WINTER OAT BREEDING FOR KENTUCKY PROGRESS REPORT FOR 2023-2024

Lauren Brzozowski and Carrie Knott
University of Kentucky

INTRODUCTION (OBJECTIVE)

Winter oats (*Avena sativa*) could increase diversity in Kentucky grain rotations. However, there is limited cultivation of winter oats in Kentucky, totaling approximately 536 acres in 2017 USDA Agricultural Census. This may be due to several factors. First, winter oats are known to be among the least cold tolerant of small grains. Second, there has not been plant breeding to date for adapted oat varieties for Kentucky climates and grain rotations (e.g., maturation date aligning with typical double crop rotation). Thus, the goal of this project is to address these major barriers to winter oat in production in Kentucky by improving our understanding of winter survival in oats, breeding new oat varieties, and assessing how oats fit into a double crop rotation. This project addresses KySGGA priorities of breeding new small grain varieties, where oats can be an option to reduce winter fallow and increase rotational diversity. Our objectives were:

Objective 1. Use variety trial data to assess the effects of winter severity on oat yield

Objective 2. Winter oat breeding

Objective 3. Evaluate viability of winter oats in a no-till double crop system

MATERIALS AND METHODS

Objective 1. Use variety trial data to assess the effects of winter severity on oat yield.
Winter survival is generally poorer in oats than wheat or rye, but the relationship between winter temperatures and winter oat survival and yield is not well established. To address this question, we collected oat performance data from state variety trials (managed by Bill Bruening, and supported by KySGGA) spanning from 2011-2023, and weather data from NASA Power. We then examined the relationship between metrics of winter weather severity and winter oat performance.

Objective 2. Winter oat breeding.
My winter oat breeding program follows a structure typical for small grains: cross-pollinations between parents, followed by advancement by family until breeding line derivation as F4:5 lines, and continuing with plot-level trials at the F5 stage for at least three years. This breeding program is new; I began this program when I started at University of Kentucky in August 2022. As such, the current material in the advanced stages of testing is advanced breeding material from North Carolina State University (Dr. Paul Murphy). I have used that material as well as other lines from the Noble Foundation and other breeding programs to generate new Kentucky-bred material. I have also selected within early generations of populations provided from other public winter oat breeding programs to develop breeding lines adapted to Kentucky.

The breeding program is focused on improving winter stress resilience, yield and test weight while

maintaining maturity timelines similar to wheat. At all stages of the breeding cycle, winter survival, winter stress and heading date are measured. For plots, yield, test weight, lodging, plant height and relevant disease severity is measured. For advanced lines in state-wide yield trials, basic quality traits like percent protein, oil and starch are evaluated by NIR. Lines with a pending variety release are evaluated for advanced quality and milling traits at a testing lab.

Crossing is conducted at a University of Kentucky greenhouse (Lexington, KY), early generation evaluations are conducted at University of Kentucky North Farm (Lexington, KY), and yield trials are evaluated at North Farm, as well as University of Kentucky research farms in Versailles, KY and Princeton, KY, and on Walnut Grove Farms in Schochoh, KY.

Objective 3. *Evaluate viability of winter oats in a no-till double crop system*.
We sought to test how oats compare to wheat in terms of subsequent soybean yield for a double crop rotation. At both North Farm and Princeton, we planted four varieties each of oats and wheat in 4 x 15 ft plots replicated four times in a randomized complete block design, for a total of 32 plots per location. We planned to harvest the small grains in June 2024, follow with a single variety of soybeans, and then assess soybean yield and quality to determine if there are advantages (or disadvantages) to double cropping with oats as compared to wheat. Unfortunately, the winter oats in the double crop trial did not survive in Princeton (the trial was in a low field; oats in an adjacent field had >95% winter survival), and both the wheat and oats suffered from severe lodging in Lexington, and this trial was not completed.

RESULTS & DISCUSSION

Objective 1. *Use variety trial data to assess the effects of winter severity on oat yield*.
We used historical state variety trial data (2011-2023) to examine the relationship between winter temperatures and oat performance. This work was conducted by a graduate student, and we found a negative correlation between the number of days below freezing and oat winter survival (winter survival was higher with fewer days below freezing during the growing season; **Figure 1**). However, this relationship did not extend to yield. Yield was not always higher in these warmer years (**Figure 2**). This has spurred further work to elucidate how timing of specific winter stresses affects yields.

Figure 1. Mean and standard error of oat winter survival in the state variety trials from 2011-2023. Color indicates the number of days below freezing in the growing season, with blue indicating more days below freezing (colder) and red indicating fewer days below freezing (warmer).

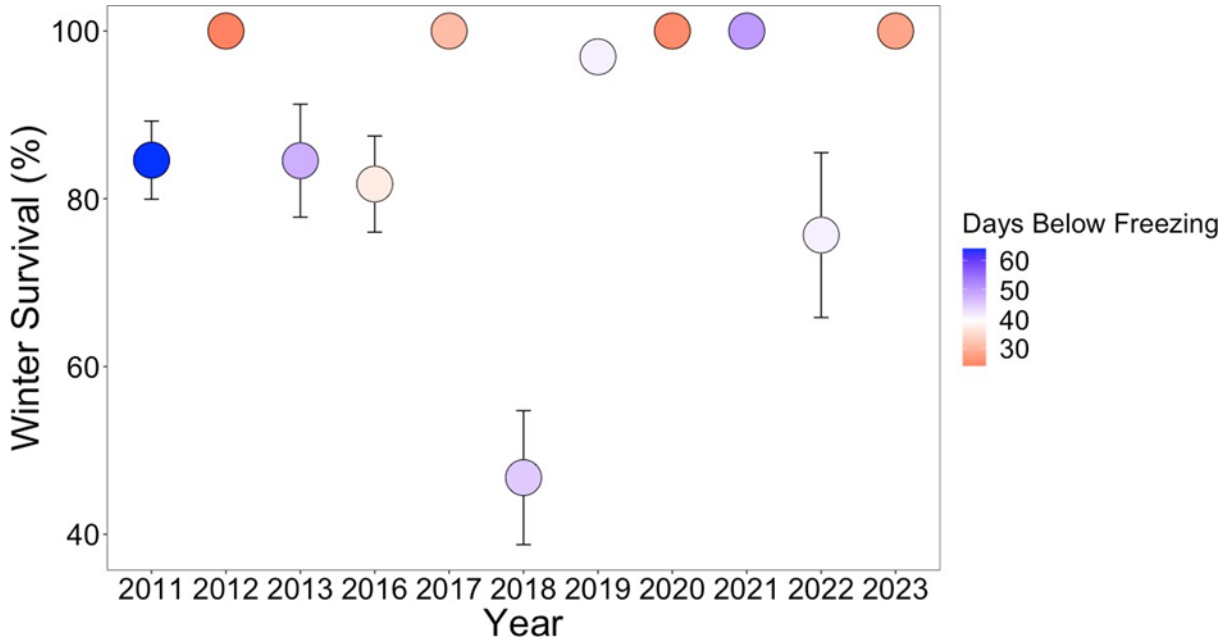
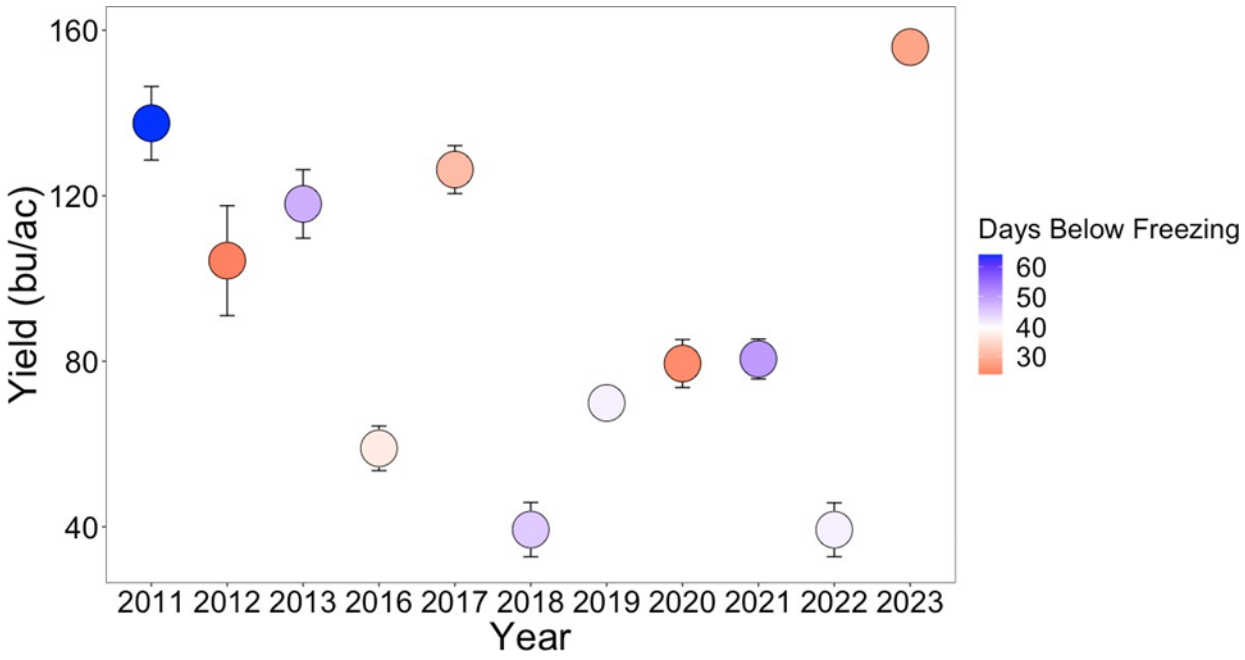


Figure 2. Mean and standard error of oat yield (32 lb bu/ac) in the state variety trials from 2011-2023. Color indicates the number of days below freezing in the growing season, with blue indicating more days below freezing (colder) and red indicating fewer days below freezing (warmer).



Objective 2. *Winter oat breeding*.

The winter oat breeding program has successfully generated new breeding lines and advanced promising lines through the breeding pipeline, up to entry of advanced lines in the state yield trials this upcoming year (2024-2025).

The breeding program has made new cross pollinations each year: 30 crosses in the 2022- 23 season, and 50 in the 2023-24 season, with the goal to have 50-80 annually hereafter. In the 2024-25 season, the F2s and F3s are UK breeding lines developed from KySGGA support in 2023- 2024.

We have also made selections within early generation material (F2 and F3 families) generously provided by other public winter oat breeding programs. This early generation material was selected for winter hardiness in Kentucky for the past two years and F4:5 breeding lines were derived in 2024. In the 2024-25 season, there will be >1000 F4:5 headrows to be evaluated. Concurrently, F5 seed harvested from F4 plots is grown in replicated plots in three environments for early yield estimation (early yield trial, EYT). In the 2024-25 season, there will be 40 entries in the EYT.

Finally, advanced lines from North Carolina State University have now been evaluated in at least two locations for two years. The advanced lines were evaluated at North Farm (**Tables 1**) and Walnut Grove Farms (**Table 2**) in 2023, and at North Farm (**Tables 3**), Woodford (**Table 4**) and Schochoh (**Table 5**; not harvested due to flooding, lodging) Princeton (**Table 6**) in 2024. Overall, these lines are on par with or had better winter survival than current commercial checks (Gerard 224, Gerard 227, Horizon 201, Horizon 578), with higher yield and test weights. The goal with these advanced lines is to select new winter oat varieties for Kentucky. Eight of these top lines will be evaluated again in the advanced yield trial (AYT) of the breeding program and have seed increases in 2024-25; these lines are indicated with a (*) in **Tables 1-5**. In addition, five of these lines will be entered into the state variety trials. Ultimately, I hope to co-release one of these lines as a new variety with NCSU.

Next steps

- To build upon our results about winter oat survival, we will conduct a study to test the effect of planting date on oat winter survival. The damage inflicted by cold temperatures depends in part on plant developmental stage, and so using a planting date gradient will allow us to capture different developmental stages at key moments of winter stresses (e.g., major freeze events). This will allow for evaluation of varieties that experience winter stresses at different developmental stages. We expect that this work will provide a clearer picture of oat resilience to winter stress and provide useful planting date information.
- The breeding program will continue to develop new breeding lines as described above.
- The double crop trial will continue.

ACKNOWLEDGEMENTS

We would like to thank the Kentucky Small Grain Growers' Association for their funding support of this project. Additional funding was provided by Hatch funding (KY006145) and University of Kentucky start-up funding to LB. Multiple undergraduate students contributed to this project, including some funded fully or in part by this project, including Ignacio Sanguinetti and Logan West.

TABLES

The tables summarize mean trait values adjusted for spatial variation for each line in the advanced trial. The commercial checks Gerard 224, Gerard 227, Horizon 201, Horizon 578 are listed at the top of the table, followed by the eight lines advancing to the advanced yield trials which are also indicated with a (*). Each table is a separate location, year.

Table 1. Oat advanced trial – 2023, Lexington, KY

Genotype	Winter Survival (%)	Height (cm)	Heading Date	Lodging (%)	Yield (bu/ac)	Test Weight (lbs)
Gerard 224	59.4	109.6	123.8	11	153.6	37
Gerard 227	69.6	119.8	126.2	47.9	158.1	38.7
Horizon 201	74.4	127.9	121.1	50.1	153.3	34.7
Horizon 578	72.5	113.9	125.1	62.5	167.5	37.6
NC20-4402*	75.1	127	124.6	25.3	227.2	37.3
NC20-4452*	73	119.8	128	15.9	133.2	37.2
NC20-4526*	61.4	117.9	122.4	42.2	136.7	39.6
NC20-4551*	72.9	123.9	125.6	66.6	153.4	40.9
NC21-6492*	80	115.9	123.1	39.4	174.5	38.1
NC21-6497*	79.5	115.7	123.8	52.7	176.3	38.5
NC21-6502*	71.9	118.6	126.9	9.2	180.3	37.6
NC21-6511*	64.4	132	123.1	12.7	172.5	35.8
NC12-3753	71.1	120.4	123.7	58.2	114.4	39.2
NC12-3922	77	117.1	123.1	13.3	156.4	39.6
NC17-6440	73.9	113.6	121.6	22.8	159.7	39.3
NC17-6550	78.8	115.8	126.6	51.3	151.4	40.6
NC19-3362	74.5	122.5	128.9	21.5	139.8	38
NC19-3542	66.5	116	126.7	52.1	134.6	37
NC20-4352	71.7	101.4	125.7	9.1	142.7	34.7

(Table 1 continues on next page)

NC20-4441	76.2	127.4	125.8	26.6	155.6	39.2
NC20-4621	64.5	135.6	130.1	37.4	164.9	39
NC20-4700	77.6	116	126.1	-4.6	155.7	37
NC20-4702	68.5	128	128.4	30.1	111.4	41.1
NC20-4795	70.8	133.7	126.2	26.5	171.7	35.5
NC21-6328	71.7	122.5	117.1	1.8	144.5	41.5
NC21-6429	75.1	116.8	126.6	52.8	142.4	37.9
NC21-6436	66.1	103.2	125.1	-12.2	83.7	33.5
NC21-6463	76.8	139.1	127.3	98.1	134.2	37.2
NC21-6475	75.6	129.6	119.2	130.2	158.6	39.1
NC21-6505	71.7	117.3	122.6	28.3	188.5	39.1
NC21-6515	73.1	107	124.8	48.7	128.9	36.4
NC21-6520	59.4	124.8	124.8	46.8	109	37.9
NC21-6521	77.9	117.6	124.4	48.5	153.4	37.4
NC21-6569	74.8	114.4	118.6	98.7	120.3	38.7
NC21-6576	76.9	116.8	120.1	95.6	154.5	39
NC21-6587	74.2	112.5	121.3	12.5	101.5	35.9
NC21-6592	68.8	114.9	119.4	98.5	109.6	39.3
NC21-6609	79.8	104.5	124.4	-10.2	181	35.8
NC21-6610	68.1	98.1	126.6	32.2	170.1	36.3

Table 2. Oat advanced trial – 2023, Schochoh, KY

Genotype	Heading Date	Yield (bu/ac)	Test Weight (lbs)
Gerard 224	114	165.8	36.9
Gerard 227	114.6	145.9	35.9
Horizon 201	116.7	128.3	34.6
Horizon 578	112.7	165.6	38.3
NC20-4402*	116.1	150.6	37.7
NC20-4452*	114.3	183.6	38.3
NC20-4526*	114.2	128.1	36.6
NC20-4551*	116.9	179.8	38.6
NC21-6492*	111.8	179.1	38.1
NC21-6497*	111.3	182	37.8
NC21-6502*	110.9	143	36.6
NC21-6511*	110.5	161.4	37.3
NC12-3753	111.6	138.9	37.9
NC12-3922	112.2	168.2	38.2
NC17-6440	112	157.8	37.7
NC17-6550	116.5	155	38.5
NC19-3362	119.3	152.8	35.6
NC19-3542	113	167.9	35.9
NC20-4352	113.7	149.2	37.3
NC20-4441	113.7	149.1	37.2
NC20-4621	123.9	176.8	38.5
NC20-4700	112.8	169.5	34.7
NC20-4702	116.4	159.1	39.9
NC20-4795	114.9	141.6	35.8
NC21-6328	110.6	124.2	38.8
NC21-6429	116.5	141.1	38.4
NC21-6436	111.9	116.6	38.9
NC21-6463	121.3	122.7	36.8
NC21-6475	112.3	118.8	39
NC21-6505	111.7	155.8	36.2
NC21-6515	113.3	130.3	38
NC21-6520	118.3	164.2	37.9
NC21-6521	117	158.1	38.1
NC21-6569	112.5	162.3	37.9
NC21-6576	111.9	130.7	36.9
NC21-6587	112.8	101.7	37.9
NC21-6592	111	139.2	37.1
NC21-6609	112.3	168.3	37
NC21-6610	113	175.3	35.9

Table 3. Oat advanced trial – 2024, Lexington, KY

Genotype	Winter Stress (1-9)	Winter Survival (%)	Height (cm)	Heading Date	Lodging (%)	Yield (bu/ac)	Test Weight (lbs)
Gerard 224	2	96.5	95.8	115.4	-8.4	128.4	34.9
Gerard 227	2	94.9	99.8	116	35.3	102.9	32.9
Horizon 201	2.2	90	114.6	117	21.8	119.5	32.7
Horizon 578	1.8	91	94.1	117.2	6.1	100.9	34.1
NC20-4402*	2.3	90.8	116.1	116.4	3.4	115.1	34.9
NC20-4452*	2.1	92	92.5	117.8	7.7	114.4	34.9
NC20-4526*	2.4	96.6	97.8	116.8	0.1	116.2	36.1
NC20-4551*	1.9	94.2	105.4	118.6	44.1	96.2	36.8
NC21-6492*	1.7	90.3	92.6	117.6	5.2	115.1	35.3
NC21-6497*	1.6	91.2	90.8	116.7	1.6	116.6	34.8
NC21-6502*	3	91.8	96.9	117.1	7.9	91.1	34.6
NC21-6511*	1.7	93.3	101.5	116.4	21.6	90.3	35.1
NC12-3753	1.5	92.2	107.1	116.1	4.4	107.3	36
NC12-3922	2	94.9	91.9	116.6	0.6	108.1	34.5
NC17-6440	2	93.6	94.9	116.9	26.5	106.1	32.9
NC17-6550	2	95.9	98.8	117.4	51.1	83.2	35.6
NC19-3362	3.1	92.6	101.5	120.4	5.9	117.2	32.8
NC19-3542	4.6	94	88.4	117.4	39.1	81.8	33.1
NC20-4352	1.9	96.3	88.2	118.8	-5	81.7	31.4
NC20-4441	2.1	92.6	97.1	116.6	32.9	85	35.3
NC20-4621	2.6	93.9	110.6	119.6	52.9	88.1	35.1
NC20-4700	2.6	87.9	93.4	116.8	5.9	117.3	32.7
NC20-4702	1.5	95	NA	119.6	87.8	45.6	35.8
NC20-4795	2.6	91.2	115.4	116.7	22.7	102.7	33
NC21-6328	2.4	89.4	100.9	111.5	5.9	106.3	38.8
NC21-6429	1.9	79.7	110.4	116.9	82.5	65.5	34.2
NC21-6436	3.6	87.1	76.8	116.3	5.3	71.5	36.1
NC21-6463	2.1	85	113.5	120.2	74.1	49.1	33.6
NC21-6475	2.1	94.6	110.5	116.4	79.7	78.3	37.4
NC21-6505	2.6	90.2	94.7	113.5	1.5	106.1	35.3
NC21-6515	2.5	91.6	83.7	118.5	52.7	56.7	33.9
NC21-6520	1.9	91.9	118.5	118.6	87.9	47.8	35.1
NC21-6521	2	90.4	106.4	118.4	94.4	93.8	34.4
NC21-6569	2.6	97.2	92	113.9	53	62.7	34.3
NC21-6576	2.3	93.5	87.7	112	70.6	85.9	34.7
NC21-6587	2.1	94.5	90.4	115.6	8.8	92.9	35.1
NC21-6592	2	91.7	104.9	115.3	88.4	72.2	36.4
NC21-6609	2.4	90.7	91.3	117.2	24.4	107.1	32.7
NC21-6610	1.9	96.2	91.4	116.9	4.2	112.8	32.9

Table 4. Oat advanced trial – 2024, Versailles, KY

Genotype	Winter Survival (%)	Height (cm)	Heading Date	Lodging (%)	Yield (bu/ac)	Test Weight (lbs)
Gerard 227	97.3	102.2	123	91.6	61	35.5
Horizon 201	94.5	112.3	122.6	99	71.8	35.8
Horizon 578	94.5	107.6	123	95.6	125.2	36.4
NC20-4402*	93.6	106.7	123	64.4	125.7	36.2
NC20-4551*	101	106.6	123.9	91.3	100.8	36.7
NC21-6492*	95.3	108.2	122.5	96.5	132.7	35.9
NC21-6497*	94.3	108.4	123	59.8	124	37
NC21-6502*	95.3	102.6	125	75.8	143.3	37.5
NC21-6511*	95.2	108.9	122.5	98.9	143.5	37.3
NC12-3922	90.7	105.9	122	70.6	129.8	37.2
NC17-6440	95.3	100	124	98.3	81.9	34.9
NC17-6550	99.3	100.3	123.1	95.2	64.7	38.5
NC20-4441	95.6	109.4	123.9	96.5	99.5	34.9
NC21-6328	92.6	102.6	119	92.2	107.4	39.9
NC21-6475	92.5	118.2	122	104	68.4	36.4
NC21-6505	91.1	111.8	125.5	90.8	137.9	38.1
NC21-6576	96.1	99.6	121	94.2	74.4	38
NC21-6592	95.5	102.7	122.5	88.8	80.5	39.5
NC21-6609	91.8	94.7	124.4	88.7	77.4	37.2
NC21-6610	94.8	97.2	124	99.7	75.2	35.4

Table 5. Oat advanced trial – 2024, Schochoh, KY

Genotype	Winter Stress (1-9)	Winter Survival (%)	Height (cm)	Heading Date	Lodging (%)
Gerard 224	1.7	100.2	NA	115.7	-3.9
Gerard 227	1.5	100	125.4	115.7	26.1
Horizon 201	2.8	100.1	138.4	116.5	23.7
Horizon 578	1.4	99.8	118.1	116.3	13.9
NC20-4402*	1.6	100.1	137.2	116.2	15.8
NC20-4452*	1.3	99.9	NA	118.3	14
NC20-4526*	1.3	100.1	130.2	116.4	38.2
NC20-4551*	0.1	99.9	132.1	119.4	25
NC21-6492*	1.6	100.1	119.1	114.9	9.3
NC21-6497*	0.9	100.1	NA	114.7	15.4
NC21-6502*	1.7	99.9	119.4	117.2	-2.4
NC21-6511*	2.1	99.8	119.4	112.9	22.8
NC12-3753	1.2	96.7	NA	113.3	17.1
NC12-3922	1.4	100	116.6	115.5	5.9
NC17-6440	1.3	100.1	119.4	117.2	9.7
NC17-6550	1.4	100	116.8	116	24.6
NC19-3362	1.3	100.1	116.8	121.4	24.2
NC19-3542	1.7	100	111.8	117.3	3.1
NC20-4352	1.3	100.1	112.9	119.9	1.3
NC20-4441	1	100.1	124.5	117.2	42.1
NC20-4621	2.4	100	145.1	120.8	1.6
NC20-4700	1.7	99.9	NA	117	29.4
NC20-4702	1.3	100.1	125.5	120.1	9.2
NC20-4795	2	100.1	127	115.4	30.1
NC21-6328	3.1	99.8	111.8	113.1	23.7
NC21-6429	1.7	99.9	NA	119.4	15.8
NC21-6436	1.1	100	104.1	113.2	30.4
NC21-6463	1.6	100	137.2	117.6	23.8
NC21-6475	1.6	100	142.2	113.3	26.7
NC21-6505	2.3	100.1	128.3	117.1	-13.5
NC21-6515	1.1	99.9	111.8	116	22.4
NC21-6520	1.6	100.1	NA	117.4	15.2
NC21-6521	1.7	99.9	114.8	118.4	15.4
NC21-6569	1.7	99.9	NA	114.1	16.7
NC21-6576	1.7	99.9	NA	114.5	19.8
NC21-6587	2.4	100	119.4	115.3	45
NC21-6592	2.1	99.9	119.4	112.9	20.2
NC21-6609	1.9	100.1	116.8	114.6	52.2
NC21-6610	2.7	100	111.8	114.3	20.1

Table 6. Oat advanced trial – 2024, Princeton, KY

Genotype	Winter Stress (1-9)	Winter Survival (%)	Height (cm)	Heading Date	Lodging (%)	Yield (bu/ac)	Test Weight (lbs)
Gerard 224	1.4	94.9	106.5	116.4	38.8	77.3	33.9
Gerard 227	1.4	94.5	112.3	116.2	42.9	80.5	32.5
Horizon 201	2.3	93.6	119.4	114.5	57.9	59.6	31.9
Horizon 578	1.5	96.3	107.3	116.4	28.6	76.1	34.9
NC20-4402*	1.5	95.8	120.5	116.6	58.6	72.9	33.5
NC20-4452*	1	95.6	110.2	117.6	28.6	81.8	33.8
NC20-4526*	1	94.8	106.4	114.2	72.3	78.2	35
NC20-4551*	0.9	95.1	116.6	118.3	28	75.9	35.6
NC21-6492*	0.9	97.6	101.6	115.3	8	87.8	34.8
NC21-6497*	2	95.1	101.3	116	6.2	81.8	35.5
NC21-6502*	1.6	97.1	105.5	115.2	0.2	77	33.2
NC21-6511*	1.9	97.6	110.3	112.4	13.8	75.2	34.3
NC12-3753	0.9	93.5	112.4	114.6	48.6	75.6	34.3
NC12-3922	2	92.5	109.8	117	26.2	71.9	35
NC17-6440	1.5	95.3	100.1	112.2	72.3	69.4	34.1
NC17-6550	2.1	94.8	115.7	117.5	71.7	55.1	34.6
NC19-3362	1.9	93	114.2	119.9	72.8	64.5	30.5
NC19-3542	1.6	93.1	141.8	117.6	51.6	81.3	32.2
NC20-4352	1.6	91.7	100.5	118.5	1.7	65.9	32.2
NC20-4441	1.9	95.6	114	116.3	39.3	67.2	34
NC20-4621	2.9	92.4	122.7	118.4	36.3	88.8	32.8
NC20-4700	2	94.2	107.2	116.4	11.7	71.4	32.7
NC20-4702	1.1	94.4	117.1	118.7	57.7	54.2	36
NC20-4795	2	93.2	124.7	115.1	21.1	70.7	31.9
NC21-6328	1.5	92.4	114.6	110.2	49.8	63.8	37.1
NC21-6429	2.6	85.5	113.5	118.1	64.1	42.3	32.2
NC21-6436	1	95.7	97.7	113.8	23	61.9	34.1
NC21-6463	2.5	94.5	120.6	117.1	90.7	51.5	29
NC21-6475	2	94.4	116.5	112.6	43.2	49.9	35.6
NC21-6505	2.4	90.1	109.3	116.3	8	71.7	34.3
NC21-6515	1	97.9	96.1	115.8	58	70.5	34.2
NC21-6520	1.1	94.2	116.4	116.2	57.7	56.6	35.1
NC21-6521	1	97	120.5	116.1	59	55.6	34.8
NC21-6569	1	97.2	101.6	112.7	32.3	58	35.7
NC21-6576	1.4	98.2	98.2	113.6	53.6	66.5	34.6
NC21-6587	2.1	95.5	100	112.6	59.1	52.7	33.7
NC21-6592	1	94.6	108.7	112.4	91.7	99.7	35.6
NC21-6609	1.9	94.7	98.9	115.3	8	68	35.3
NC21-6610	2	95.1	102.4	115.2	32.3	86.9	34.5