

# Simulated Freeze-kill Risk of Carinata relative to Phenology and Sowing Dates at Eight Sites in the Southeast US

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# Introduction and Objectives

- Brassica carinata is proposed as a “green” jet-fuel crop to be grown during winter fallow acres in the Southeastern USA.
- **The Issue:** Carinata is only winter-hardy to -7 to -9 C (20.8 to 17.6 F) and winter-kill of carinata occurred in several regions in 2022-2023 as well as prior seasons.
- **Objectives:**
  - To illustrate the CROPGRO model ability to simulate life cycle phenology and yield of carinata, describing cardinal temperatures for phenology progression and winter-kill.
  - To simulate frequency of winter-kill for long-term 35-year weather for 6 sowing dates for 8 sites in the Southeast.
- **Added goal:** To solicit additional information from SPARC scientists to document winter-kill relative to known temperature records (*we do not know enough on this*)

# CROPGRO-Carinata Simulation Model

- CROPGRO – Mechanistic simulation of Carbon, Water, and N balance of crop and soil
- Based on understanding of crop, soil, weather, management interactions
  - Morphological, phenological development
  - Photosynthesis, respiration, growth
  - Root water & N uptake, stress effects on growth processes
- Predict growth, yield, timing (Outputs)
- Require information (Inputs)
  - Field, soil characteristics
  - Weather (daily)
  - Cultivar characteristics
  - Management
- Boote, K. J., R. Seepaul, M. J. Mulvaney, A. K. Hagan, M. Bashyal, S. George, I. Small, and D. L. Wright. 2021. Adapting the CROPGRO model to simulate growth and production of *Brassica carinata*, a bio-fuel crop. GCB-Bioenergy 13:1134-1148.  
<https://doi.org/10.1111/gcbb.12838>.

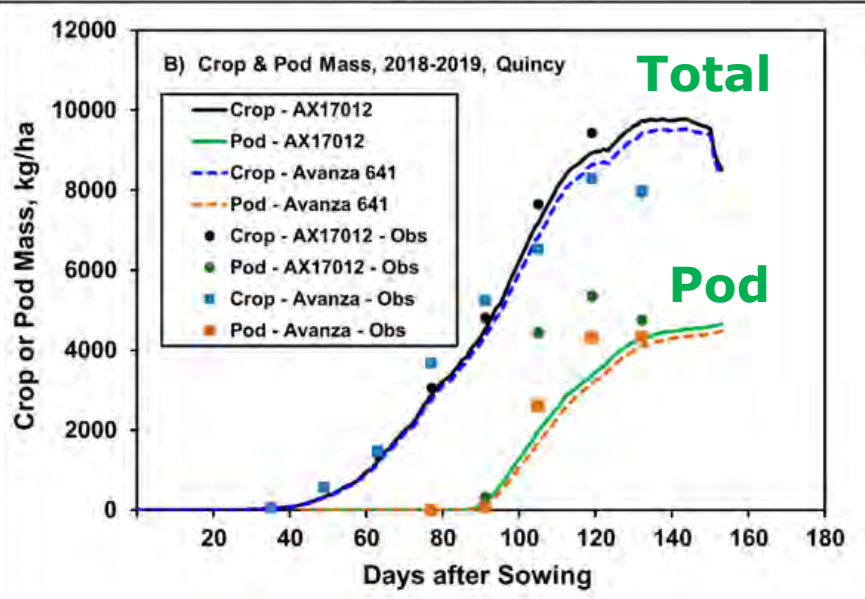
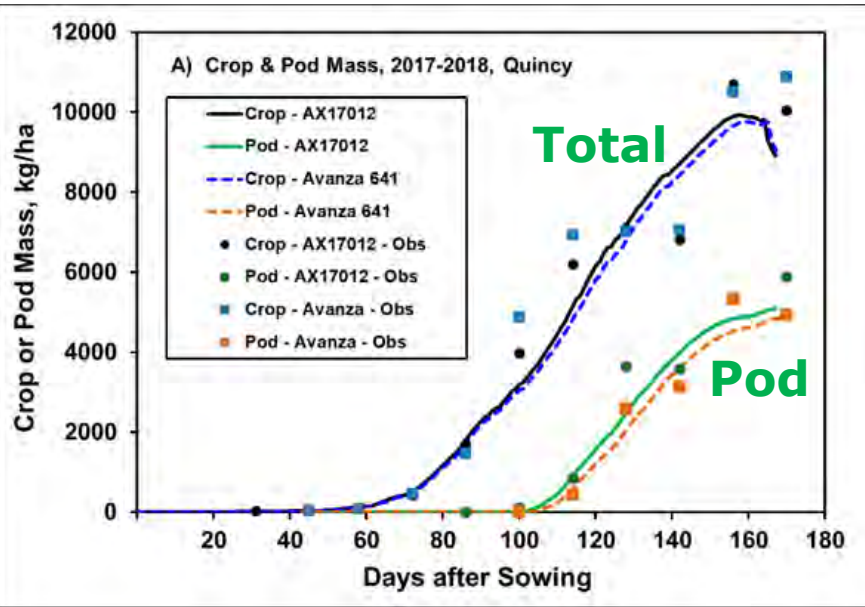
# Cardinal Temperatures for Processes

Species file defines  $T_b$ ,  $T_{opt1}$ ,  $T_{opt2}$ ,  $T_{max}$ , and shape of functions for temperature effects on processes: rate of leaf appearance, reproductive progress, leaf area expansion, photosynthesis, pod addition or single seed growth rate.

$T_b$	$T_{opt1}$	$T_{opt2}$	$T_{max}$	Shape	Process
5.0	25.0	29.0	39.0	LIN	V-stage, leaf appear
0.0*	21.0*	25.0*	35.0*	LIN	Reproductive progr
0.0*	30.0	32.0	39.0	LIN	Leaf Photosynthesis
2.0	12.0	20.3*	29.8*	QDR	Pod Addition
1.0	15.0	24.5*	35.5*	QDR	Seed Growth
-11.0 C (14.4 F)!!				Lethal killing temperature!!	

\*Same values as canola. !!total plant foliage.

# CROPGRO Carinata Model – Example Simulations



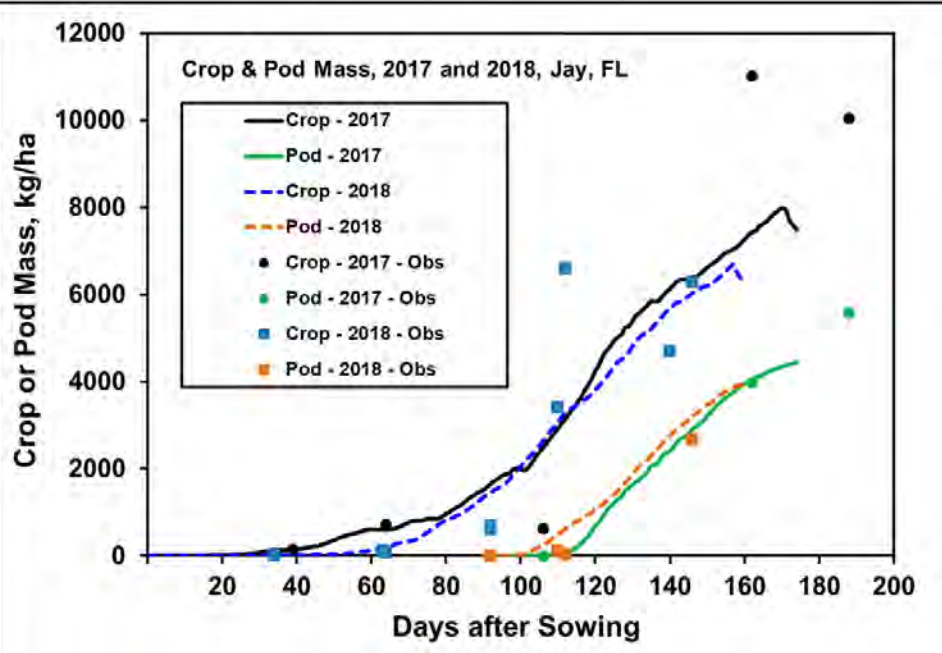
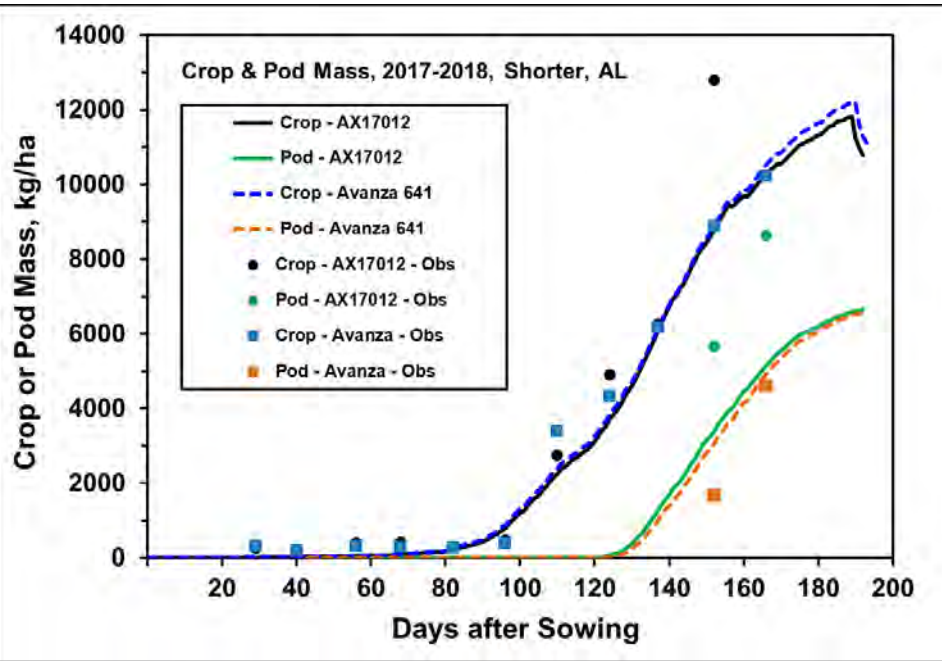
Total crop and pod mass of AX17012 and Avanza 641 at Quincy (A) 2017-18 & (B) 2018-19

2017-18 was cold. 2018-19 was warmer with shorter cycle.

CLDL	16.0
PPSEN	-.012
EM-FL	42.0 ptd
FL-SH	8.0 ptd
FL-SD	19.5 ptd
SD-PM	38.5 ptd

# CROPGRO Carinata Model Simulations

Simulated Crop & Pod Mass, AX17012 & Avanza in 2017-2018 season, Shorter, AL.

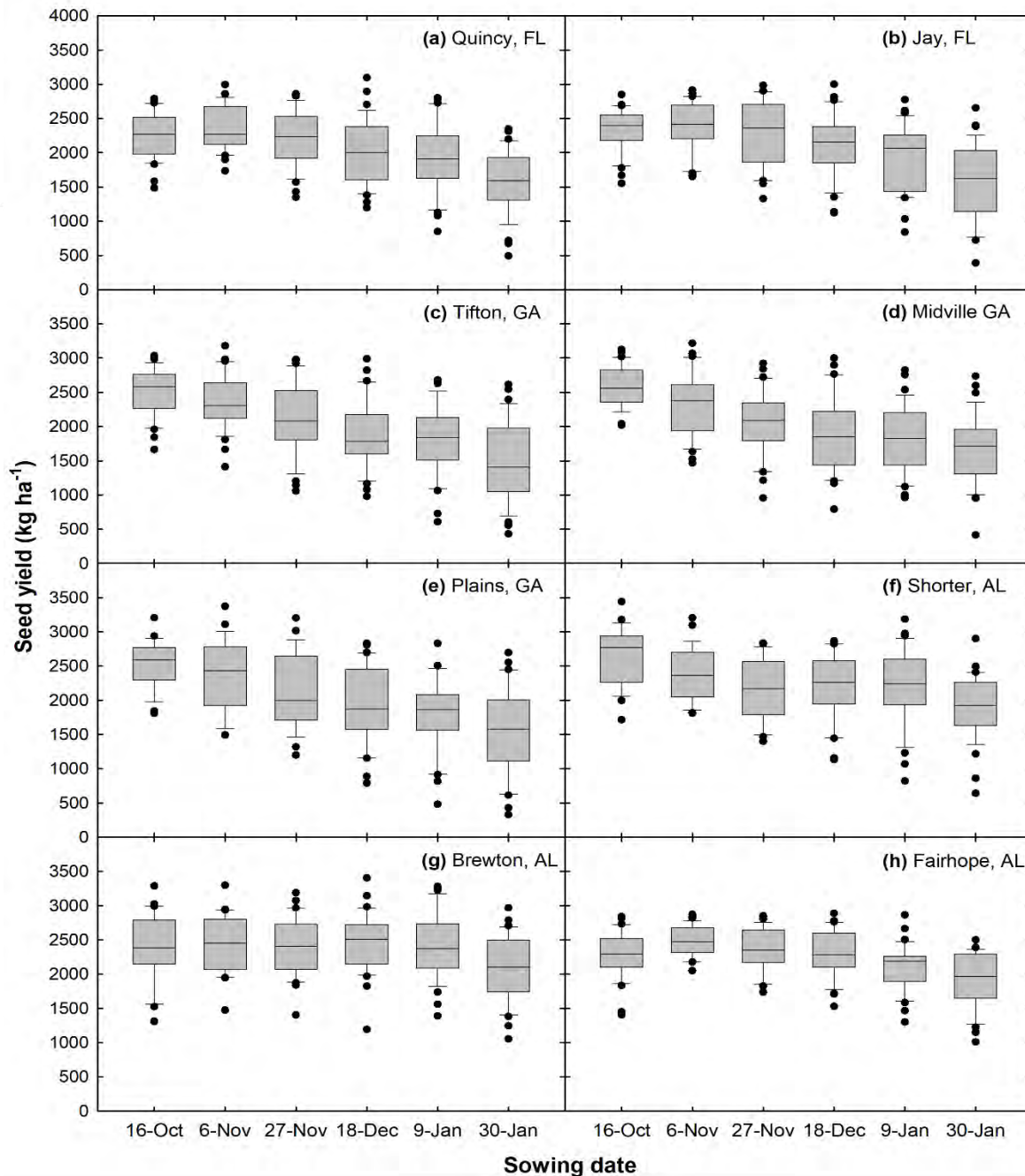


Simulated Crop & Pod Mass in two seasons 2017-18, 2018-19, at Jay, FL

# Methods – Simulate Frequency of Freeze-kill

- Simulations at 8 sites (Jay, Fairhope, Brewton, Shorter, Quincy, Tifton, Midville, Plains). Same as Boote paper.
- 35-year weather records from 1984 to 2019
- Simulated 6 sowing dates at 3-week intervals:(Oct 16, Nov 6, Nov 27, Dec 18, Jan 9, Jan 30)
- Output seed yield, time to harvest, and % failed crops
- Evaluated 3 possible killing temperatures (-7 C, -9 C, and -11 C). Same as 20.8, 17.6, and 14.4 F.
- When model encounters a minimum night temperature (Tmin) of this value, all foliage is killed, thus limiting further growth and yield at that point.
- Assume no differential growth stage sensitivity. Is flowering more sensitive? Argentina paper indicates “yes”

# CROPGRO Carinata Model Effect of Sowing Date



Seed yield vs sowing date at 8 sites, showing median yield and 50%-tile box-and-whisker. Not including failures at -11C.

Early sowing best at most sites, except Quincy, Jay and Fairhope where 2<sup>nd</sup> date, 6 Nov was better.

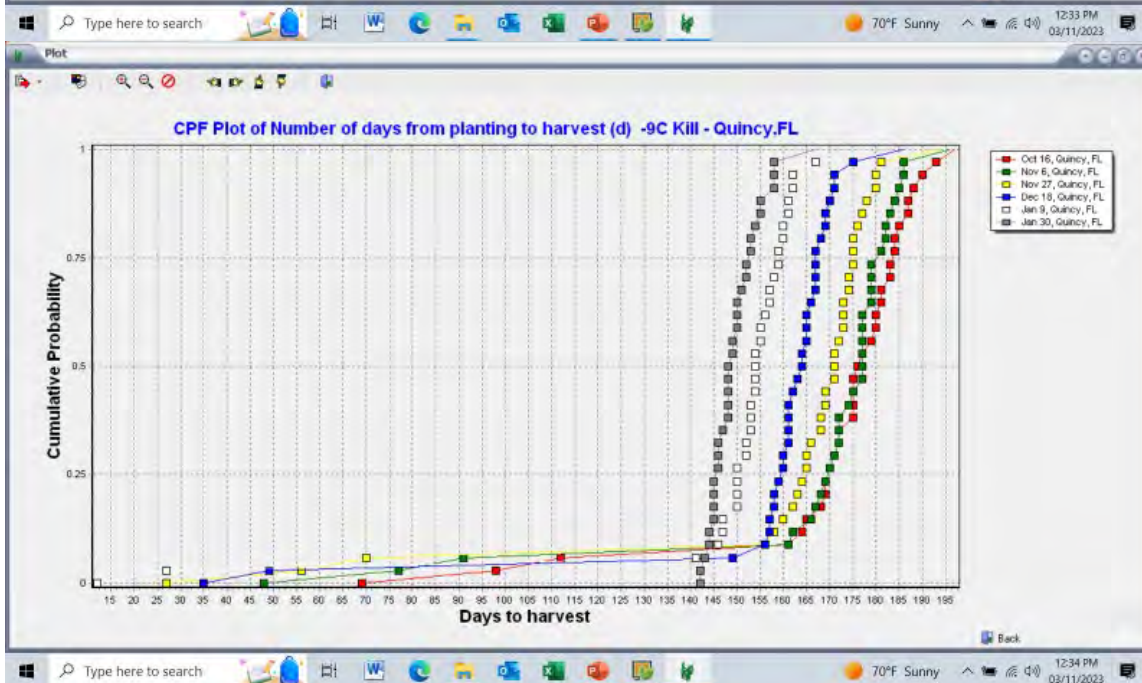
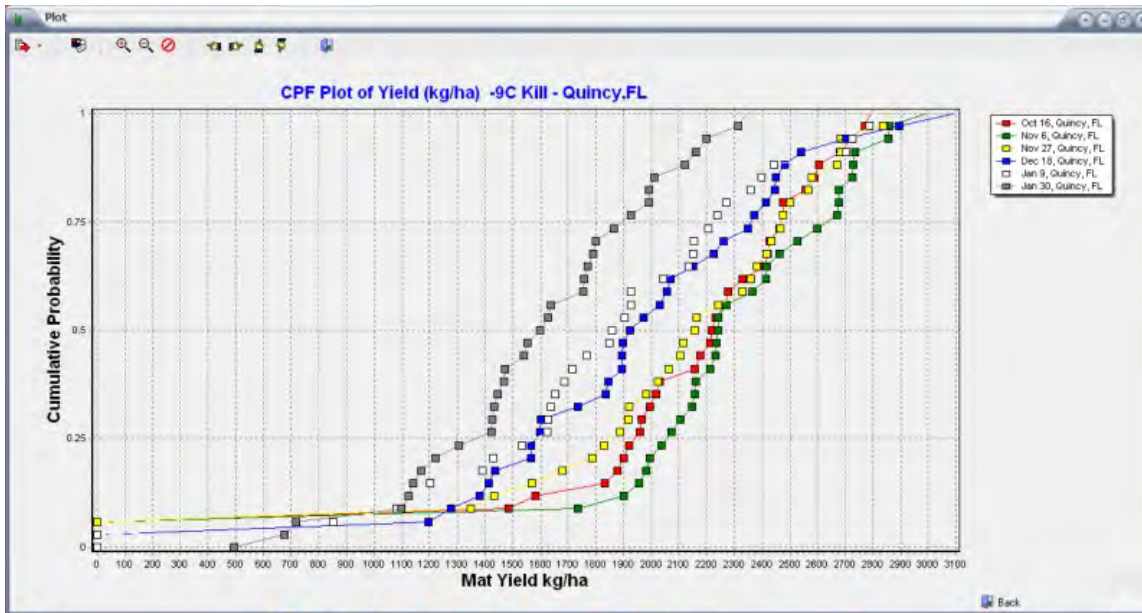


# Carinata Model

Quincy: CPF of yield for 6 sowing dates. Nov 6 best yield, declining with later sowing.

9% failure, 3 of 35 years, if -9C lethal temperature.

Days to maturity decrease with later sowing. Accelerates with long day & warmer temperature.

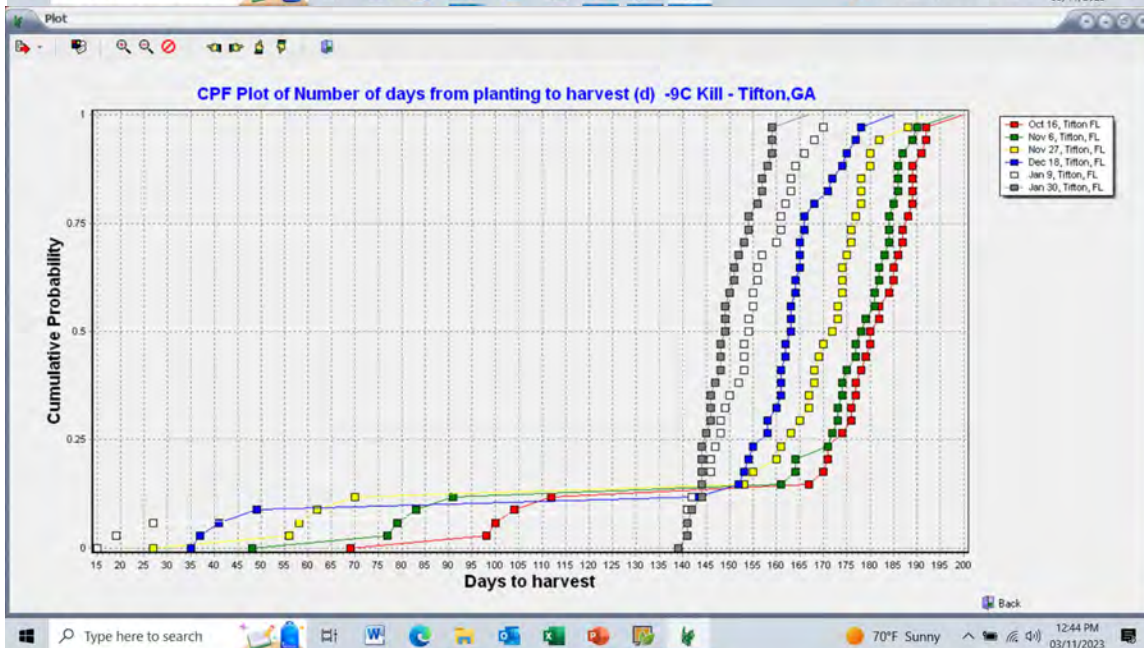
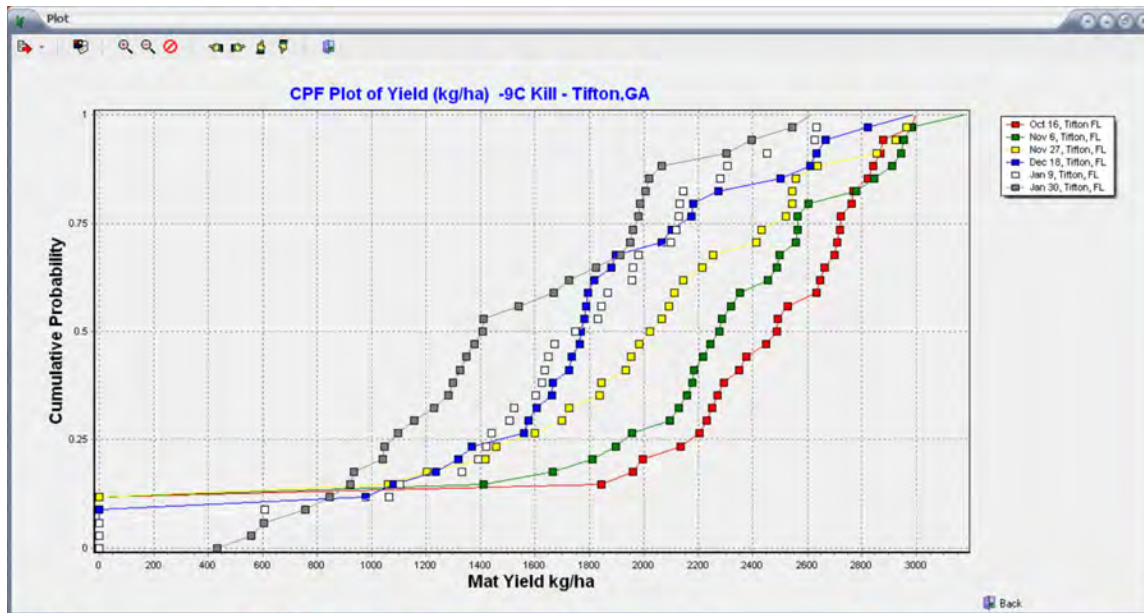


# Carinata Model

Tifton: Probability of yield for 6 sowing dates. Oct 16 best yield, declining with later sowing.

14% failure, 5 of 35 years, if -9C lethal temperature. No failure for Jan 30.

Days to maturity decrease with later sowing. Accelerates with long day & warmer temperature.

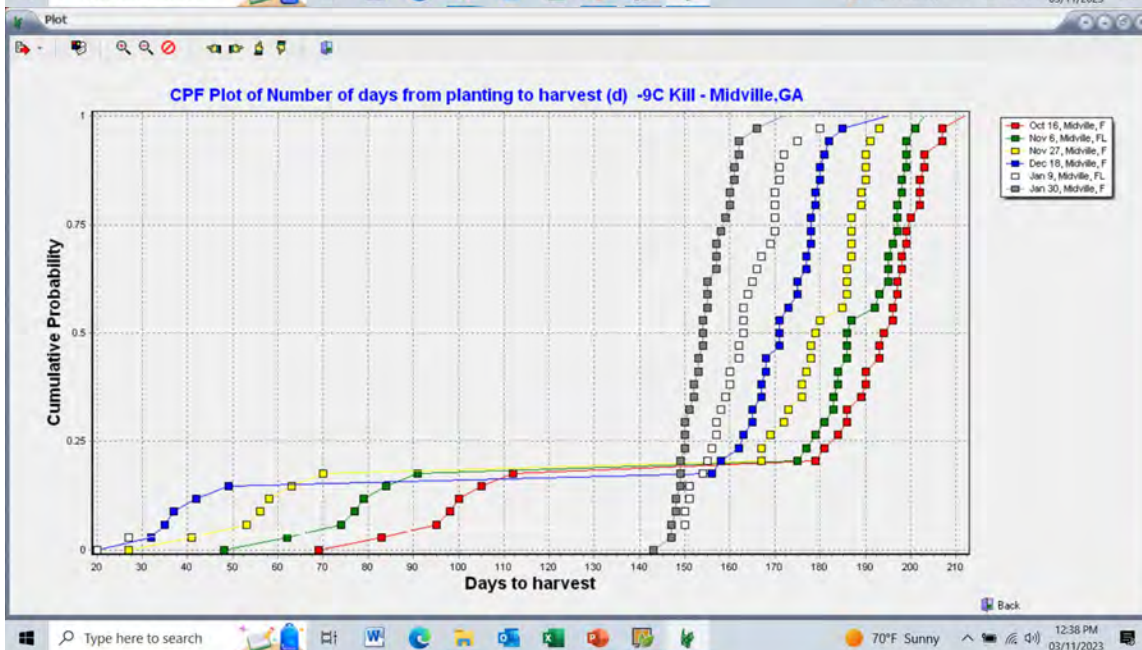
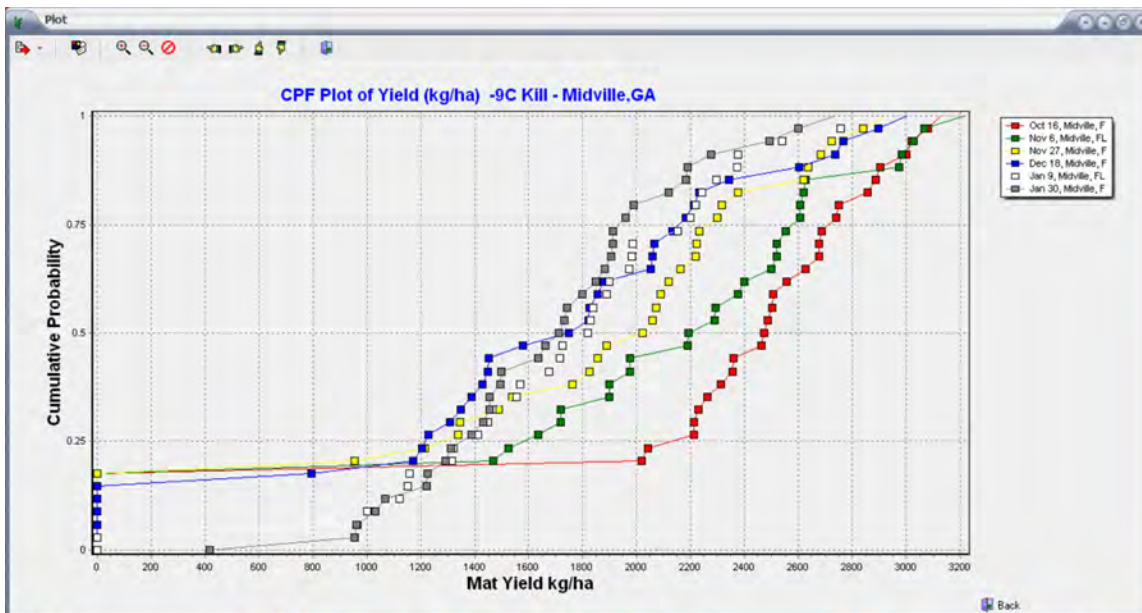


# Carinata Model

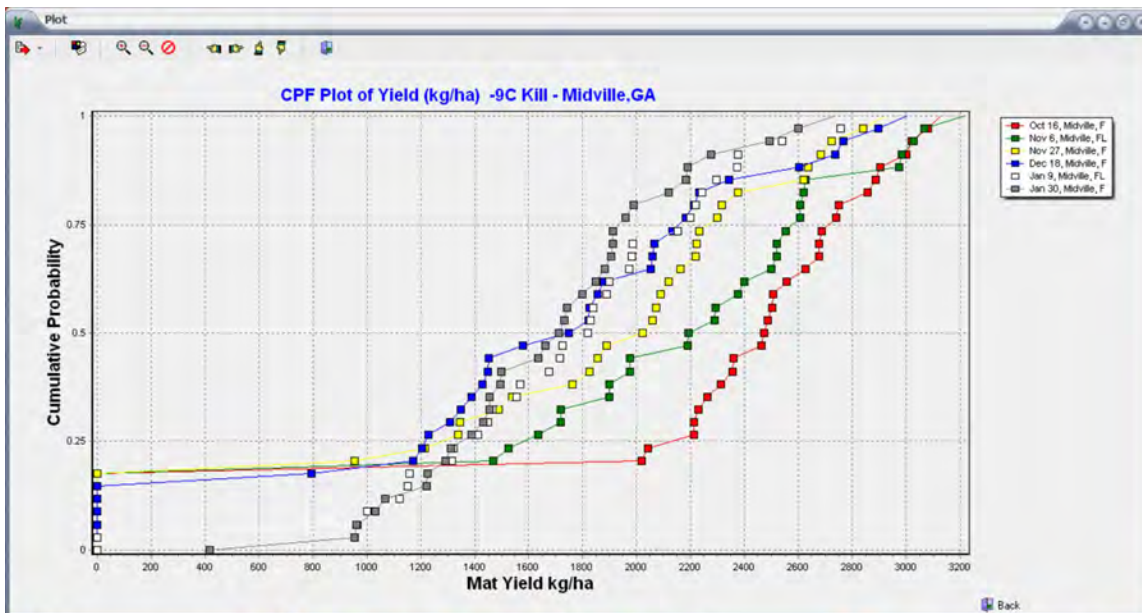
Midville: Probability of yield for 6 sowing dates. Oct 16 best yield, declining with later sowing.

20% failure, 7 of 35 years, if -9C lethal temperature.

Days to maturity decrease with later sowing. Accelerates with long day & warmer temperature.

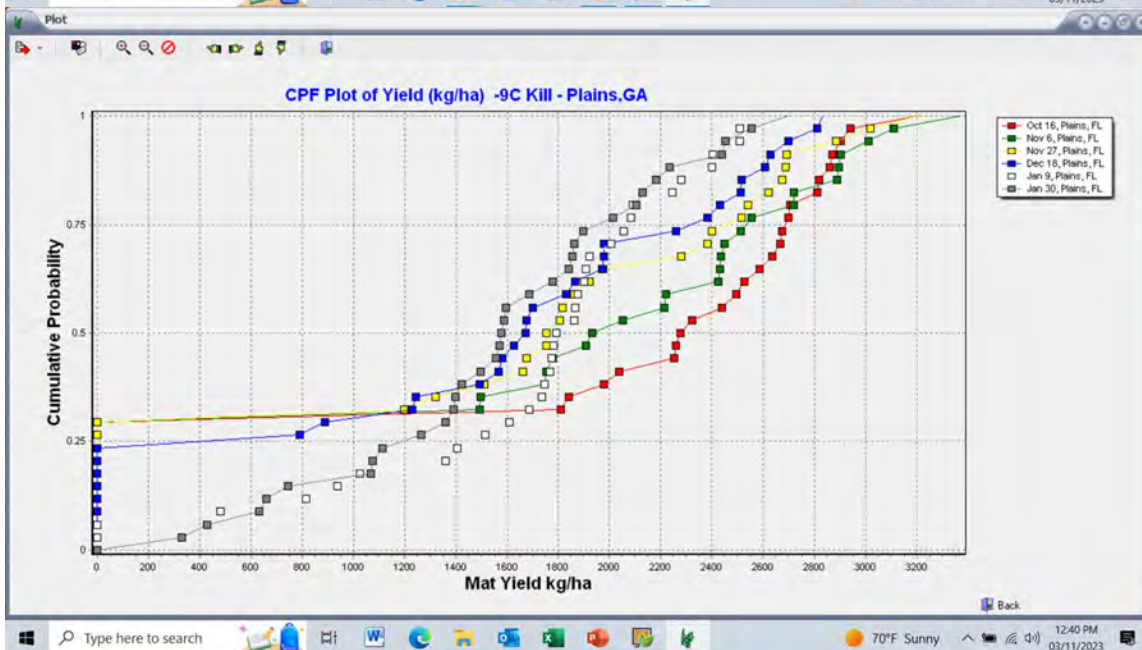


# Carinata Model



Midville: CPF of yield for 6 sowing dates. Oct 16 best yield, declining with later sowing.

20% failure, 7 of 35 years, if -9C lethal temperature.



Plains: CPF of yield for 6 sowing dates. Oct 18 best yield, declining with later sowing.

31% failure, 11 of 35 years, if -9C lethal temperature.

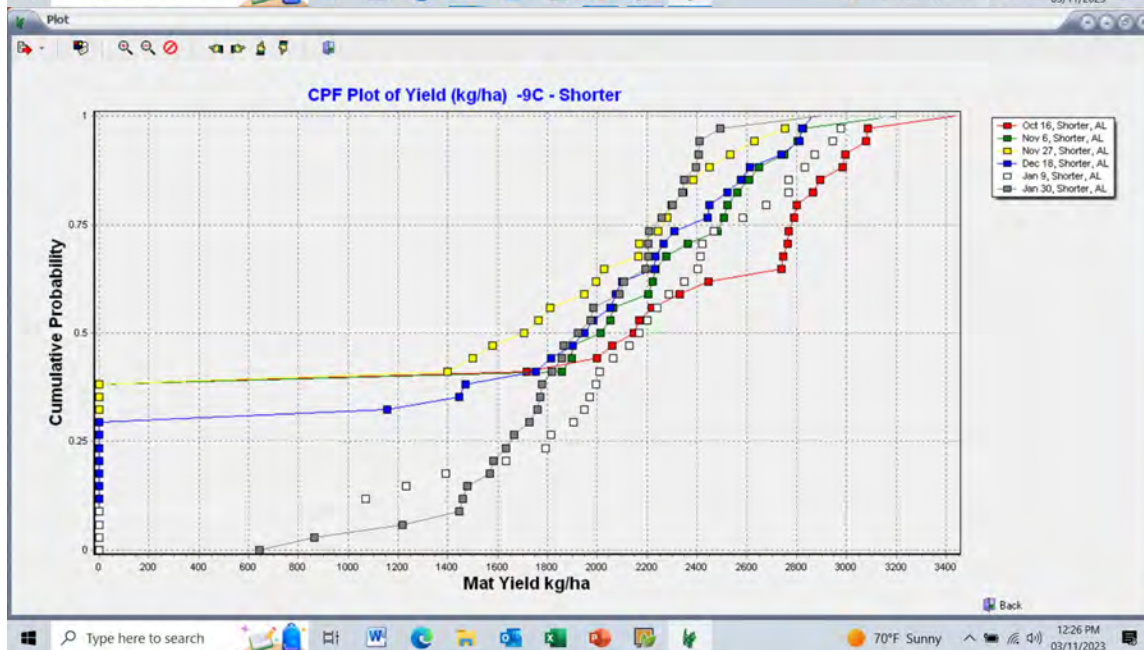
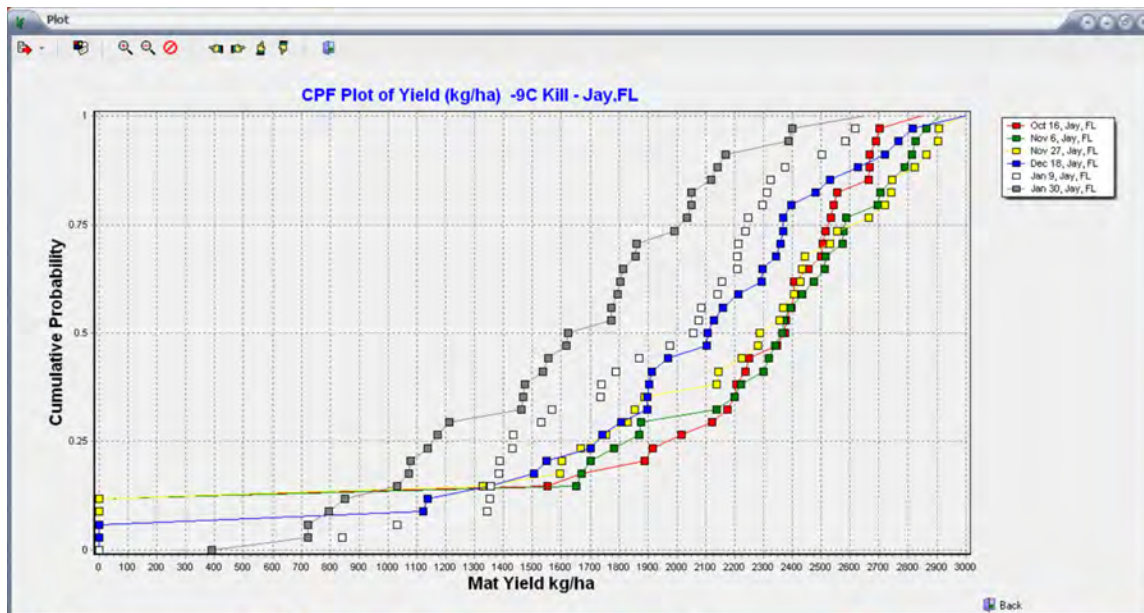
## Carinata Model

Jay: CPF of yield for 6 sowing dates. Nov 6 & 27 best yield, decline with later sowing.

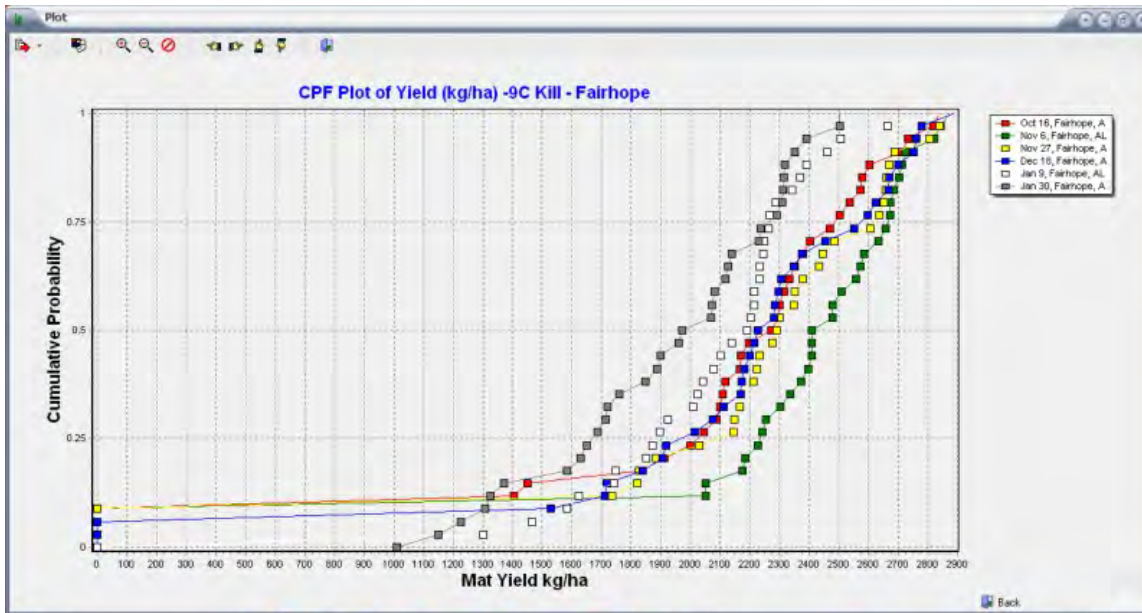
14% failure, 5 of 35 years, if -9C lethal temperature.

Shorter: CPF of yield for 6 sowing dates. Oct 16 & Jan 9 best yields, less sowing date effect.

40% failure, 14 of 35 years, if -9C lethal temperature.



# Carinata Model



Fairhope: CPF of yield for 6 sowing dates. Nov 6 best yield, decline with later sowing.

11% failure, 4 of 35 years, if -9C lethal temperature.

Brewton: CPF of yield for 6 sowing dates. Dec 18 best yield, less sowing date effect (why?).

29% failure, 10 of 35 years, if -9C lethal temperature.

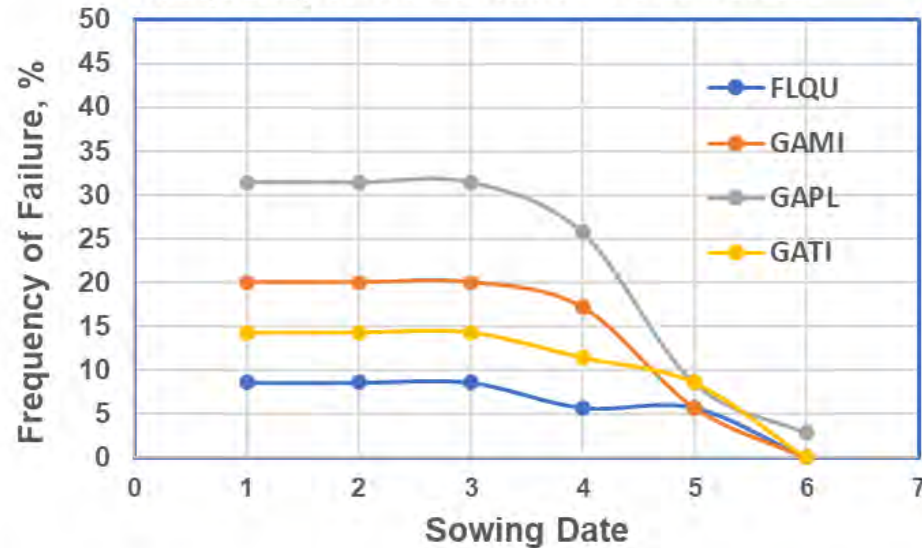
## Carinata Model

Tifton, Quincy, Jay, Fairhope have 10-15% chance of freeze-kill (out of 35 years) for optimum sowing dates.

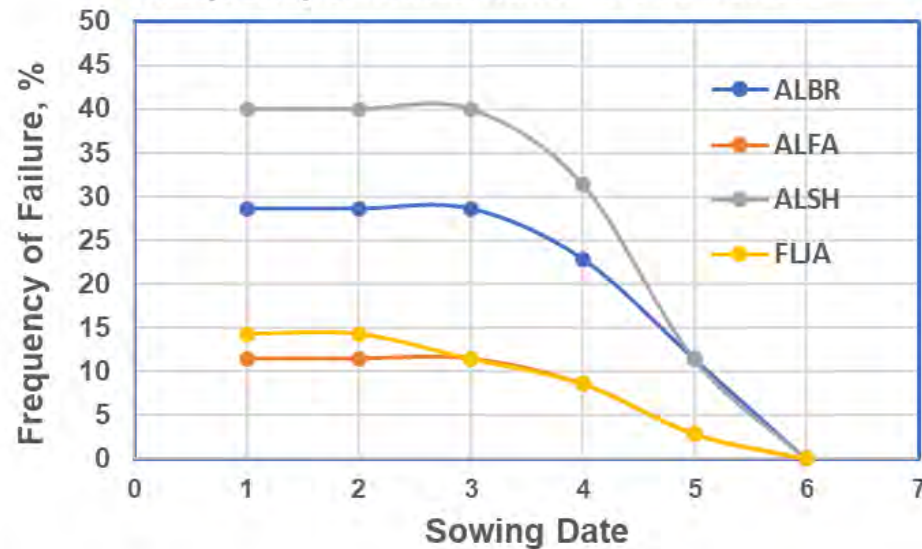
More northerly sites, Midville, Plains, Brewton, Shorter have 20 to 40% chance of freeze-kill.

Avoid freeze? Sow in late January?

Frequency of Winter-Kill if -9 C at 4 Sites



Frequency of Winter-Kill if -9 C at 4 Sites



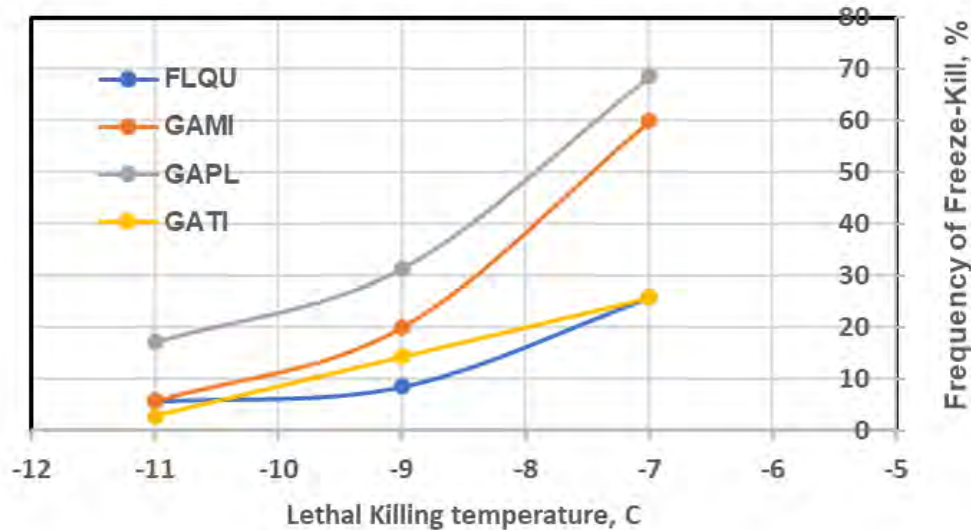
## Carinata Model

Degree of freeze-kill decreases as lethal temperature drops from -7 to -9 to -11 C (20.8, 17.6, and 14.4 F).

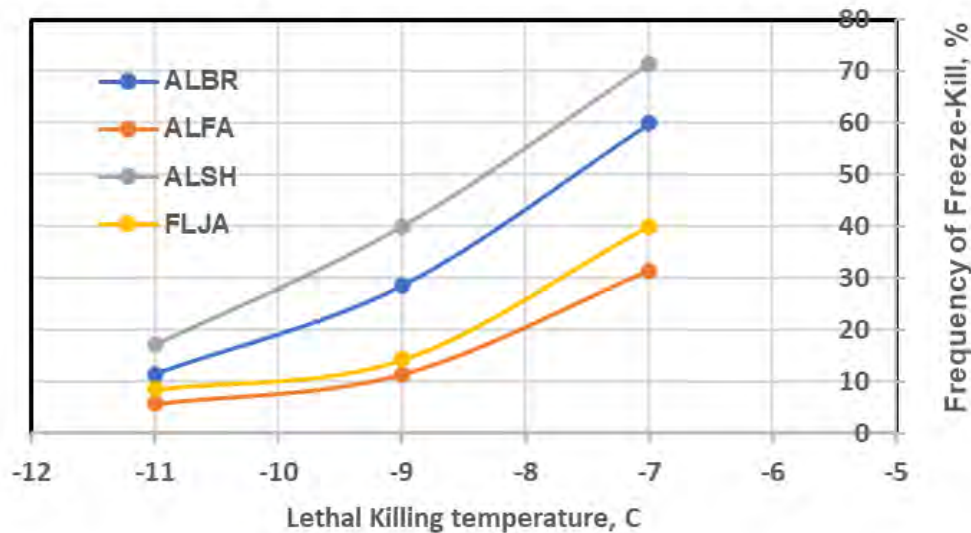
What is the lethal temperature and can genetics improve it?

For northerly sites, Midville, Plains, Brewton, Shorter, the risk is high unless a -11C tolerance can be achieved.

Frequency of Failure vs. Lethal Temperature at 4 Sites



Frequency of Failure vs. Lethal Temperature at 4 Sites





## Conclusions

- CROPGRO Carinata model was used to simulate yield and winter-kill sensitivity for 35-years of weather for 8 sites.
- Winter-kill is a significant concern and varies by region, because less in Tifton, Quincy, Jay, Fairhope, but greater in more northerly locations (Midville, Plains, Brewton, Shorter).
- Consider late January sowing in northerly locations to avoid freeze. Means giving up on second summer crop.
- OR: Insurance against crop loss (industry & Gov't)? Replant?
- Need more freeze-tolerance in carinata.
- Need more information on freeze damage thresholds
- Recommend a group effort with SPARC scientists: collect and evaluate knowledge of past documented winter-kill relative to known temperature records.
- Bad years: 1985, 1986, 1989, 1996, 2014 – ENSO signal?