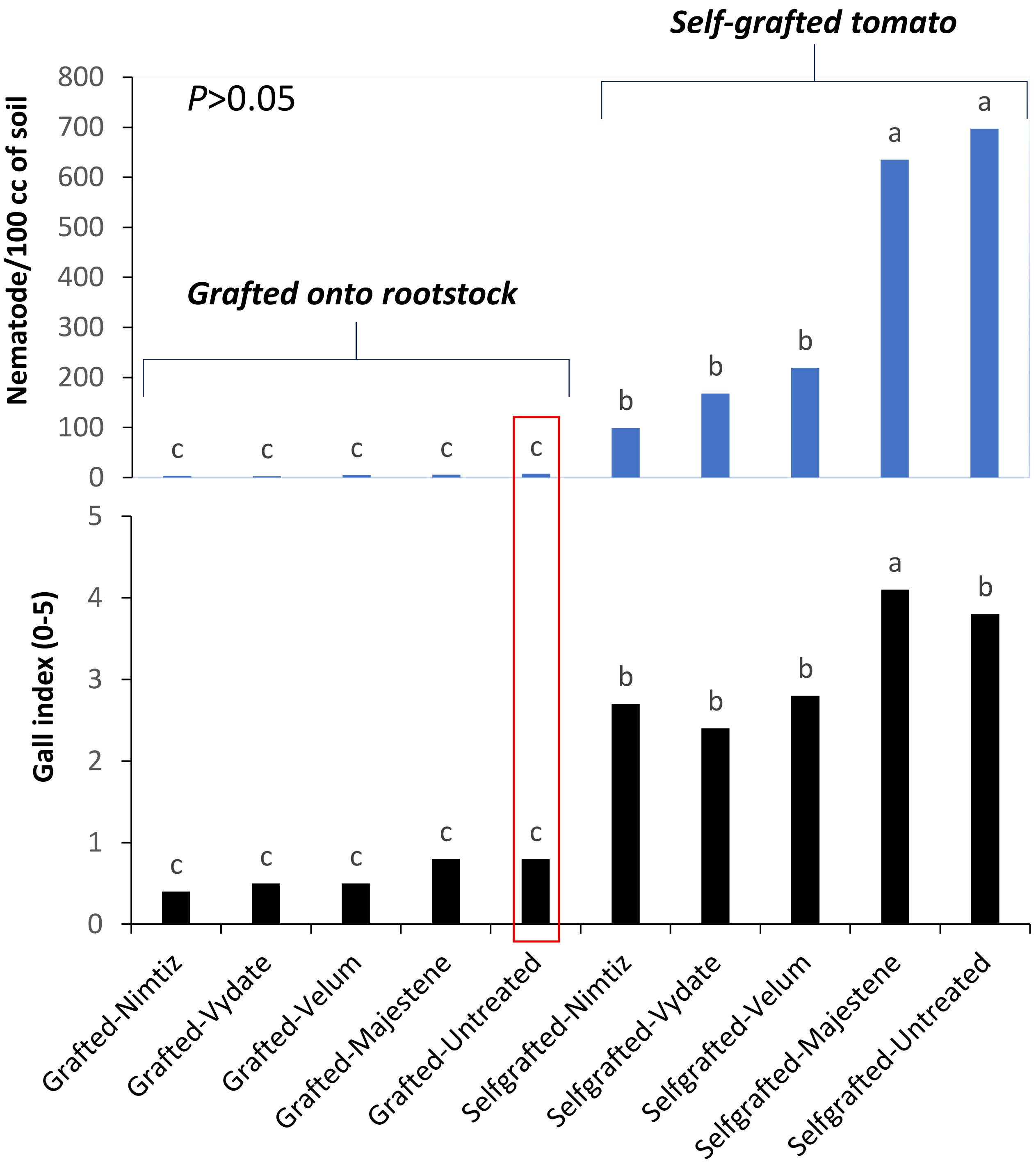
Greenhouse screening of *Solanum sisymbriifolium* genotypes/varieties revealed high resistance response to infection with major root-knot nematode species (except *M. javanica*)



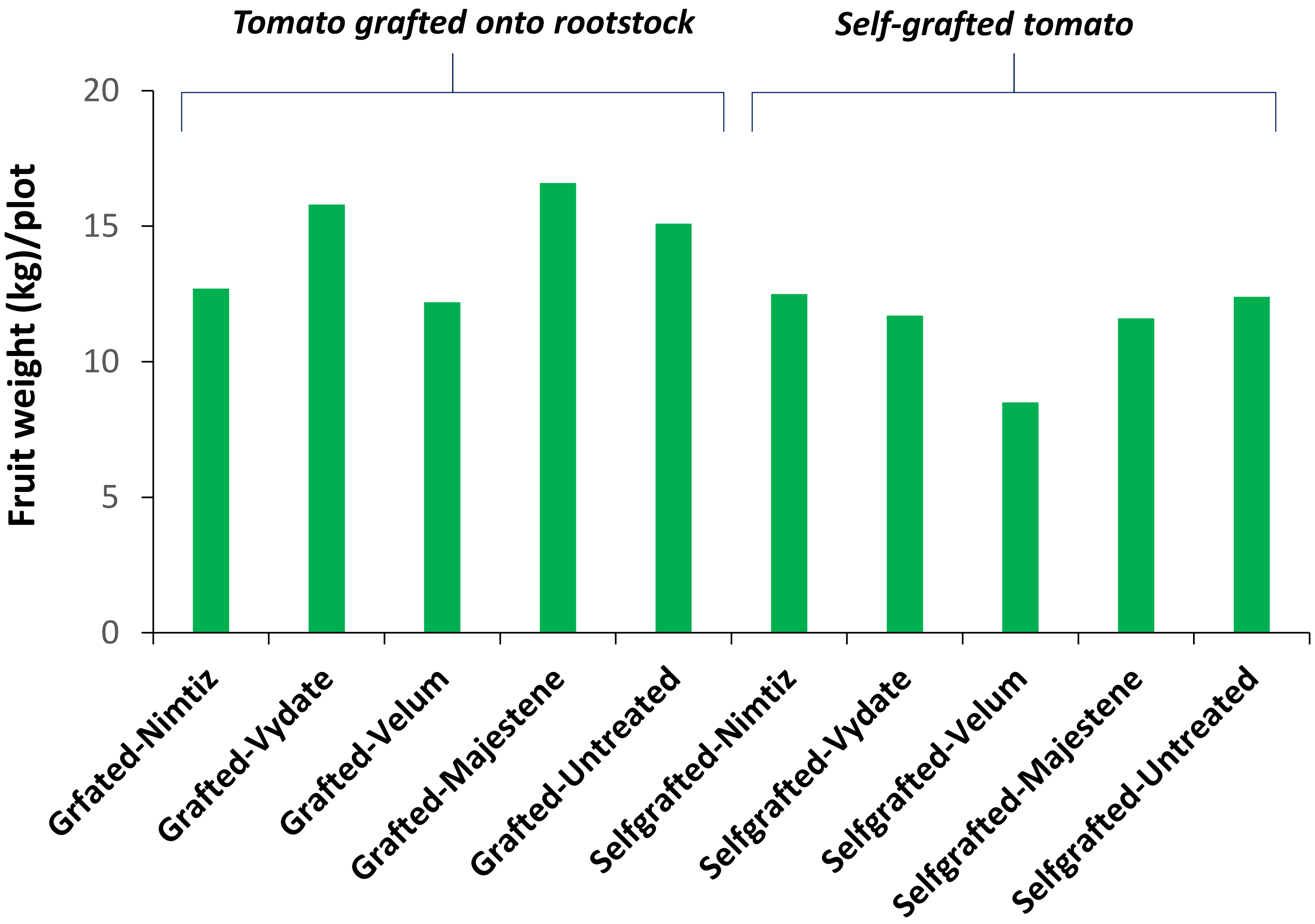


Field evaluation of the effectiveness of grafting tomato (cv. Roadster) onto *Solanum sisymbriifolium* and nematicides on root gall severity and soil populations of *M. incognita*:



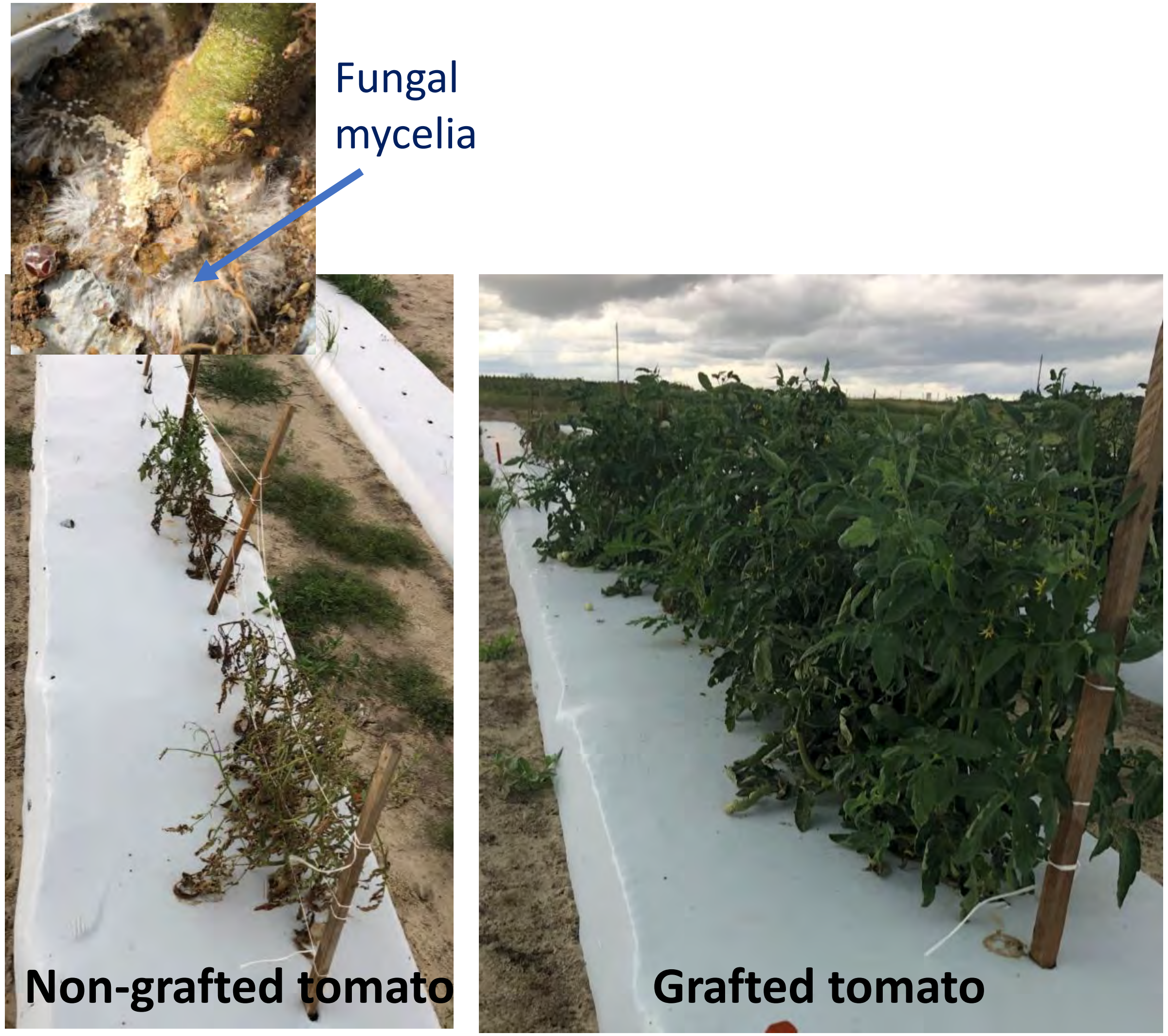


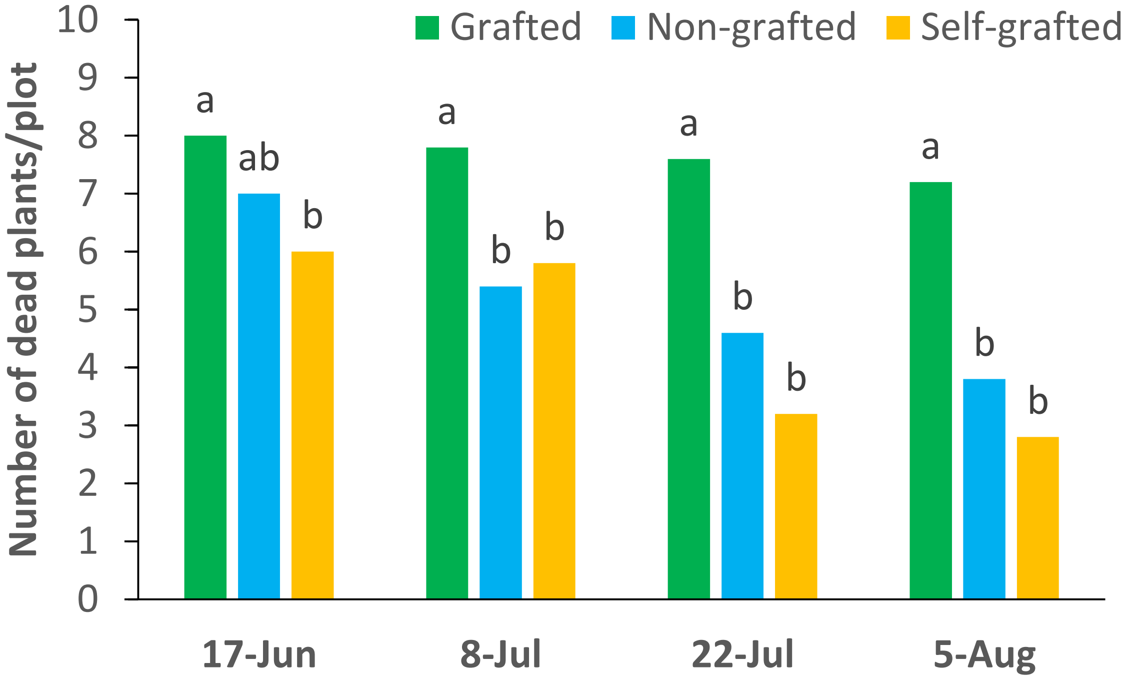
Tomato yield: Grafting tomato onto *Solanum sisymbriifolium* did not affect total fruit weight compared to self-grafted tomatoes.

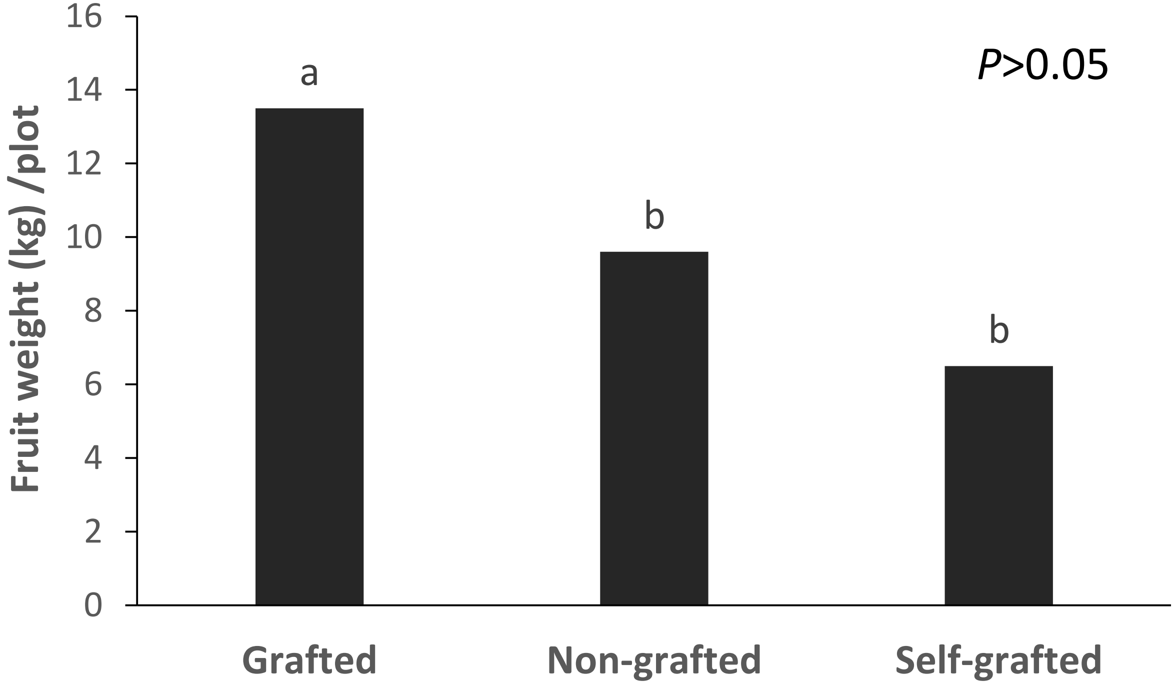


Fruits were graded based on their size

Response of *Solanum sisymbriifolium* rootstock to infection with *Sclerotium rolfsii*, the cause of southern blight disease







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- GA Commodity Commission for Vegetables

Questions?

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