Supplementary materials to the manuscript

Figures

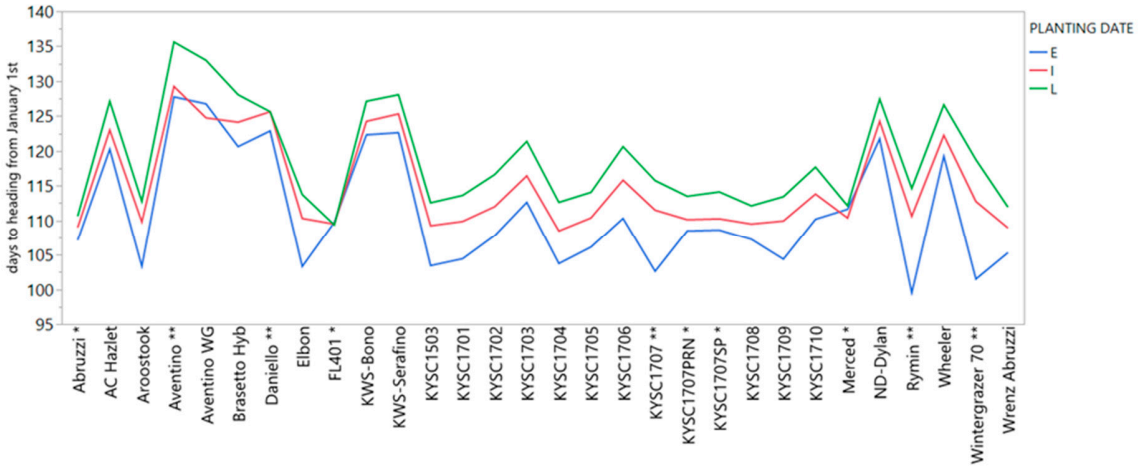
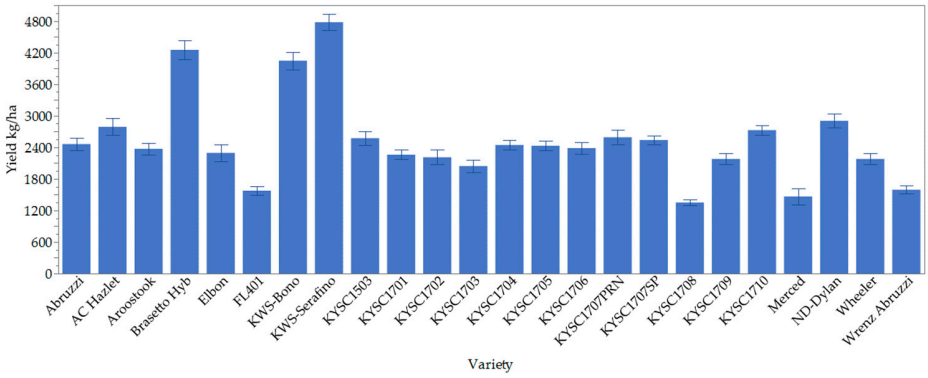


Figure S1. Mean number of days to heading for each rye variety of all environments over planting dates. E – Early Planting Date, I – Intermediate, L – Late; *varieties tested in 2018/2019 season only; **varieties testes in 2019/2020 season only.

Figure S2. Lodging resistance of rye varieties tested in 2019 over all planting dates, by location.

a



b

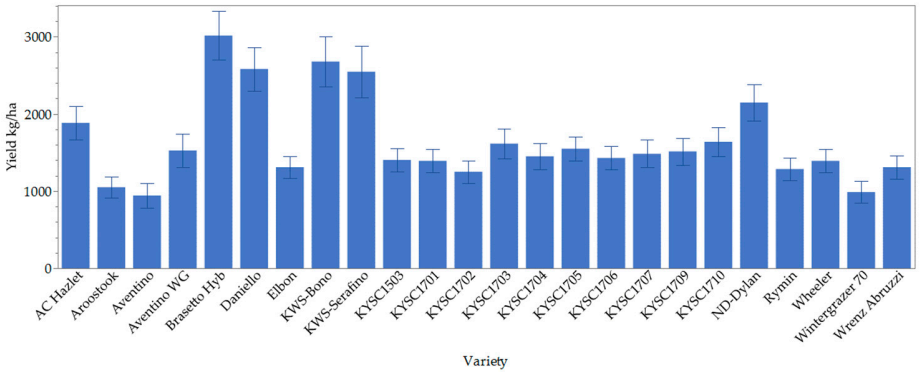


Figure S3. Mean yield of rye varieties harvested in (a) 2019, and (b) 2020.

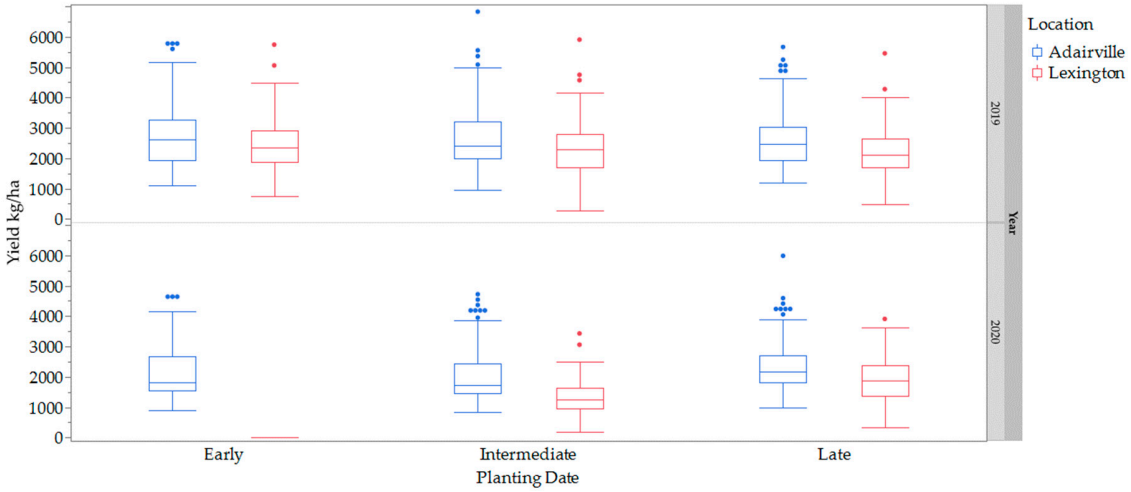


Figure S4. Mean yield of rye varieties planted in three dates in two locations in 2019 and 2020.

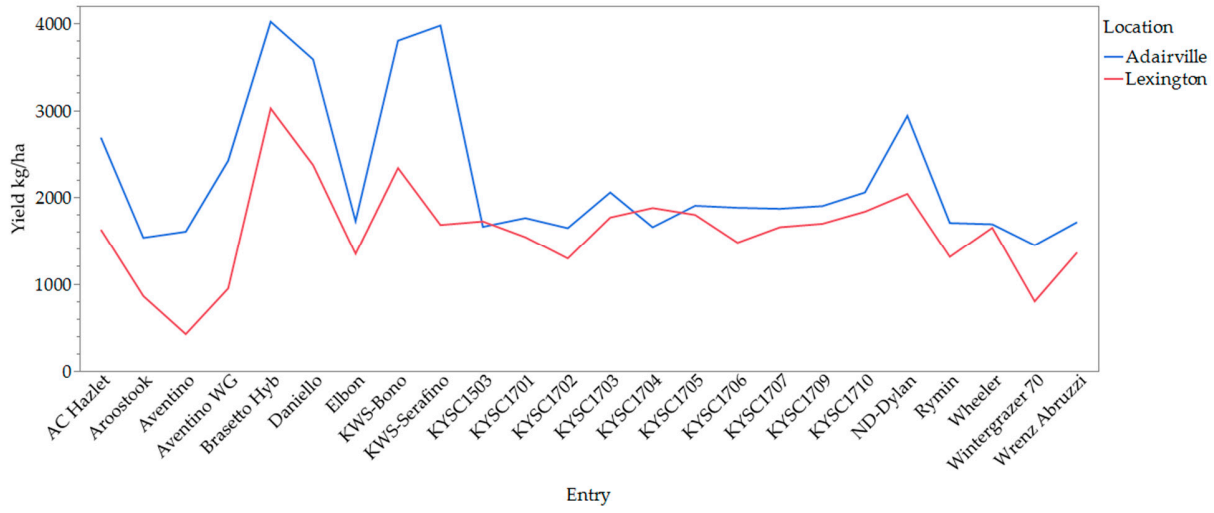


Figure S5. Mean yield of rye varieties tested in 2020 at two locations.

Tables

Table S1. Significance of F-test for Fusarium head blight, Septoria leaf blotch and lodging resistance.

	Fusarium Head Blight	Septoria Leaf Blotch	Lodging
Overall			
Environment	0.69 ns	0.0001 ***	<.0001 ***
Variety	<.0001 ***	<.0001 ***	<.0001 ***
Planting Date	<.0001 ***	0.37 ns	0.0004 ***
Environment × Variety	0.01 **	0.11 ns	<.0001 ***
Environment × Planting Date	<.0001 ***	0.66 ns	0.005 **
Variety × Planting Date	<.0001 ***	0.88 ns	0.51 ns
2019			
Location	0.13 ns	<.0001 ***	<.0001 ***
Variety	<.0001 ***	<.0001 ***	<.0001 ***
Planting Date	<.0001 ***	0.0006 ***	<.0001 ***
Location × Variety	0.21 ns	<.0001 ***	<.0001 ***
Location × Planting Date	<.0001 ***	0.002 ***	<.0001 ***
Variety × Planting Date	0.23 ns	0.30 ns	0.0001 ***
2020			
Location	0.004 **	0.02 *	<.0001 ***
Variety	<.0001 ***	<.0001 ***	<.0001 ***
Planting Date	<.0001 ***	0.002 **	0.002 **
Location × Variety	<.0001 ***	0.0002 ***	<.0001 ***
Location × Planting Date	<.0001 ***	0.07 ns	0.002 **
Variety × Planting Date	<.0001 ***	0.14 ns	0.36 ns
Adairville			
Year (1)	0.0025 **	<.0001 ***	<.0001 ***
Variety	<.0001 ***	<.0001 ***	<.0001 ***
Planting Date	<.0001 ***	<.0001 ***	<.0001 ***
Year × Variety	<.0001 ***	<.0001 ***	<.0001 ***
Year × Planting Date	<.0001 ***	0.11 ns	<.0001 ***
Variety × Planting Date	0.24 ns	0.41 ns	0.01 **
Lexington			
Year (1)	<.0001 ***	<.0001 ***	<.0001 **
Variety	<.0001 ***	<.0001 ***	<.0001 ***
Planting Date	<.0001 ***	0.37 ns	0.28 ns
Year × Variety	0.35 ns	0.01 *	<.0001 ***
Year × Planting Date	<.0001 ***	0.03 *	0.97 ns
Variety × Planting Date	0.004 **	0.18 ns	0.2 ns

Note. *, p≤0.05; **, p≤0.01; ***, p≤0.001; ns, non-significant.

(1) Based on One way ANOVA by location

Table S2. Analysis of variance of rye yield at three planting dates and two locations, 2019 and 2020.

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
		2019			
LOC	1	4200	4200	58.739	1.01e−13 ***
GENOTYPE	23	95585	4156	58.121	<2e−16 ***
Planting Date	2	692	346	4.840	0.008 **
LOC: GENOTYPE	23	6532	284	3.972	4.15e−09 ***
GENOTYPE: Planting Date	46	5762	125	1.752	0.002 **
LOC: Planting Date	2	102	51	0.713	0.49 ns
Residuals	478	34179	72		
		2020			
LOC	1	11164	11164	208.484	< 2e−16 ***
GENOTYPE	23	51852	2254	42.100	< 2e−16 ***
Planting Date	2	4247	2124	39.659	2.22e−16 ***
LOC: GENOTYPE	23	9981	434	8.104	< 2e−16 ***
GENOTYPE: Planting Date	46	2632	57	1.068	0.36 ns
LOC: Planting Date	1	626	626	11.698	0.000693 ***
Residuals	383	20509	54		

Note. *, $p \leqslant 0.05$; **, $p \leqslant 0.01$; ***, $p \leqslant 0.001$; ns, non-significant.

Table S3. Rye variety mean yield (kg ha^{-1}) in each planting date over all environments, 2019-2020.

Variety	Early	Intermediate	Late
Abruzzi	2481.1 ± 283.9	2355.9 ± 187	2545.1 ± 168.4
AC Hazlet	2190.7 ± 347.4	2594.6 ± 258.2	2227.5 ± 115.5
Aroostook	1708.7 ± 322.4	1661.8 ± 176.4	1762.3 ± 153.3
Aventino	875.2 ± 351.6	1027.6 ± 324.4	924.1 ± 161.7
Aventino WG	1311.1 ± 504.6	1448.5 ± 264.7	1819.1 ± 325.7
Brasetto Hyb	3240.4 ± 506.3	3970.8 ± 283.4	3691.8 ± 172.8
Daniello	1753.1 ± 675.2	2689.4 ± 308.1	3305.5 ± 267.5
Elbon	1898.3 ± 337.5	1715.3 ± 134.7	1791.1 ± 153.9
FL401	1286.4 ± 64.8	1591.8 ± 124.9	1846.3 ± 135.4
KWS-Bono	2892.9 ± 457.7	3472.3 ± 269.8	3722.6 ± 298.2
KWS-Serafino	3584.2 ± 557.8	3799.8 ± 392.8	3603.5 ± 304.8
KYSC1503	1785.2 ± 322.9	2091.1 ± 182.2	2085.4 ± 148.6
KYSC1701	1633.1 ± 266.5	1803.5 ± 158	2040.1 ± 70
KYSC1702	1475.5 ± 249.9	1836.3 ± 227.9	1880.2 ± 135.9
KYSC1703	1524.9 ± 264.5	1911.9 ± 171	2053.1 ± 146.9
KYSC1704	1528.4 ± 248.3	1883.2 ± 165	2433.7 ± 122.9
KYSC1705	1769.7 ± 290.7	1935.3 ± 118.7	2266.3 ± 96.1
KYSC1706	1824.7 ± 315.7	1778.1 ± 95.8	2121.5 ± 128.1
KYSC1707	832.6 ± 324.5	1383.7 ± 189.3	2239.3 ± 171.5
KYSC1707PRN	2618 ± 131	2892.3 ± 309.6	2264.7 ± 188.3
KYSC1707SP	2435.2 ± 103.6	2448.7 ± 94.9	2727.5 ± 215.2
KYSC1708	1445.4 ± 106.8	1303.1 ± 71.1	1298.7 ± 87.9
KYSC1709	1517.1 ± 262.1	1825.5 ± 124	2197 ± 128.3
KYSC1710	1910.9 ± 314.9	2213.8 ± 184.6	2423.1 ± 126.9
Merced	1206.7 ± 147.8	1366.2 ± 287.6	1824.8 ± 318.5
ND-Dylan	2260 ± 358.3	2684.4 ± 186.7	2630.4 ± 154.3
Rymin	797 ± 321.3	1380.3 ± 183.4	1685.4 ± 145.9
Wheeler	1555.3 ± 257.2	1857.3 ± 129.8	1947.7 ± 141.5
Wintergrazer 70	794.5 ± 305.3	846.1 ± 195.3	1323.6 ± 228.8
Wrenz Abruzzi	1084.15 ± 167.92	1456.45 ± 107.25	1812.3 ± 99.5

Table S4. Rye variety mean of number of tillers (m^{-2}), 2019.

Variety	Overall	Early	Intermediate	Late
Abruzzi	885 ± 27.3	949 ± 36.9	868.3 ± 45	837.8 ± 51.4
AC Hazlet	491 ± 31.8	567.8 ± 34.7	513.1 ± 61.5	392 ± 27.6
Aroostook	609.4 ± 31.4	704.1 ± 52.8	562.4 ± 20.6	561.5 ± 56.2
Brasetto Hyb	583.7 ± 19.6	626.1 ± 27.4	579.5 ± 35.2	545.4 ± 33.9
Elbon	414.4 ± 41.9	582.1 ± 51.2	338.1 ± 20.8	322.9 ± 46.9
FL401	507.1 ± 41.8	538.2 ± 87.6	503.2 ± 76.1	479.9 ± 71.7
KWS-Bono	621 ± 25.8	656.6 ± 65.9	585.7 ± 12.6	620.8 ± 44.8
KWS-Serafino	527.7 ± 8.6	523.9 ± 14	549.9 ± 9.2	509.5 ± 15.8
KYSC1503	775.6 ± 26.5	765.2 ± 50.3	837.8 ± 22.6	723.9 ± 49.9
KYSC1701	578.3 ± 29.5	669.2 ± 57.7	576.8 ± 7.2	488.8 ± 27.7
KYSC1702	517.6 ± 35.8	628.8 ± 54.7	495.1 ± 30.3	428.8 ± 56.9
KYSC1703	499.6 ± 22.5	557.1 ± 53	499.6 ± 15.2	442.2 ± 18
KYSC1704	567.2 ± 16.5	593.8 ± 41.6	580.4 ± 19.2	527.4 ± 7.6
KYSC1705	630.3 ± 18.7	687.1 ± 24.7	612.7 ± 36.5	591.1 ± 14.8
KYSC1706	558.5 ± 20.2	592 ± 53.7	574.1 ± 11.1	509.5 ± 14.9
KYSC1707PRN	621.3 ± 27.9	645.8 ± 73.5	626.1 ± 35.6	592 ± 37.4
KYSC1707SP	566 ± 31.2	613.6 ± 85.7	544.5 ± 30.1	540 ± 36.4
KYSC1708	460.8 ± 23.6	526.5 ± 28.8	479 ± 26.1	376.7 ± 26.9
KYSC1709	617.7 ± 12.5	594.7 ± 15.1	635.1 ± 18	623.4 ± 29.5
KYSC1710	571.7 ± 16.6	610.9 ± 29.8	553.4 ± 35.7	550.8 ± 10.4
Merced	366 ± 26.8	407.2 ± 57.7	329.2 ± 53.8	361.5 ± 25.8
ND-Dylan	534.9 ± 22.9	612.7 ± 15	525.6 ± 32.9	466.4 ± 29.5
Wheeler	465.2 ± 16.2	455.7 ± 27.2	487.1 ± 28	453 ± 33.7
Wrenz Abruzzi	397.7 ± 21.7	400.1 ± 37.9	378.5 ± 38.7	414.4 ± 45.2
Significance of Effect				
Planting Date		<.0001 ***		
Variety		<.0001 ***		
Planting Date × Variety		0.24 ns		

Note. *, p≤0.05; **, p≤0.01; ***, p≤0.001; ns, non-significant.

Table S5. Correlation of DON content with other traits measured in Lexington, 2019.

Planting Date	Trait	Mean	Correlation	Lower 95%	Upper 95%	Sign Prob	Covariance
E	Earliness	115.84	0.17	−0.25	0.54	0.42	0.66
E	FHB index	5.41	−0.02	−0.42	0.39	0.93	−0.01
E	Height [in]	62.75	0.51	0.13	0.76	0.01	2.09
E	Lodging	7.34	0.36	−0.05	0.66	0.09	0.36
E	Yield kg/ha	2457.46	−0.16	−0.53	0.26	0.45	−98.36
I	Earliness	118.74	0.25	−0.17	0.60	0.23	1.56
I	FHB index	4.13	0.16	−0.26	0.53	0.44	0.20
I	Height [in]	63.19	0.48	0.10	0.74	0.02	3.38
I	Lodging	7.24	0.30	−0.12	0.63	0.16	0.51
I	Yield kg/ha	2362.20	−0.20	−0.56	0.22	0.34	−234.14
L	Earliness	120.58	0.17	−0.25	0.54	0.43	0.67
L	FHB index	5.83	0.21	−0.21	0.56	0.33	0.18
L	Height [in]	64.39	0.27	−0.15	0.60	0.21	1.32
L	Lodging	7.26	0.40	0.00	0.69	0.05	0.41
L	Yield kg/ha	2226.43	−0.32	−0.64	0.10	0.13	−184.23

Table S6. Rye variety means of DON content of 24 varieties tested in an inoculated scab nursery, 2021.

Variety	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
KYSC1702	6.33	2.80	1.62	-0.63	13.29
KYSC1706	5.03	1.88	1.08	0.37	9.70
KWS-Daniello	4.80	1.97	1.14	-0.09	9.69
KWS-Brasetto	4.43	2.41	1.39	-1.56	10.43
KYSC1707	3.83	1.99	1.15	-1.10	8.77
KYSC1710	3.77	0.35	0.20	2.89	4.64
AC Hazlet	3.53	1.62	0.93	-0.48	7.55
KYSC1705	3.53	1.02	0.59	1.00	6.07
ND-Dylan	3.50	1.06	0.61	0.87	6.13
Elbon	3.40	0.75	0.44	1.52	5.28
KYSC1710 selected	3.37	0.21	0.12	2.85	3.88
KYSC1709	3.23	0.57	0.33	1.82	4.65
Rymin	3.20	1.41	0.81	-0.30	6.70
Wheeler	3.13	1.17	0.68	0.22	6.04
KYSC1704	3.08	2.01	1.16	-1.91	8.07
KYSC1701	3.07	0.21	0.12	2.55	3.58
KYSC1703	3.03	1.46	0.84	-0.59	6.65
KYSC1503	3.00	1.30	0.75	-0.23	6.23
KWS-Bono	2.90	0.96	0.56	0.50	5.30
KWS-Serafino	2.70	1.14	0.66	-0.12	5.52
Wintergrazer 70	2.50	1.59	0.92	-1.44	6.44
Aroostook	2.43	1.36	0.78	-0.94	5.81
Aventino WG	2.30	1.14	0.66	-0.52	5.12
Wrenz Abruzzi	1.97	1.35	0.78	-1.39	5.34

Source	DF	Sum of Squares	Mean Square	F Ratio
name	23.00	63.11	2.74	1.27 ns
Error	48.00	103.64	2.16	
C. Total	71.00	166.76		

Note. *, p≤0.05; **, p≤0.01; ***, p≤0.001; ns, non-significant.

Table S7. Correlations of variety FHB index mean for varieties tested in 2019 and 2020 planting date plots and 2020 and 2021 Scab Nursery.

	2021 SN	2020 and 2021 SN	2020 SN	2019 plots	2020 plots	2019 plots (Lexington)	2020 plots (Lexington)
2021 SN	1.00	0.85	0.59	0.70	0.77	0.59	0.70
2020 and 2021 SN	0.85	1.00	0.92	0.59	0.68	0.50	0.61
2020 SN	0.59	0.92	1.00	0.42	0.58	0.36	0.52
2019 plots	0.70	0.59	0.42	1.00	0.93	0.97	0.91
2020 plots	0.77	0.68	0.58	0.93	1.00	0.91	0.98
2019 plots (Lexington)	0.59	0.50	0.36	0.97	0.91	1.00	0.90
2020 plots (Lexington)	0.70	0.61	0.52	0.91	0.98	0.90	1.00

SN—Scab Nursery, plots—Planting Dates Study Plots.

Table S8. Correlation coefficients of daily air temperature at anthesis and yield of hybrid and conventional rye varieties in Adairville, 2019.

	Max Air Temperature at Anthesis	Min Air Temperature at Anthesis	Max-Min Air Temperature at Anthesis
Hybrid	0.48	0.31	0.41
Conventional	-0.01	0.01	-0.02