Northern NY Agricultural Development Program
2024 Project Report

Breeding Cereal Rye for Late-Season Cover Crop Planting

Project Leader:

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Collaborating NNY Producers:

- Sam Dyer, Dyer Farm, Plattsburgh, NY
- Andrew Menard, Happy Havens Farm, Mooers, NY
- Terry Pominville, Pominville Farms, Croghan NY.

Background:

Fall-planted cover crops help reduce soil erosion and nutrient runoff, filter surface and groundwater, add organic matter to the soil, reduce weeds and pests, and sequester carbon in the soil. Cereal rye is the most common cover crop due to its unparalleled biomass production, weed suppression, and growth under cold conditions. While rye is a popular cover crop among northern growers, challenges for farmer adoption remain. In March 2022, a focus group of 14 northern New York (NNY) farmers and service providers identified short planting windows, adaptation to cold climate, and seed cost as the main challenges to cover cropping in the region. Improved winter hardiness and tolerance of late planting were identified as top areas for future research and breeding. In 2024, our research team concluded a two-year cereal rye variety and planting date trial initiated in 2022, in which we sought to identify varieties more tolerant of late planting and better adapted for cover crop use in NNY. We also continued selecting cereal rye breeding populations for cold-soil emergence and vigor. We also started distribution of a national survey focused on cereal rye breeding needs.

Previous and ongoing related work

The Northern New York Agricultural Development Program (NNYADP) has funded two years (2022-2023 and 2023-2024 cover cropping seasons) of cereal rye variety and planting date trials across NNY. Experiments have been planted in the following locations:

- CUAES Willsboro Research Farm, Willsboro, NY;
- Extension Learning Farm, Canton, NY (2022-2023 season only);
- 3 farms in Northern New York (Lewis and Clinton Counties); and
- Homer C. Thompson Vegetable Research Farm, Freeville, NY (outside funding).

The experiment included 6 rye varieties in the 2022-2023 season and 14 varieties in the 2023-2024 season. Rye was planted on up to four dates between September 25 and October 25 at the research stations and a single date on farms. Data collection included soil testing, seedling emergence, plant vigor, winter survival, growth stage, and biomass.

A set of experiments was also initiated to develop cereal rye with improved ability to emerge and produce sufficient biomass when planted late in the fall. Selection nurseries were planted in Willsboro (NNYADP), Freeville, and St. Paul, MN (other funding). The nurseries include 11 populations derived from crosses between northern-adapted cereal rye cultivars (Aroostook and ND Gardner) and southern-adapted breeding lines with high allelopathy. The nursery at the Willsboro Research Farm was planted on October 13, 2023. Emergence and vigor will be evaluated in fall 2023. The same populations were also planted in a Cornell laboratory in Ithaca, NY in a thermogradient table, which is a controlled environment used to test seed germination over a range of temperatures. The experiment was planted in October 2023 under cold temperatures (2-5°C), and plants were selected among and within families for rapid emergence and vigor. Selected plants will be vernalized and intermated in the greenhouse over the winter (2023-2024), and a second cycle of evaluation and selection will take place in the thermogradient table in spring 2024.

In addition to the experiment described above, the Moore lab is engaged in several projects related to cover crop management and breeding. Dr. Moore leads a national Cover Crop Breeding (CCB) Network, which includes rye breeding nurseries in New York, Maryland, Minnesota, and North Carolina, and 15 testing locations across the country. The lab is also testing rye varieties in combination with hairy vetch to determine flowering time and compatibility for roller-crimper systems.

Methods:

Variety x planting date trials

The variety x planting date experiment took place over two years: fall 2022-spring 2023 (Year 1) and fall 2023-spring 2024 (Year 2). The experiment was conducted at the Miner Agricultural Research Institute in Chazy, NY (both years) and at the Cornell Cooperative Extension of St. Lawrence County Extension Learning Farm (ELF) in Canton, NY (Year 1 only) in coordination with a trial planted at the Homer C. Thompson Vegetable Research Farm in Freeville, NY (both years). The trial was planted on up to four dates between 25 September and 25 October (Table 1). The experiment included 6 rye varieties in Year 1 and 14 varieties in Year 2 (Table 2). Plots were drill seeded at a rate of 112 lb/acre.

Fall data collection varied by site, but included emergence (assessed visually on a percentage basis) and vigor (evaluated on a 1 to 9 scale, with 1 as the least vigorous plot and 9 as the most vigorous). Emegence and vigor were recorded approximately every 2 weeks after each planting date. As with fall data collection, spring data collection varied by site but included percent stand at green-up, plant height, vigor, heading date, maturity at harvest, lodging at

harvest, rye biomass, weed biomass, and grain yield. Winter survival was calculated from the values for spring stand and fall emergence. Members of the Moore Lab traveled to some locations in NNY to assist with data collection and biomass sampling when needed.

Table 1. Experimental locations and planting dates, Breeding Cereal Rye for Late-Season Cover Crop Planting project Year 1: fall 2022-spring 2023 and Year 2: fall 2023-spring 2024.

Location	Year	Planting Date 1	Planting Date 2	Planting Date 3	Planting Date 4
Miner Agricultural Research Institute (Chazy)	1	25 September	5 October	13 October	25 October
	2	25 September	10 October	17 October	6 November
Extension Learning Farm (Canton)	1	--	12 October	--	26 October
Homer C. Thompson Vegetable Research Farm (Freeville)	1	30 September	12 October	20 October	25 October
	2	25 September	4 October	13 October	25 October
Happy Haven Farm (Mooers)	1	--	3 October	--	--
	2	--	--	--	24 October
Dyer Farm (Plattsburgh)	1	--	12 October	--	--
	2	--	--	16 October	--
Pominville Farms (Croghan, NY)	1	--	6 October	--	--
	2	27 September	--	--	--

Table 2. Cereal rye varieties planted in variety x planting date and on-farm trials, Breeding Cereal Rye for Late-Season Cover Crop Planting project Year 1: fall 2022-spring 2023 and Year 2: fall 2023-spring 2024.

Variety	Planted Year 1 (all sites)	Planted Year 2 (research stations)	Planted Year 2 (Clinton County farms)	Planted Year 2 (Lewis County farm)
Aroostook	Yes	Yes	Yes	Yes
CoverMax	No	Yes	Yes	No
Danko	Yes	Yes	Yes	Yes
Elbon	Yes	Yes	Yes	Yes
Guardian	Yes	Yes	Yes	Yes
Hazlet	Yes	Yes	Yes	Yes
Musketeer	No	Yes	No	No
NC20-R114	No	Yes	No	No
NC20-R109	No	Yes	No	No
NC20-R103-2	No	Yes	No	No
ND Gardner	Yes	Yes	Yes	Yes
Rymin	No	Yes	No	No
Sangaste	No	Yes	No	No
Wrens Abruzzi	No	Yes	Yes	Yes

On-farm variety trial

Variety trials were planted on three farms in NNY in both fall 2022 and fall 2023 (Table 1), including a subset of the varieties evaluated in the research station trial (Table 2). The trials were planted by Clinton County Soil and Water Conservation District personnel in strip plots following cash crop harvest on each participating farm. On-farm data collection varied by site,

but included seedling emergence, plant vigor, winter survival, plant height, canopy cover, and biomass.

Rye breeding
Starting in Fall 2023, a set of experiments were also initiated to breed cereal rye with improved emergence and productivity when planted late in the fall. These experiments included: (1) rye breeding nursery, (2) selection in controlled environment, (3) field evaluation, and (4) controlled environment evaluation.

A **rye breeding nursery** was planted in fall 2023 in Willsboro, NY, in conjunction with nurseries in Freeville, NY, and St. Paul, MN, which included some of the same breeding populations. The Willsboro nursery included 11 populations derived from crosses between northern-adapted cereal rye cultivars (Aroostook and ND Gardner) and southern-adapted breeding lines with high allelopathy.

The nursery at the Willsboro Research Farm was planted on October 13, 2023. The nursery was evaluated for emergence, fall and spring vigor, and winter survival. A total of 44 plants were selected; non-selected plants were removed prior to anthesis and selected plants were allowed to intermate and seed was harvested from these plants. The same populations were also **selected in a controlled environment** to compare efficacy of selecting in the field vs. controlled environment and to determine whether the controlled environment can be used to increase the rate of gain in breeding for emergence and productivity at late planting. The populations were planted in a laboratory in Ithaca, NY, in a thermogradient table, which is a controlled environment used to test seed germination over a range of temperatures.

The population was selected for two cycles of selection in the thermogradient table, conducted in fall 2023 and spring 2024. In each cycles of the experiment, rye was planted under cold temperatures (2-5°C), and data collection included days to emergence, temperature at emergence (monitored with sensors below the soil surface), number of plant emerged, and vigor. Plants were selected among and within families.

A total of 58 plants were selected in the first cycle and 143 were selected in the second cycle. Selected plants were vernalized and intermated in the greenhouse to form the next cycle of selection.

A **field evaluation** of the breeding populations was planted in Willsboro, NY (October 17, 2024) in conjunction with a field evaluation in Freeville, NY (October 21, 2024). The experiment included eight entries, including six breeding populations and two commercial cultivars (Table 3). The Willsboro location had to be replanted on November 8 due to a planting error, and emergence and vigor data were not collected due to snowfall soon after planting. However, plant emergence was confirmed in January 2025, and data will be collected as soon as plots are free of snow. After greenup in spring 2025, data will be collected on spring stand, vigor, biomass, and seed yield.

In January 2025, the same populations were planted in a controlled environment evaluation in Ithaca, NY. Populations were planted in the thermogradient table using the same temperature programs as above. Plants will be evaluated for days to emergence, number of emerged plants, and vigor. Upon completion of the field and controlled environment evaluations, we will analyze combined data to determine: (1) the efficacy of selecting in the field vs. controlled environment, and (2) the correlation between performance in the field vs. controlled environment. The most promising populations will continue to be selected for traits relevant to emergence and productivity under late planting.

Table 3. Cereal rye varieties and breeding populations included in 2024-2025 evaluations, Breeding Cereal Rye for Late-Season Cover Crop Planting project.

	Name	Description
1	NY-Cold-C0	Base population for selection experiment
2	NY-Cold-C1-F	Cycle 1 of field selection
3	NY-Cold-C1-C	Cycle 1 of controlled environment selection
4	NY-Cold-C2-C	Cycle 2 of controlled environment selection
5	24NYCRL	Late-flowering rye population selected in Freeville, NY (2023-2024)
6	24NYCRE	Early-flowering rye population selected in Freeville, NY (2023-2024)
7	Aroostook	Commercial check cultivar
8	ND Gardner	Commercial check cultivar

Farmer survey

Given the importance of cereal rye across the U.S. as a winter hardy cover crop and a grain and forage crop, and the likelihood that challenges and needs are likely to overlap between Northern New York and other regions (especially northern U.S.), we made the decision to expand the scope of the planned rye survey to be national and address other end uses in addition to as a cover crop. Rye experts from across the U.S. were consulted to expand and revise the survey content throughout 2024. The survey includes information about the state and county of the respondent, so it will be possible to disaggregate data specific to Northern New York. The survey is being distributed online via the Qualtrics platform, and is live for responses and being actively distributed. In 2025, results from the survey will be analyzed, published, and shared widely in Northern New York and beyond.

Results:

Variety x planting date trials

Due to the variation in planting dates and varieties included and data collected at each site and year of the experiment, data are analyzed on an individual site-year basis.

Emergence was generally consistent across varieties and planting dates (>80%), except in the fourth planting in Chazy (both Year 1 and 2). In Chazy in Year 1 values ranged between 45% and 80% emergence, and in Year 2 no emergence was observed until spring.

Winter survival varied by site. The lowest values were in Canton in 2023 with mean values less than 50% for all variety and planting date combinations, and some values as low as 9% survival on the later date. In Chazy, mean winter survival was greater than 70% for all varieties in planting dates 1-3. However, winter survival was generally less than 50% for planting date 4 in Year 1, and in Year 2 winter survival could not be calculated for planting date 4 since there was no fall emergence. Winter survival was excellent (>95%) across all plots in Freeville in both years.

Monthly mean temperatures were relatively similar across sites, with Canton and Chazy somewhat colder than Freeville in the winter months (Figure 1). Monthly minimum temperatures generally followed the same trend, except that Freeville experienced a cold snap in December 2022 that did not occur in the other locations (Figure 2). Precipitation patterns were more variable by site, but Canton in general had lower precipitation than other sites (which would also translate to less snow cover), and may have contributed to lower total biomass compared to other sites (Figure 3).

Figure 1. Monthly mean temperature across all site-years

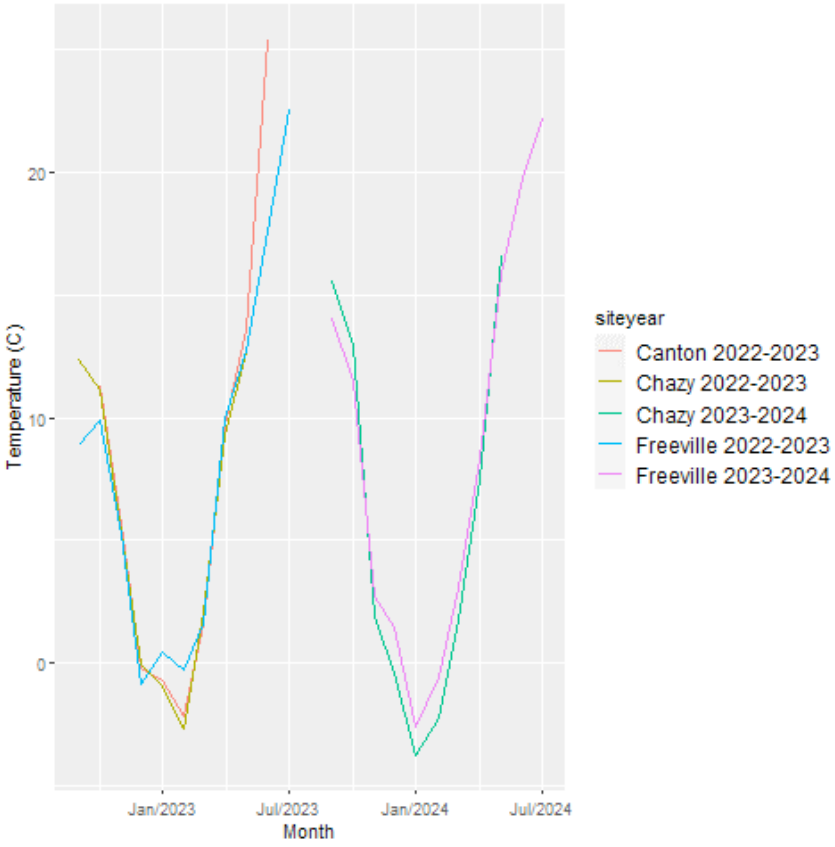


Figure 2. Monthly minimum temperature across all site-years.

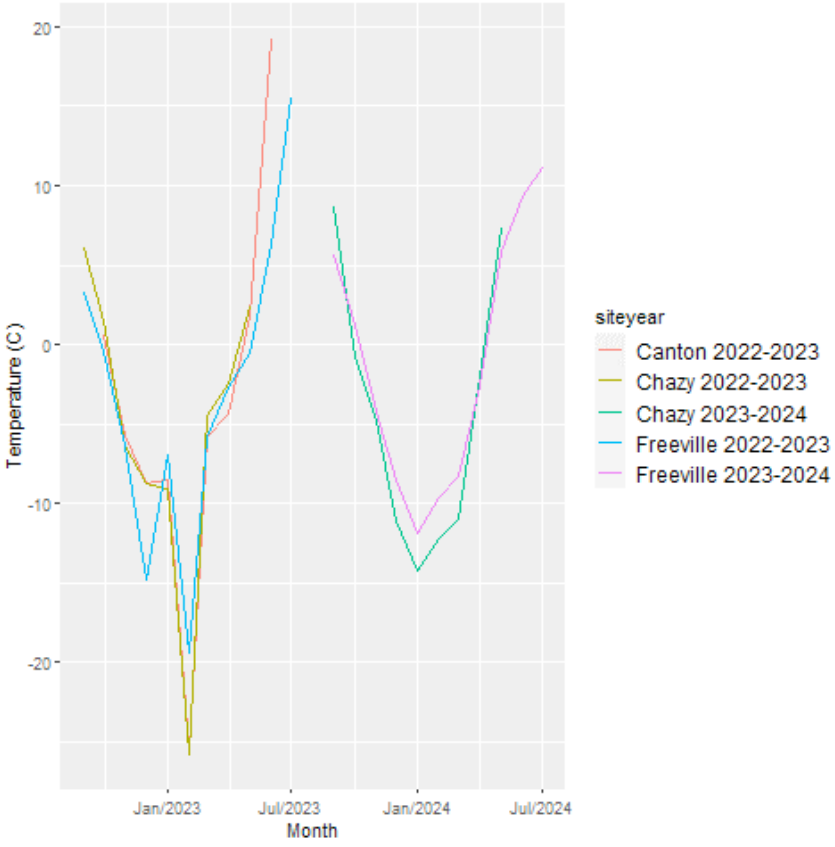
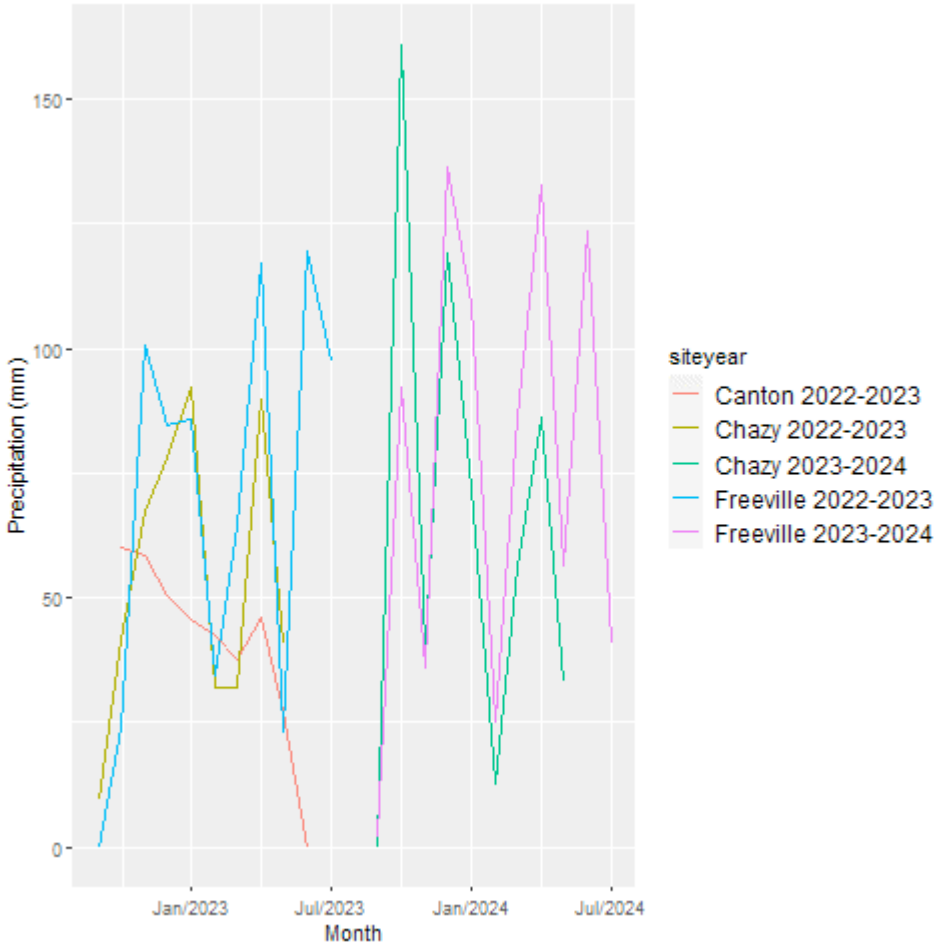


Figure 3. Monthly precipitation across all site-years.



Biomass data were collected in every site-year of the experiment. Data were analyzed for each site using a linear mixed effect model with variety, planting date, and variety x planting date as fixed effects and replication as a random effect. Variety and planting date had a significant effect on the total biomass produced at every site and year tested, and the interaction between variety and planting date was significant only in Freeville in Year 2 (Table 4).

Table 4. Summary of significant variables in analysis of variance for biomass across each site-year of the experiment, Breeding Cereal Rye for Late-Season Cover Crop Planting project. *"*" indicates significance at the 0.05 level, and "***" indicates significance at the 0.001 level.*

Site-Year	Variety	Planting Date	Variety x Planting Date
Canton, 2022-2023	*	*	
Chazy, 2022-2023	***	*	
Chazy, 2023-2024	***	***	
Freeville, 2022-2023	***	***	
Freeville, 2023-2024	***	***	*

Among the site-years without a statistically significant interaction effect, ND Gardner was either the top-performing variety or statistically equivalent to the top variety for biomass yield, and Danko was consistently the worst, across all site-years and planting dates. Additional varieties were planted in Chazy in 2023-2024, and among the new entries, Rymin and Wrens Abruzzi also ranked highly in terms of biomass yield (Table 5).

Table 5. Pairwise comparisons for biomass yield by variety (averaged across planting dates) in the following site-years: Canton, 2022-2023; Chazy, 2022-2023; Chazy, 2023-2024; and Freeville, 2022-2023 Breeding Cereal Rye for Late-Season Cover Crop Planting project. *Letters indicate statistically equivalent groupings within each column (site-year).*

Variety	Dry Biomass (lb/acre)			
	Canton, 2022-2023	Chazy, 2022-2023	Chazy, 2023-2024	Freeville, 2022-2023
Aroostook	1974^{abc}	6292^{cd}	5168^{cdef}	3919^{bc}
CoverMax			4690^{efg}	
Danko	1224^{d}	5966^{d}	4218^{g}	3686^{c}
Elbon	2143^{ab}	6946^{b}	5493^{bc}	5466^{a}
Guardian	1515^{bcd}	6683^{bc}	4649^{fg}	4471^{b}
Hazlet	1394^{cd}	6601^{bc}	5154^{cde}	4097^{bc}
Musketeer			4689^{efg}	
NC20-R103-2			4333^{g}	
NC20-R109			5189^{cd}	
NC20-R114			5083^{cdef}	
ND Gardner	2181^{a}	7827^{a}	5946^{ab}	5162^{a}
Rymin			6168^{a}	
Sangaste			5008^{def}	
Wrens Abruzzi			5812^{ab}	

In Freeville in 2023-2024, there was a significant interaction effect between variety and planting date. In the planting dates 3 and 4, top varieties were inconsistent (but Danko remained the worst biomass producer), and biomass yields were quite. In planting date 1, ND Gardner, Wrens Abruzzi, and a breeding population (NC20-114) were top producers, and Rymin, Hazlet, and Elbon were also statistically equivalent to those lines. Planting date 2 showed similar results to the other sites, with Elbon and Rymin at the top and ND Gardner and Wrens Abruzzi also statistically equivalent to those lines (Table 6).

Table 6. Pairwise comparisons for biomass yield by variety and planting date in Freeville, 2023-2024, Breeding Cereal Rye for Late-Season Cover Crop Planting project. *Letters indicate stastistically equivalent groupings within each column (planting date).*

Variety	Dry Biomass (lb/acre)			
	Planting Date 1	Planting Date 2	Planting Date 3	Planting Date 4
Aroostook	4930^{c}	4821^{cde}	2369^{bcde}	1575^{abc}
CoverMax	5378^{c}	3182^{f}	2529^{abcde}	1351^{abc}
Danko	5999^{bc}	3560^{ef}	1556^{e}	1031^{c}
Elbon	7235^{ab}	6761^{a}	3086^{abc}	2062^{abc}
Guardian	5256^{c}	3662^{ef}	1613de	1626^{abc}
Hazlet	7081^{ab}	5096^{bcd}	2478^{abcde}	1383^{abc}
Musketeer	5954^{bc}	3035^{f}	2542^{abcde}	1178^{bc}
NC20-R103-2	5736^{c}	3989^{def}	2190^{cde}	2478^{a}
NC20-R109	5557^{c}	4731^{cde}	2900^{abcd}	1428^{abc}
NC20-R114	7350^{a}	5295^{bc}	2990^{abc}	1985^{abc}
ND Gardner	7984^{a}	5711^{abc}	3387^{abc}	2414^{ab}
Rymin	7170^{ab}	6677^{a}	3521^{ab}	1921^{abc}
Sangaste	5960^{bc}	3380^{f}	2426^{bcde}	1408^{abc}
Wrens Abruzzi	7407^{a}	6146^{ab}	3765^{a}	2113^{abc}

In Year 1, planting dates did not have the expected effect on biomass yield. In Canton, biomass yield was slightly higher for the later planting date (although it was quite low and both dates compared to other locations). In Chazy, planting date 3 had slightly higher biomass yield than planting date 2, and yields were generally high compared to other site-years. Other site-years followed the expected pattern of declining biomass yield with later plantings (Table 7).

Table 7. Pairwise comparisons for biomass yield by planting date in the following site-years: Canton, 2022-2023; Chazy, 2022-2023; Chazy, 2023-2024; and Freeville, 2022-2023, Breeding Cereal Rye for Late-Season Cover Crop Planting project. *Letters indicate statistically equivalent groupings within each column (site-year).*

Variety	Dry Biomass (lb/acre)			
	Canton, 2022-2023	Chazy, 2022-2023	Chazy, 2023-2024	Freeville, 2022-2023
Planting Date 1		7047[a]	6244[a]	6731[a]
Planting Date 2	1518[b]	6422[b]	5836[b]	4261[b]
Planting Date 3		6688[ab]	4639[c]	3726[c]
Planting Date 4	1959[a]	Not sampled	3738[d]	3150[d]

On-farm variety trial

Biomass was collected on the farm in Lewis County in both years. Variety had a statistically significant effect in both years; again, Elbon and ND Gardner were among the top varieties in both years, and Wrens Abruzzi was the top performer when included in Year 2 (Table 8).

Table 8. Pairwise comparisons for biomass yield by variety in Lewis County in 2022-2023 and 2023-2024, Breeding Cereal Rye for Late-Season Cover Crop Planting project. *Letters indicate statistically equivalent groupings within each column (site-year).*

	Dry Biomass (lb/acre)	
Variety	Year 1 (2022-2023)	Year 2 (2023-2024)
Wrens Abruzzi		1318[a]
Elbon	2273[a]	1202[ab]
ND Gardner	1965[ab]	1167[abc]
VNS		988[abc]
Guardian	1485[bc]	932[abc]
Hazlet	1485[bc]	765[c]
Danko	1459[bc]	1031[abc]
Aroostook	1453[c]	889[bc]

Biomass was not collected on the two farms in Clinton County, but canopy cover and plant height data were collected in Year 1 (without replication). There was some variation in variety rank for canopy cover between the two farms, but Elbon and ND Gardner had the tallest plant heights on both farms (Table 9). In Year 2, these data were not collected due to spotty establishment but a visual assessment showed that Elbon had the strongest performance consistent with other sites.

Table 9. Canopy cover and plant height on Clinton County farms, **Breeding Cereal Rye for Late-Season Cover Crop Planting project.**

Variety	Canopy Cover (%)		Plant Height (in)	
	Dyer Farm	*Menard Farm*	*Dyer Farm*	*Menard Farm*
Aroostook	34.3	44.3	14	10
Danko	32.9	53.1	14	12
Elbon	68.7	62.8	26	18
Guardian	63.5	50.6	15	12
Hazlet	33.7	30.1	13	10
ND Gardner	52.8	40.8	20	16

Conclusions:

Our main research question for this experiment was whether any rye varieties were better adapted to later planting than others. We did see that some rye varieties were more productive than others (e.g., Elbon, ND Gardner, Rymin, Wrens Abruzzi) and these varieties were ranked highly across site-year and planting date, indicating stable performance within the region. Except in some planting dates in Freeville in 2023-2024, we did not see major changes in the top variety, so it appears that the same top varieties could be planted regardless of timing. When planting rye on a marginal planting date, planting a more productive variety may determine whether a farmer can produce sufficient biomass to suppress weeds and provide other cover crop benefits.

Outreach:

- Willsboro Farm Open House, July 2024.
- Cornell Organic Field Crop Conference, February 6, 2025.
- Spring 2025: results from the planting date experiment will be written up as an extension report for the Moore Lab website, regional meetings and CCE email lists, and as a peer-reviewed publication submission.

Next Steps:

- **Rye breeding data** will continue to be collected in the field and controlled environment evaluations through Summer 2025. Graduate student Raksha Thapa will analyze the data and publish results as a chapter in her Ph.D. dissertation. We will continue to select promising populations identified in the evaluations.

- **Farmer Survey:** In winter-spring 2025, we will continue to disseminate the grower survey and then analyze results. Results will be shared through an extension report, presentations at farmer meetings and academic conferences, and through a peer-reviewed publication (2026).

For More Information:

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