Integrated management of **Aphanomyces and Fusarium root rot** in field peas: (4) Optimizing planting date

Michael Wunsch, Suanne Kallis, Jesse Hafner, Aaron Fauss NDSU Carrington Res. Ext. Center

in collaboration with Edson Ncube and Audrey Kalil, NDSU Williston Research Extension Center

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Aphanomyces and Fusarium root rot of **field peas**: Impact of **planting date**

Response to planting date in fields with elevated **native root rot pressure**

Fields with elevated Aphanomyces and Fusarium root rot caused by a long history of field pea and lentil production.
Williams, Mountrail and McLean Counties, ND (2019, 2020); Carrington, ND (2017-2020)
Long-term no-till at Williams, Mountrail and McLean County on-farm sites. Direct-seeded or conventional till in Carrington.

Root rot was minimized when soil temperature was < 50°F
(7 days after planting at 2" seeding depth).

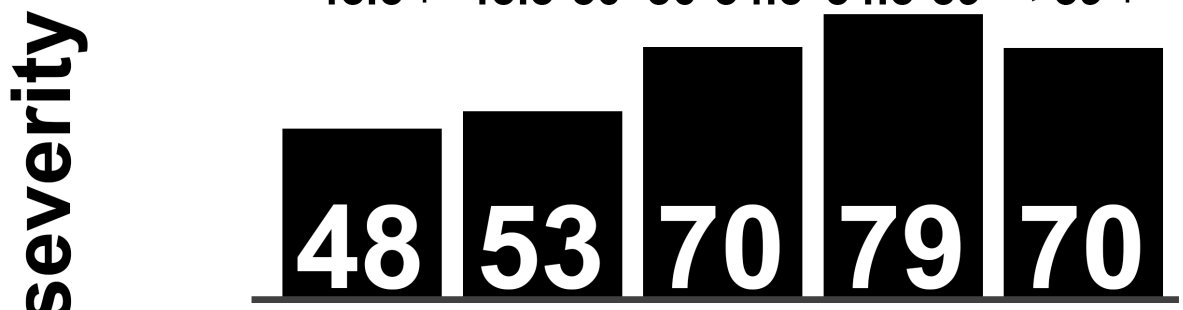
Presented are average results for field peas grown without fungicide seed treatment or with various different seed treatments.

Seeding rate = 330,000 viable seeds/ac.

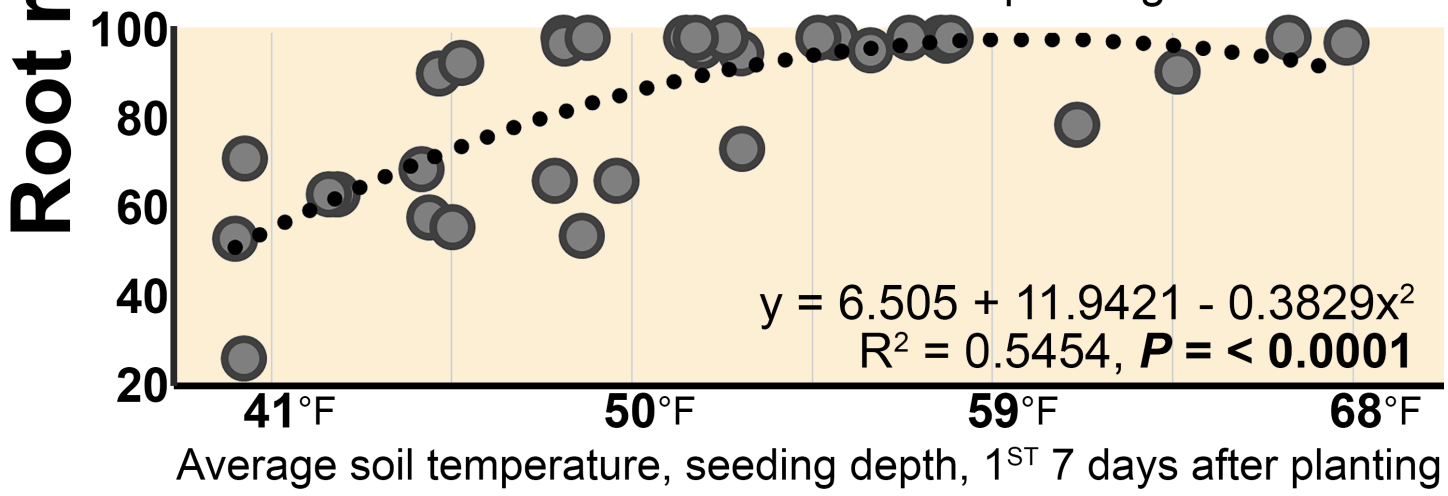
Diagnostic testing conducted on symptomatic diseased roots (genotype by sequencing, qPCR, traditional microbiology): *Aphanomyces euteiches* and multiple *Fusarium* species detected in each of the field studies

Soil temperature was recorded by installing data-logging soil temperature sensors at seeding depth that recorded soil temperature every 2 hours.

AVERAGE SEVERITY (% root and epicotyl diseased)
vs. soil temperature at seeding depth, 1ST 7 days after planting



RELATIVE ROOT ROT SEVERITY (0 to 100)
relative to maximum root rot across planting dates



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Fields with elevated Aphanomyces and Fusarium root rot caused by a long history of field pea and lentil production.
Williams, Mountrail and McLean Counties, ND (2019, 2020); Carrington, ND (2017-2020)
Long-term no-till at Williams, Mountrail and McLean County on-farm sites. Direct-seeded or conventional till in Carrington.

Yield optimized when soil temperature was 45.5-50°F (7 days after planting at 2" seeding depth).

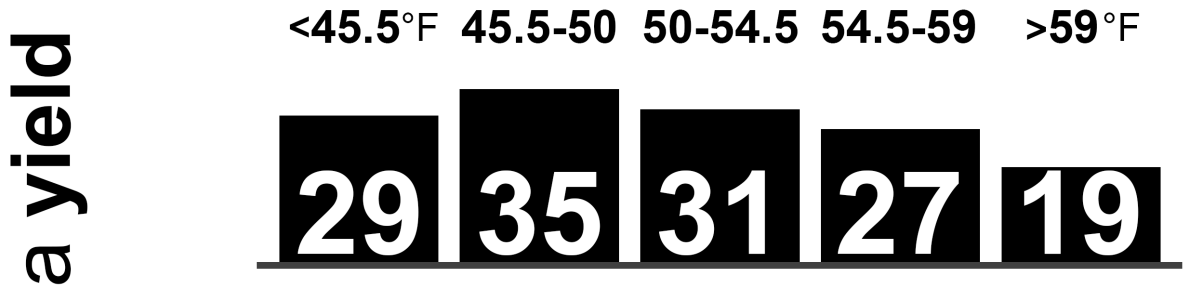
Presented are average results for field peas grown without fungicide seed treatment or with various different seed treatments.

Seeding rate = 330,000 viable seeds/ac.

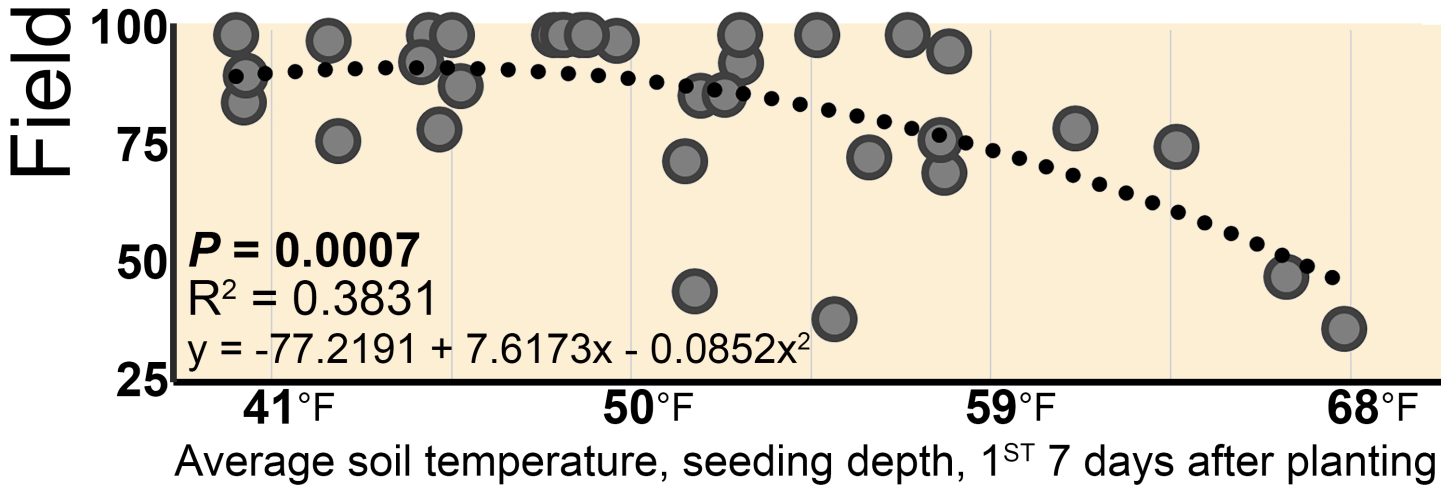
Diagnostic testing conducted on symptomatic diseased roots (genotype by sequencing, qPCR, traditional microbiology): *Aphanomyces euteiches* and multiple *Fusarium* species detected in each of the field studies

Soil temperature was recorded by installing data-logging soil temperature sensors at seeding depth that recorded soil temperature every 2 hours.

AVERAGE YIELD (bushels/acre)
vs. soil temperature at seeding depth, 1ST 7 days after planting



RELATIVE YIELD (0 to 100)
relative to maximum yield across planting dates



Aphanomyces and Fusarium root rot of **field peas**: Impact of **planting date**

Response to planting date in fields with elevated **native root rot pressure**

Fields with elevated Aphanomyces and Fusarium root rot caused by a long history of field pea and lentil production.
Williams, Mountrail and McLean Counties, ND (2019, 2020); Carrington, ND (2017-2020)
Long-term no-till at Williams, Mountrail and McLean County on-farm sites. Direct-seeded or conventional till in Carrington.

Emergence often suffered in cold soils, especially <43°F (7 days after planting at 2" seeding depth).

Presented are average results for field peas grown without fungicide seed treatment or with various different seed treatments.

Seeding rate = 330,000 viable seeds/ac.

Diagnostic testing conducted on symptomatic diseased roots (genotype by sequencing, qPCR, traditional microbiology): *Aphanomyces euteiches* and multiple *Fusarium* species detected in each of the field studies

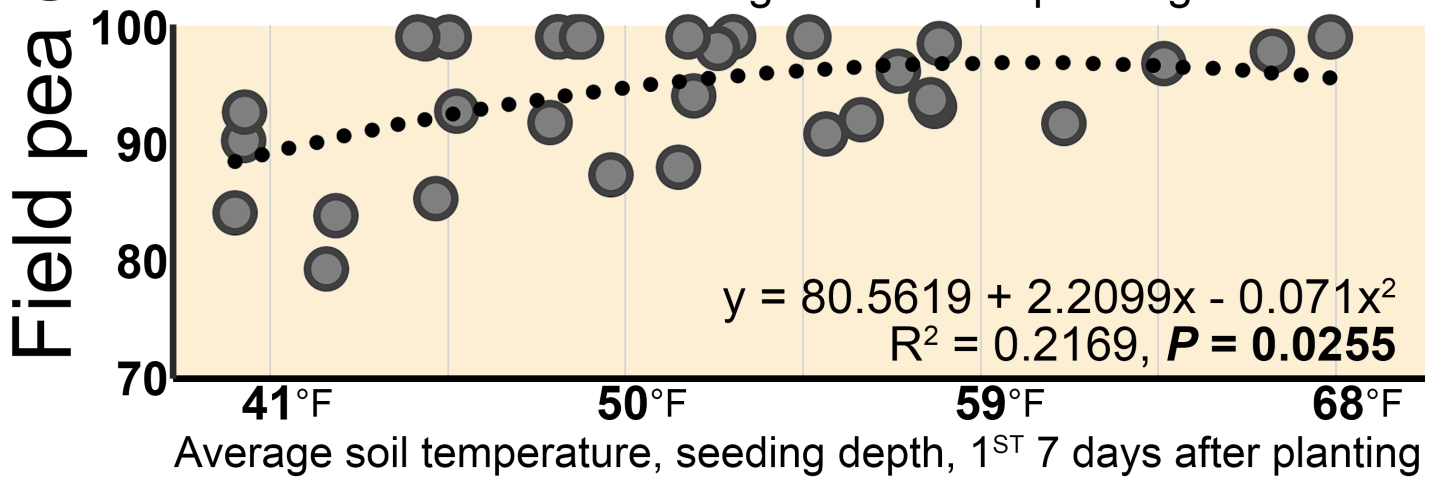
Soil temperature was recorded by installing data-logging soil temperature sensors at seeding depth that recorded soil temperature every 2 hours.

AVERAGE EMERGENCE (% of viable seeds)

vs. soil temperature at seeding depth, 1ST 7 days after planting

RELATIVE EMERGENCE (0 to 100)

relative to maximum emergence across planting dates



Aphanomyces and Fusarium root rot of **field peas**: Impact of **planting date**

In fields with Aphanomyces and Fusarium root rot pressure, field pea agronomic performance was optimized by planting when soils were approximately **43 to 50°F at 2-inch seeding depth**, average day and night across the first 7 days after planting.

- Consistent results relative to soil temperature were observed irrespective of tillage system (long-term no-till versus conventional tillage). Because long-term no-till warms up more slowly, no-till production should facilitate a wider window of time to plant at this target soil temperature.
- **There is a penalty to planting too early.** Planting peas at soils that averaged 39 to 41°F reduced yield potential.
- **There is a penalty to planting too late**. Aphanomyces and Fusarium are pathogens favored by warm soils. Planting into cool soils gives the peas an opportunity to get established before conditions become highly favorable for the pathogens.
- **Planting into cool soils increases the risk of losses to Pythium and Rhizoctonia**. Fungicide seed treatments are effective tools for managing these pathogens.
- This soil temperature can be targeted on the basis of your current soil temperature at seeding depth (average, day and night) and the 10-day forecast.

Fusarium root rot of **field peas**: Impact of **planting date**

Response to planting date in studies inoculated with **Fusarium**

Fields conducted in fields that do not have a long history of field pea and/or lentil production and that do not have problems with Aphanomyces or Fusarium root rot.
Long-term no-till production: Williston, ND (2018, 2019) Direct-seeded or conventional tillage: Carrington, ND (2017-2019)

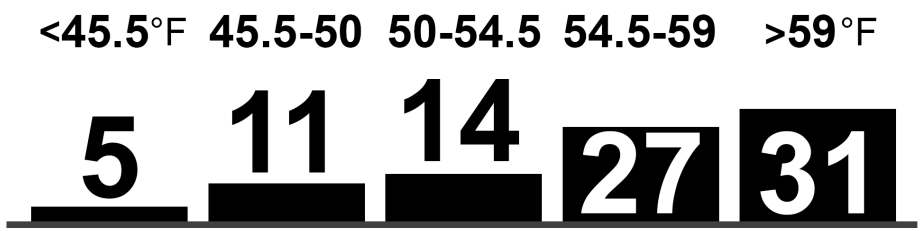
Root rot was minimized when soil temperature was < 54.5°F (7 days after planting at 2" seeding depth).

Presented are average results for field peas grown without fungicide seed treatment or with various different seed treatments.

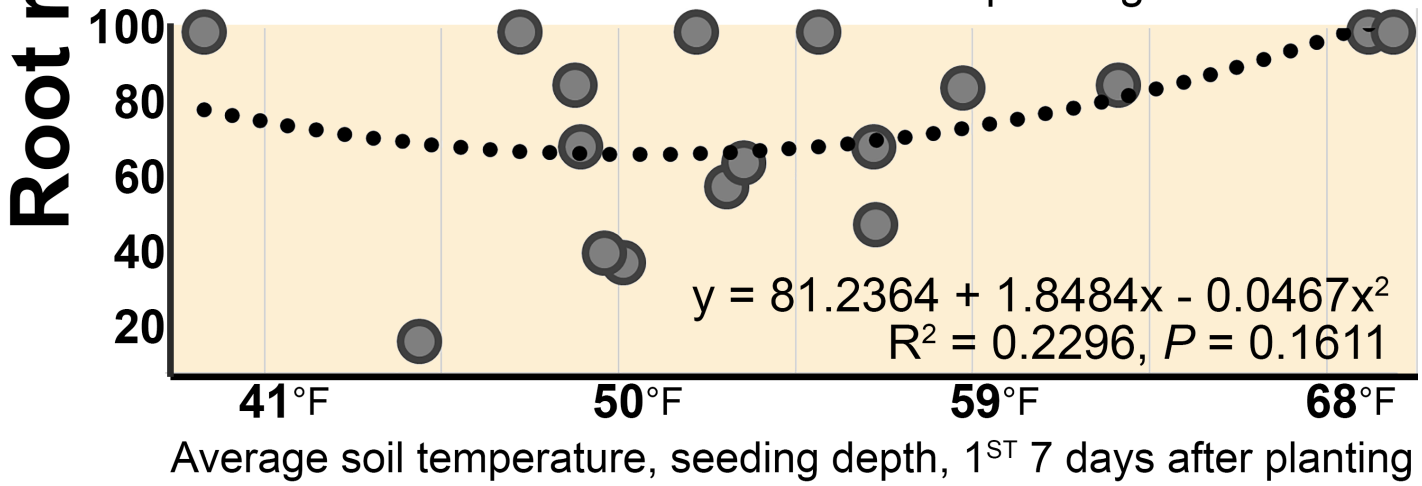
Seeding rate = 330,000 viable seeds/ac.

Field peas were planted in fields without an existing Aphanomyces or Fusarium root rot problem. Eight isolates of *Fusarium* spp. pathogenic to peas, including *F. avenaceum, F. solani*, were grown on soaked, autoclaved millet, dried, and then placed in-furrow with the field pea seed at planting.

AVERAGE SEVERITY (% root and epicotyl diseased)
vs. soil temperature at seeding depth, 1ST 7 days after planting



RELATIVE ROOT ROT SEVERITY (0 to 100)
relative to maximum root rot across planting dates



Fusarium root rot of **field peas**: Impact of **planting date**

Response to planting date in studies inoculated with **Fusarium**

Fields conducted in fields that do not have a long history of field pea and/or lentil production and that do not have problems with Aphanomyces or Fusarium root rot.
Long-term no-till production: Williston, ND (2018, 2019) Direct-seeded or conventional tillage: Carrington, ND (2017-2019)

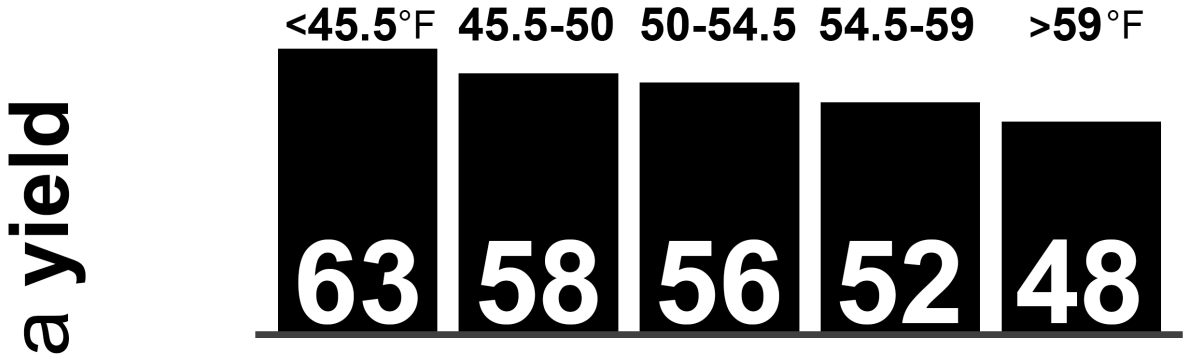
Yield optimized when soil temperature was <45.5°F (7 days after planting at 2" seeding depth).

Presented are average results for field peas grown without fungicide seed treatment or with various different seed treatments.

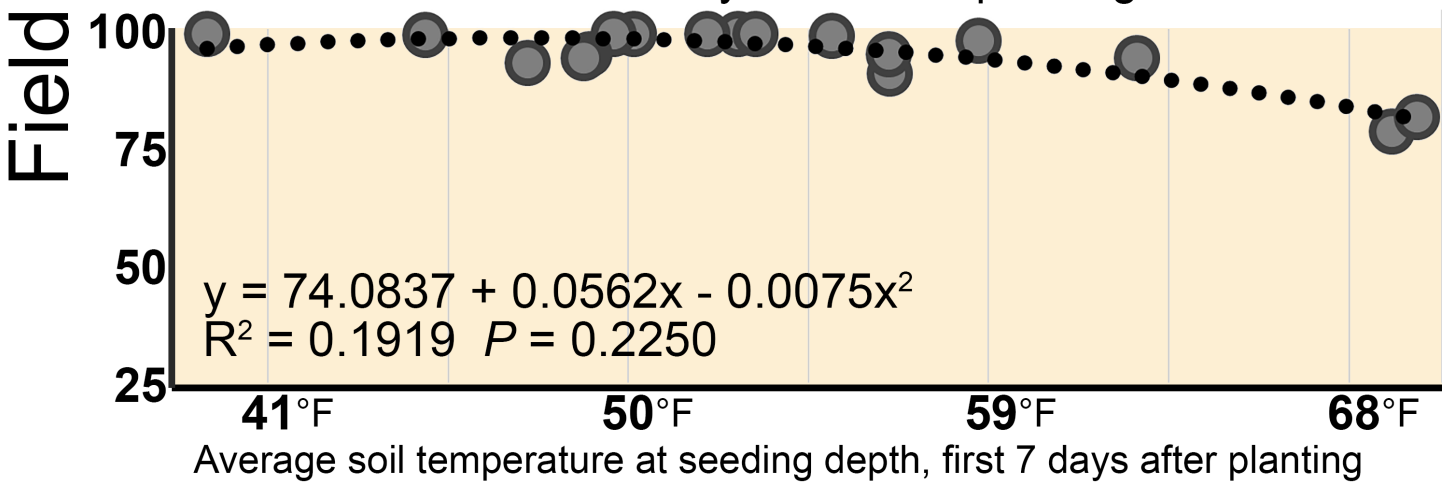
Seeding rate = 330,000 viable seeds/ac.

Field peas were planted in fields without an existing Aphanomyces or Fusarium root rot problem. Eight isolates of *Fusarium* spp. pathogenic to peas, including *F. avenaceum, F. solani*, were grown on soaked, autoclaved millet, dried, and then placed in-furrow with the field pea seed at planting.

AVERAGE YIELD (bushels/acre)
vs. soil temperature at seeding depth, 1ST 7 days after planting



RELATIVE YIELD (0 to 100)
relative to maximum yield across planting dates



Fusarium root rot of **field peas**: Impact of **planting date**

Response to planting date in studies inoculated with **Fusarium**

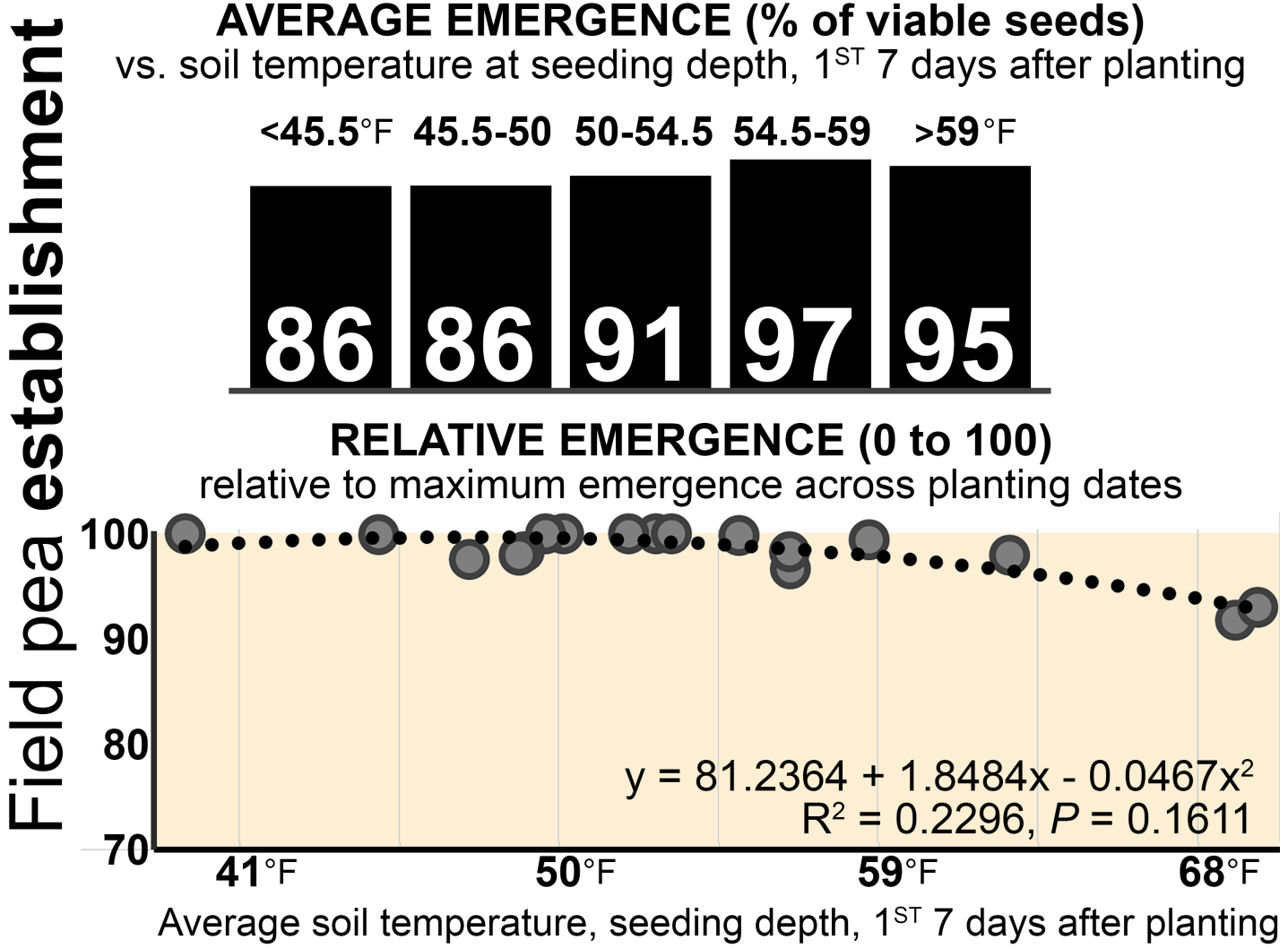
Fields conducted in fields that do not have a long history of field pea and/or lentil production and that do not have problems with Aphanomyces or Fusarium root rot.
Long-term no-till production: Williston, ND (2018, 2019) Direct-seeded or conventional tillage: Carrington, ND (2017-2019)

Establishment was only slightly reduced in cold soils
(7 days after planting at 2" seeding depth).

Presented are average results for field peas grown without fungicide seed treatment or with various different seed treatments.

Seeding rate = 330,000 viable seeds/ac.

Field peas were planted in fields without an existing Aphanomyces or Fusarium root rot problem. Eight isolates of *Fusarium* spp. pathogenic to peas, including *F. avenaceum, F. solani*, were grown on soaked, autoclaved millet, dried, and then placed in-furrow with the field pea seed at planting.



Aphanomyces and Fusarium root rot of **field peas**: Impact of **planting date**

Field peas inoculated with the Fusarium root rot pathogen and grown in **fields without a long history of growing peas or lentils** and without elevated native Aphanomyces or Fusarium pressure:

- Field pea agronomic performance was optimized by planting very early, **39 to 45°F at 2-inch seeding depth**, average day and night across the first 7 days after planting.
- The number of studies conducted was limited and none of these studies experienced very cold weather in mid-April. When soil temperatures average around 40°F, it is early in the spring and a few days of very cold weather often occur. It would be well-advised to wait until soil temperatures warm to **43 to 50°F at 2-inch seeding depth,** average first 7 days after planting**.**
- Consistent results relative to soil temperature were observed irrespective of tillage system (long-term no-till versus direct-seeded or conventional tillage).
- **In fields without a long history of pea or lentil production, field pea establishment was excellent even in cool soils.** This suggests that Pythium and Rhizoctonia pressure were relatively low. The yield gains conferred by fungicide seed treatment (data not shown) were low even with early planting, again suggesting that Pythium and Rhizoctonia were not significant constraints in fields that lacked a long history of pea or lentil production.

Aphanomyces and Fusarium root rot of field peas: Planting date studies conducted across fields **differing** in the **interval since peas last grown**

Carrington, ND (2023, 2024)

Research methods:

Randomized studies with six replicates (randomized complete block with a split-split-plot arrangement, main factor = plant date, sub-factor = variety, sub-sub-factor = seed treatment)

Plots 5 ft x 30 ft at planting, 5 ft x approx. 20 ft at harvest.

Plots consist of 7 rows, each 7.5 inches apart

Seeding rate = 330,000 viable seeds/ac.

Tillage: mixture of direct seeding into previous year's crop (7 studies/year) and full conventional tillage (4 studies/year).

Data collection:

Root rot: assessed at early to mid vegetative growth (4-10 nodes). The percent of the epicotyl + top 2.5 cm of the tap root diseased; assessed on 16, 36, or 50 roots/plot, depending on study and planting date. Half of the roots were collected from each plot end outside of the area assessed for yield.

Wilt: assessed at mid to late pod-fill. A visual estimate of the percent of the plants exhibiting root rot associated wilt symptoms. This was always assessed at a consistent growth stage across field pea varieties within each planting date.

Within each study, every effort was made to assess root rot and wilt at a consistent growth stage across every planting date and every field pea variety.

Yield: moisture was assessed at harvest and yields are reported at a standard 13.5% moisture

Fusarium and Aphanomyces root rot of field peas: Impact of **planting date**

Carrington, ND (2024):

High Aphanomyces pressure; *Fusarium avenaceum* at moderate levels

Studies with **low disease** severity

Field:	Field Q9A	Field Q9F	Field Q9G	Average
Last year seeded to peas:	**2019**	**2016**	**2013**	
Aphanomyces euteiches (thousand DNA copies/gram of root)				
AAC **Julius**	**66052**	**3**	**21**	**22026**
AAC **Profit**	**42345**	**1**	**2**	**14116**
Fusarium oxysporum (thousand DNA copies/gram of root)				
AAC **Julius**	**0**	**0**	**0**	**0**
AAC **Profit**	**0**	**0**	**0**	**0**
Fusarium avenaceum (thousand DNA copies/gram of root)				
AAC **Julius**	**314**	**1**	**0**	**105**
AAC **Profit**	**127**	**0**	**0**	**42**

Carrington, ND **(2024)**

Diagnostic qPCR testing conducted by the National Agriculture Genotyping Center. Results represent the average across nine qPCR tests per study (bulked samples across replicates 1 and 2, replicates 3 and 4, and replicates 5 and 6 from each of three planting dates). For all fields except 18south and 17, testing was conducted only on non-fungicide treated seed and each of the 9 tests for each variety in each study represents a combined sample of two 1-cm long epicotyl segments, one collected from each of the two experimental replicates bulked within that planting date. For fields 18south and 17, each of the 9 tests for each variety in each study represents the combined sample of 10 1-cm long epicotyl segments, one collected collected from each fungicide seed treatment (non-treated versus four different fungicide seed treatment) and two replicates. The 1-cm long epicotyl segments were collected from a plant with root rot symptoms typical of that plot.

Studies with **high disease** severity

Field:	Field 17	18 north	Field 1	Field Q9D	Q9E west	18 south	Field Q9B	Q9E east	Average
Last year seeded to peas:	**2021**	**2020**	**2020**	**2020**	**2018**	**2015**	**2015**	**2015**	
Aphanomyces euteiches (thousand DNA copies/gram of root)									
AAC **Julius**	**13456**	**23709**	**10868**	**62634**	**92513**	**19479**	**29061**	**25648**	**34671**
AAC **Profit**	**37538**	**23453**	**112343**	**83690**	**56400**	**66357**	**29709**	**35824**	**55664**
Fusarium oxysporum (thousand DNA copies/gram of root)									
AAC **Julius**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
AAC **Profit**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Fusarium avenaceum (thousand DNA copies/gram of root)									
AAC **Julius**	**92**	**66**	**64**	**244**	**1119**	**267**	**127**	**96**	**259**
AAC **Profit**	**140**	**171**	**180**	**370**	**205**	**387**	**84**	**249**	**223**

Fusarium and Aphanomyces root rot of field peas: Impact of **planting date**

Carrington, ND (2024): four planting dates from late April to mid-June

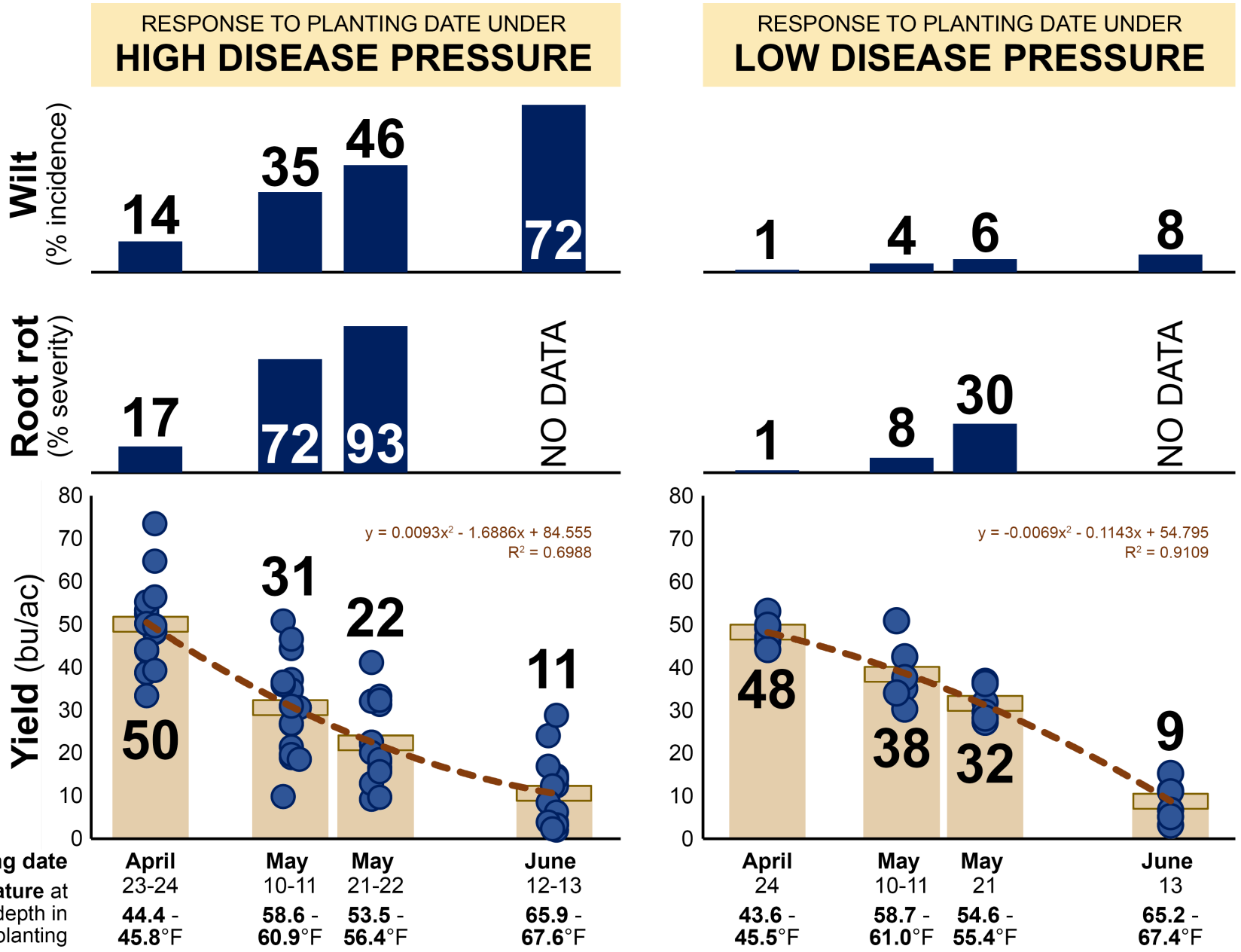
High pressure: 8 studies, all with >15% average wilt across all four planting dates.

High pressure: 3 studies, all with <10% average wilt across all four planting dates

Root rot was assessed at early/mid vegetative growth

Wilt was assessed at mid/late pod-fill

AAC Julius and **AAC Profit** peas; 330,000 viable seeds/ac. Shown are the combined results across 11 fields differing in the number of years since peas were last grown. Shown are data from peas grown without seed treatment. Circles denote performance of one field pea variety in one planting date in one replicated study.



Fusarium and Aphanomyces root rot of field peas: Impact of **planting date**

Carrington, ND (2023):

High Aphanomyces pressure; *Fusarium oxysporum* at low levels

Studies with **low disease** severity

Field:	Field Q9A	Field Q9F	Field Q9G	Average
Last year seeded to peas:	**2019**	**2016**	**2013**	
Aphanomyces euteiches (thousand DNA copies/gram of root)				
AAC **Julius**	**319**	**0**	**0**	**106**
AAC **Profit**	**47422**	**0**	**0**	**15807**
Fusarium oxysporum (thousand DNA copies/gram of root)				
AAC **Julius**	**5.0**	**1.6**	**4.8**	**4**
AAC **Profit**	**0**	**0**	**0**	**0**
Fusarium avenaceum (thousand DNA copies/gram of root)				
AAC **Julius**	**0**	**0**	**0**	**0**
AAC **Profit**	**0**	**0**	**0**	**0**

Carrington, ND **(2023)**

Diagnostic qPCR testing conducted by the National Agriculture Genotyping Center. Results represent the average across four qPCR tests per study (one per planting date). Each test represents a combined sample of six 1-cm long epicotyl segments, one collected from each of the six experimental replicates within each planting date. The 1-cm long epicotyl segments were collected from a plant with root rot symptoms typical of that plot. Testing was only conducted on plants grown from non-treated seed (no fungicide seed treatment).

Studies with **high disease** severity

Field:	Field Q9D	F18 north	Field 1	F18 north	Q9E west	Field Q9B	F18 south	Q9E east	Average
Last year seeded to peas:	**2020**	**2020**	**2020**	**2019**	**2018**	**2015**	**2015**	**2015**	
Aphanomyces euteiches (thousand DNA copies/gram of root)									
AAC **Julius**	**38558**	**16818**	**154627**	**10670**	**17290**	**47830**	**25260**	**10616**	**40209**
AAC **Profit**	**40581**	**10563**	**120633**	**957**	**72670**	**37114**	**751**	**110068**	**49167**
Fusarium oxysporum (thousand DNA copies/gram of root)									
AAC **Julius**	**0**	**1.9**	**0**	**0**	**0**	**0**	**0**	**0**	**0.2**
AAC **Profit**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Fusarium avenaceum (thousand DNA copies/gram of root)									
AAC **Julius**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
AAC **Profit**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Fusarium and Aphanomyces root rot of field peas: Impact of **planting date**

Carrington, ND (2023): wet spring precluded early planting; 4 plant dates, mid/late May to early June

High pressure: 8 studies, all with >15% average % wilt across all four planting dates

High pressure: 3 studies, all with <10% average % wilt across all four planting dates

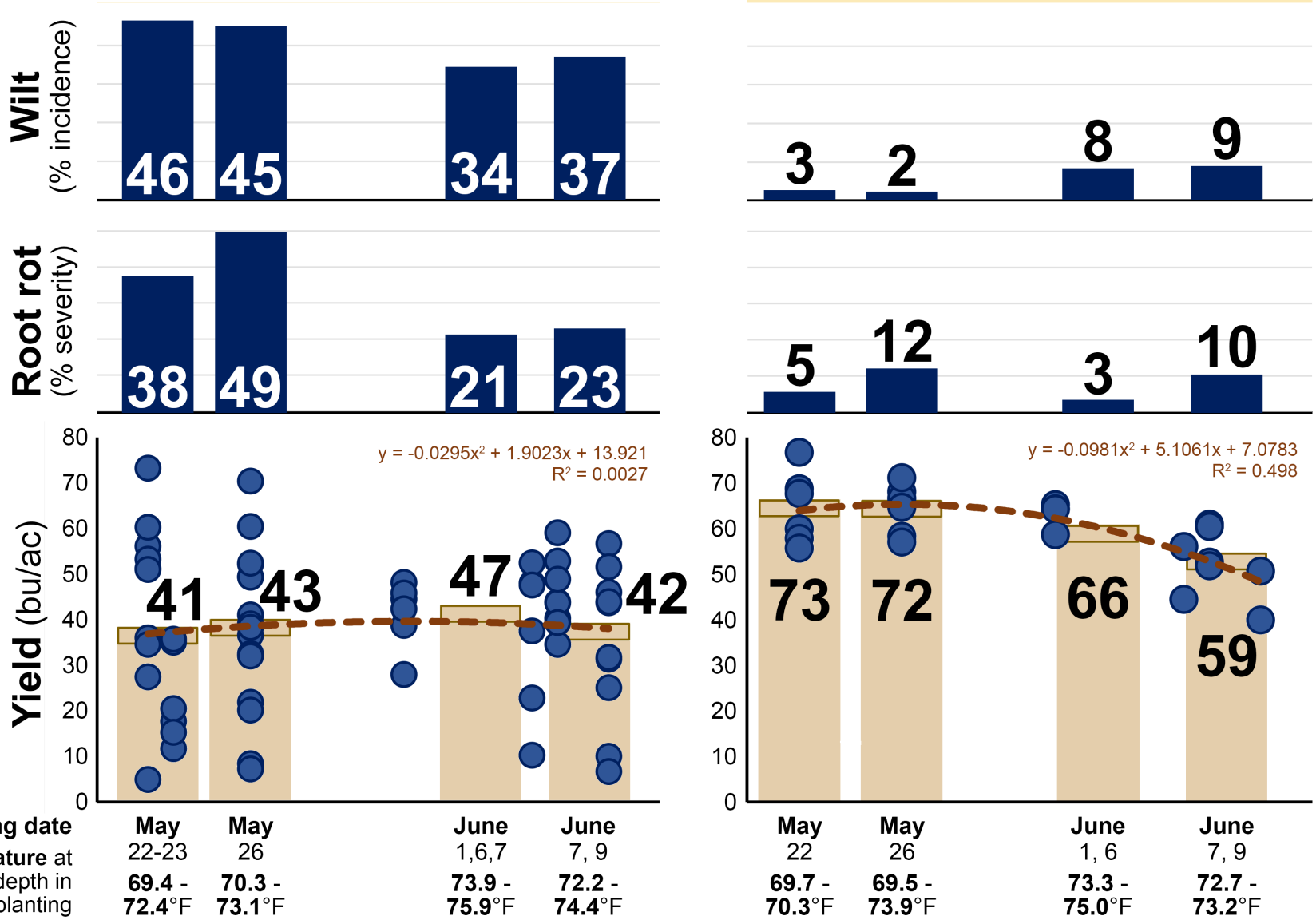
Root rot was assessed at early/mid vegetative growth

Wilt was assessed at mid/late pod-fill

AAC Julius and **AAC Profit** peas; 330,000 viable seeds/ac. Shown are data from peas grown without seed treatment. Shown are the combined results across 11 fields differing in the number of years since peas were last grown. Circles denote performance of one field pea variety in one planting date in one replicated study.

RESPONSE TO PLANTING DATE UNDER
HIGH DISEASE PRESSURE

RESPONSE TO PLANTING DATE UNDER
LOW DISEASE PRESSURE



Aphanomyces and Fusarium root rot of field peas: Planting date studies conducted across fields **differing** in the **interval since peas or lentils last grown**

Williston, ND (2023, 2024)

Research methods:

Randomized studies with six replicates (randomized complete block with a split-split-plot arrangement, main factor = plant date, sub-factor = variety, sub-sub-factor = seed treatment)

Plots 5 ft x 30 ft at planting, 5 ft x approx. 20 ft at harvest.

Plots consist of 7 rows, each 7.5 inches apart

Seeding rate = 330,000 viable seeds/ac.

Tillage: long-term no-till

Data collection:

Root rot: assessed at early to mid vegetative growth (4-10 nodes). The percent of the epicotyl + top 2.5 cm of the tap root diseased; assessed on minimum 30 roots/plot. Half of the roots were collected from each plot end outside of the area assessed for yield.

Within each study, every effort was made to assess root rot at a consistent growth stage across every planting date and every field pea variety.

Yield: moisture was assessed at harvest and yields are reported at a standard 13.5% moisture

Fusarium and Aphanomyces root rot of field peas: Impact of **planting date**

Williston, ND (2024): three planting dates, late April to mid-May

Low Aphanomyces and Fusarium root rot pressure

Study number; last year seeded to pea/lentil:	497-24 **2018**	498-24 **2022**	499-24 **2020**	Average
Fusarium oxysporum (thousand DNA copies/gram of root)				
AAC **Julius**	**42**	**29**	**51**	**41**
Fusarium avenaceum (thousand DNA copies/gram of root)				
AAC **Julius**	**0**	**61**	**35**	**32**
Fusarium acuminatum (thousand DNA copies/gram of root)				
AAC **Julius**	**0**	**6**	**59**	**22**
Fusarium redulens (thousand DNA copies/gram of root)				
AAC **Julius**	**0**	**0**	**0**	**0**
Fusarium solani (thousand DNA copies/gram of root)				
AAC **Julius**	**0**	**0**	**0**	**0**
Aphanomyces euteiches (thousand DNA copies/gram of root)				
AAC **Julius**	**10**	**0**	**12**	**7**
***Pythium* spp.** (thousand DNA copies/gram of root)				
AAC **Julius**	**0**	**6**	**0**	**2**
Rhizoctonia solani (thousand DNA copies/gram of root)				
AAC **Julius**	**18992**	**377**	**15**	**6461**

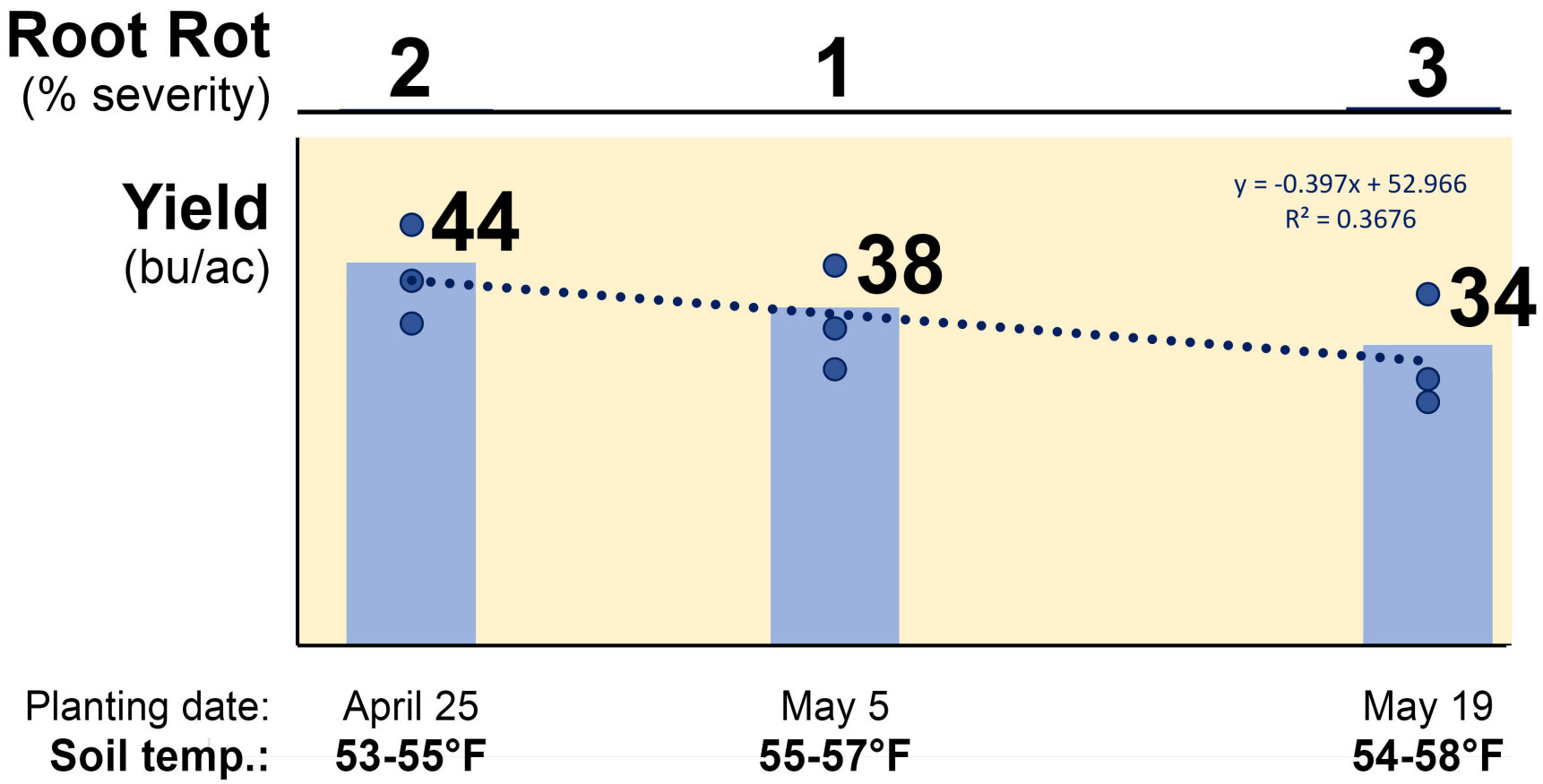
Williston, ND **(2024)**

Diagnostic qPCR testing conducted by the National Agriculture Genotyping Center. Results represent the average across three qPCR tests per study (one test per planting date, with each test conducted on a bulked sample of diseased epicotyl sections collected across all six replicates of the study). Testing was conducted only on non-fungicide treated seed. From each experimental replicate, a 1-cm long epicotyl segment was collected from a plant with root rot symptoms typical of that plot. The epicotyl segments were bulked across the six experimental replicates. For each of the three planting dates conducted in each study, a single sample consisting of six epicotyl segments was tested by qPCR.

Fusarium and Aphanomyces root rot of field peas: Impact of **planting date**

Williston, ND (2024): three planting dates, late April to mid-May

Fields with low root rot pressure: penalty to delayed planting low



Soil temperature (average, day and night) at 2-inch seeding depth, first 7 days after planting.

'AAC Julius' yellow field pea. Seeding rate = 330,000 viable seeds/ac. The data presented are from peas grown without a seed treatment.

Shown is the combined analysis across three studies differing in the number of years since peas or lentils were last grown. Circles denote results from one planting date in one study. All studies were conducted on fields under long-term no-till management.

Fusarium and Aphanomyces root rot of field peas: Impact of **planting date**

Williston, ND (2023):
Four planting dates, late April to mid-May
Low Aphanomyces and Fusarium pressure

Williston, ND (2023)

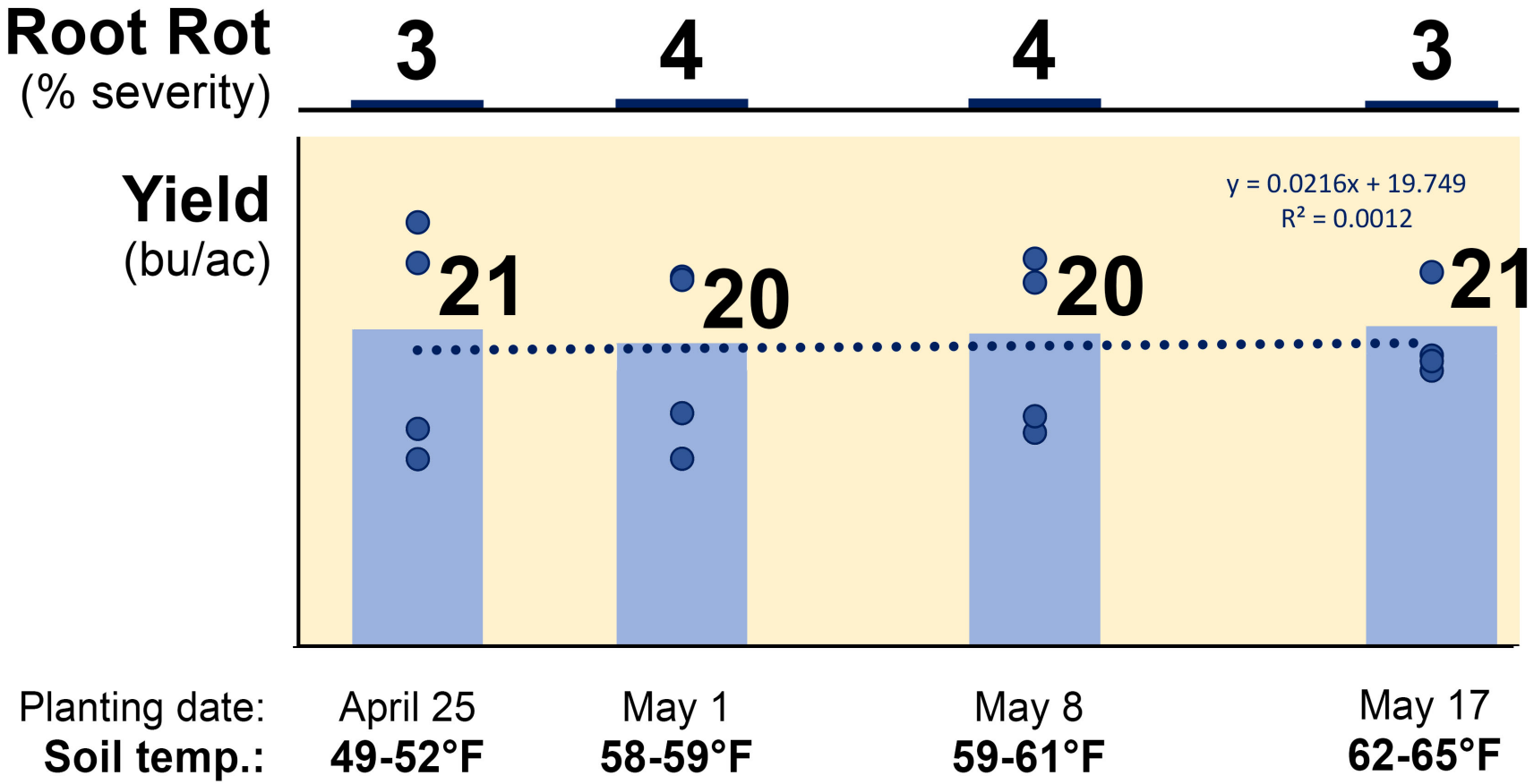
Study number; last year seeded to pea/lentil:	487-23 **2018**	489-23 **2020**	Average
Aphanomyces euteiches (thousand DNA copies/gram of root)			
AAC **Julius**	**0**	**0**	**0**
AAC **Profit**	**0**	**0**	**0**
Fusarium oxysporum (thousand DNA copies/gram of root)			
AAC **Julius**	**0**	**1041**	**521**
AAC **Profit**	**0**	**1348**	**674**
Fusarium avenaceum (thousand DNA copies/gram of root)			
AAC **Julius**	**0**	**0**	**0**
AAC **Profit**	**0**	**0**	**0**

Diagnostic qPCR testing conducted by the National Agriculture Genotyping Center. Results represent the average across four qPCR tests per field pea variety per study (one test per variety per planting date, with each test conducted on a bulked sample of diseased epicotyl sections collected across all six replicates of the study). Testing was conducted only on non-fungicide treated seed. From each field pea variety and each experimental replicate, a 1-cm long epicotyl segment was collected from a plant with root rot symptoms typical of that plot. The epicotyl segments were bulked across the six experimental replicates.

Fusarium and Aphanomyces root rot of field peas: Impact of **planting date**

Williston, ND (2023): Four planting dates, late April to mid-May

Fields with low root rot pressure: no penalty to delayed planting in 2023



Soil temperature (average, day and night) at 2-inch seeding depth, first 7 days after planting.

'AAC Julius' and 'AAC Profit' yellow field peas, seeding rate = 330,000 viable seeds/ac. The data presented are from peas grown without a seed treatment.

Shown is the combined analysis across three studies differing in the number of years since peas or lentils were last grown. Circles denote results from an individual study. All studies were conducted on fields under long-term no-till management.

Aphanomyces and Fusarium root rot of **field peas**: Impact of **planting date**

Across fields with a long history of field pea and/or lentil production and differing in number of years since peas or lentils were last grown,

- Field pea agronomic performance was optimized in fields with elevated Aphanomyces and Fusarium root rot pressure by planting when soils were approximately **43 to 50°F at 2-inch seeding depth**, average day and night across the first 7 days after planting.
- Where root rot pressure was low, the yield penalty to late planting was lower. The yield penalty associated with late planting increases with Aphanomyces and Fusarium root rot pressure.
- When early planting is not possible, weather conditions later in the season influence the degree of penalty associated with late versus very late planting.

Overall conclusions:

- In fields with Aphanomyces and Fusarium root rot pressure, field pea agronomic performance is optimized by planting when soils are approximately **43 to 50°F at 2-inch seeding depth**, average day and night across the first 7 days after planting.
- This soil temperature can be targeted on the basis of your current soil temperature at seeding depth (average, day and night) and the 10-day forecast.
- **Fungicide seed treatment is advised** when planting field peas early in fields with a long history of peas and/or lentils. Pythium and Rhizoctonia pressure appears to increase with repeated cropping of peas and lentils, and fungicide seed treatment has provided strong yield gains in fields with a long pea and/or lentil history.
- **The penalty to late planting is lower in fields with low Aphanomyces and Fusarium pressure.**
- **Planting too early reduces field pea yield potential.** Planting should be delayed until soil temperatures are expected to average 43 to 50°F at 2-inch seeding depth, average day and night across the first 7 days after planting.

Integrated management of **Aphanomyces and Fusarium root rot** in field peas

Michael Wunsch, Suanne Kallis, Jesse Hafner, Aaron Fauss NDSU Carrington Res. Ext. Center

in collaboration with Edson Ncube and Audrey Kalil, NDSU Williston Research Extension Center

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