plants

MDPI

Supplementary materials

Phenotyping and Identification of Molecular Markers Associated with Leaf Rust Resistance in the Wheat Germplasm from Kazakhstan, CIMMYT and ICARDA

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Table S1. Analysis of variance (ANOVA) on traits of productivity and leaf rust resistance of a winter wheat collection

Experiment	Factor	SS	df	MS	F-value	p-Value	h_b^2, %
AUDPC	Genotype	5923734	69	85851	3.89	<0.001	0.79
	Year	5197	1	5197	0.235	0.62	
	Residuals	1522749	69	22069			
NDVI	Genotype	0.3701	69	0.005363	1.486	0.05	0.59
	Year	0.009	1	0.009446	2.617	0.11	
	Residuals	0.2491	69	0.003610			
DH	Genotype	1277.89	69	18.52	2.758	<0.001	0.43
	Year	1230.18	1	1230.1	183.2	<0.001	
	Residuals	463.32	69	6.71			
PH	Genotype	27987.9	69	405.62	3.19	<0.001	0.66
	Year	5136.46	1	5136.46	40.4	<0.001	
	Residuals	8773.54	69	127.15			
SL	Genotype	181.83	69	2.635	3.192	<0.001	0.75
	Year	1.45	1	1.454	1.762	0.18	
	Residuals	56.95	69	0.825			
SS	Genotype	390.18	69	5.654	1.994	<0.01	0.64
	Year	18.84	1	18.841	6.64	0.012	
	Residuals	195.71	69	2.836			
GS	Genotype	4808.48	69	69.68	1.63	<0.05	0.57
	Year	549.96	1	549.96	12.94	<0.001	
	Residuals	2933.25	69	42.51			
WGS	Genotype	12.68	69	0.183	1.414	0.076	0.56
	Year	1.02	1	1.028	7.91	<0.01	
	Residuals	8.97	69	0.13			
TKW	Genotype	2320.07	69	33.62	2.91	<0.001	0.74
	Year	14.43	1	14.43	1.24	0.26	
	Residuals	797.07	69	11.55			

Note: PH, cm - plant height, DH - days to heading, SL, cm - spike lengths, SS - the mean number of spikelets/spike, GS - grains/spike, WGS, g - the weight of grain/spike, TKW, g - thousand kernel weights

Table S2. Agronomic performance of the 70 wheat cultivars and breeding lines evaluated at the KRIAPG station, Kazakhstan. Data are the means of two assessments made in 2021 and 2022.

#	Name	Origin	2021								2022							
			NDVI	DH	PH, cm	SL, cm	SS	GS	WGS, g	TKW, g	NDVI	DH	PH, cm	SL, cm	SS	GS	WGS, g	TKW, g
1	Alatau	KZ	0.73	227	110	11.73±1.13	19.71±1.70	42.60±4.27	1.86±0.29	43.62	0.72	217	125	10.54±0.78	19.8±1.62	46.4±4.33	2.31±0.35	49.78
2	Almaly	KZ	0.71	232	78	8.53±0.53	14.90±0.99	19.20±1.93	0.73±0.12	37.97	0.62	215	75	8.77±0.35	15.90±0.74	24.40±3.17	1.09±0.21	44.71
3	Aliya	KZ	0.71	231	113	10.00±0.85	17.60±1.90	32.90±5.51	1.32±0.10	40.09	0.69	219	105	10.42±0.61	21±1.15	50.3±5.14	2.22±0.29	44.14
4	Azharly	KZ	0.8	225	94	11.96±0.48	20.20±0.63	51.60±6.00	2.30±0.25	44.5	0.7	218	122	11.35±0.98	19.9±1.45	49.6±7.89	2.14±0.15	43.15
5	Akbidaj	KZ	0.7	222	89	8.14±0.34	14.00±0.82	28.90±2.60	1.06±0.11	36.71	0.69	212	112	10.1±0.6	19.6±1.96	40.0±4.19	1.82±0.25	45.48
6	Batyr	KZ	0.68	226	63	8.51±0.37	13.90±0.74	37.90±3.48	1.61±0.22	42.53	0.73	216	133	8.92±0.64	17±1.05	38.40±4.03	1.59±0.16	41.8
7	Egemen 20	KZ	0.7	228	115	12.41±0.56	19.82±1.40	41.45±3.64	2.01±0.21	48.46	0.71	225	117	11.6±0.67	17.5±2.07	38±13.68	1.61±0.74	42.37
8	Farabi	KZ	0.69	225	64	8.54±0.36	15.50±0.71	37.10±6.90	1.09±0.26	29.43	0.6	216	90	9.24±0.87	16.7±1.64	43.6±7.32	1.60±0.32	36.7
9	Mataj	KZ	0.61	228	107	12.71±1.36	23.00±1.70	57.00±13.81	2.81±0.65	41.97	0.77	228	110	9.76±1.09	18±1.63	36.7±8.83	1.28±0.25	34.88
10	Kyzyl bidaj	KZ	0.69	222	70	11.99±0.64	18.1±0.88	44.6±3.72	1.62±0.29	36.32	0.66	217	119	10.37±0.90	17.20±1.14	35.20±4.94	1.57±0.21	44.72
11	Keremet	KZ	0.52	222	68	9.55±0.69	20.00±2.75	33.90±4.91	1.47±0.19	43.27	0.65	217	98	9.81±0.56	21.8±1.32	55.6±6.77	2.42±0.27	43.53
12	Koksu	KZ	0.51	221	75	9.95±0.44	17.60±0.84	42.90±4.72	1.99±0.35	46.34	0.65	214	103	9.92±0.77	17.7±1.06	47.3±6.65	2.49±0.31	52.64
13	Kokbidaj	KZ	0.66	225	77	8.00±0.53	18.20±0.92	41.10±3.03	1.89±0.40	45.96	0.6	222	85	8.76±0.74	19.6±1.17	56±5.6	2.44±0.31	43.57
14	Karaspan	KZ	0.71	222	118	10.80±0.59	18.30±0.95	31.60±4.14	1.23±0.15	38.86	0.7	218	120	10.93±0.72	19.5±1.08	52.9±7.75	2.21±0.42	41.78
15	Karlygash	KZ	0.54	225	98	10.55±0.50	18.40±1.51	36.80±4.37	1.44±0.10	38.99	0.69	217	103	10.94±0.61	20.1±1.52	55.6±7.95	2.16±0.46	38.85
16	Kazakhstanskaya 10	KZ	0.74	227	119	8.70±0.54	15.60±0.52	24.80±3.39	1.13±0.27	45.65	0.71	220	122	11.67±1.14	19±1.63	43.5±5.85	1.74±0.32	40
17	Progress	KZ	0.56	220	81	9.40±0.52	14.90±0.88	37.60±4.90	1.23±0.16	32.61	0.64	218	102	10.94±1.02	18.5±0.85	46.9±7.23	2.11±0.52	44.99
18	Prezident	KZ	0.44	226	101	9.62±0.44	18.30±0.67	37.10±4.48	1.58±0.24	42.67	0.73	224	98	7.87±0.64	17.3±2.06	39.4±5.48	1.68±0.15	42.64
19	Raminal	KZ	0.62	226	79	10.05±0.44	18.00±1.05	41.70±3.53	1.80±0.40	43.09	0.68	220	98	10.4±0.9	19.6±1.51	43.6	1.85±0.45	42.32
20	Rasad	KZ	0.73	228	80	10.35±0.71	19.00±1.15	48.50±2.72	2.24±0.19	46.25	0.67	222	101	10.39±1.08	20.8±1.32	51.5±6.17	2.21±0.20	42.95
21	Rausin	KZ	0.71	224	92	9.55±0.55	14.80±0.79	38.80±2.90	1.46±0.13	37.73	0.66	217	105	9.45±1.3	16.5±1.58	37.70±3.09	1.39±0.26	36.9

22	Reke	KZ	0.7	225	85	9.15±0.82	16.30±1.06	37.50±4.93	1.37±0.11	36.45	0.66	216	104	8.64±0.62	18±2.16	42.1±5.02	1.63±0.24	38.72
23	Zhalyn	KZ	0.62	231	94	10.08±0.50	17.20±1.03	46.80±5.03	1.70±0.32	36.3	0.71	222	103	11.64±0.89	20.4±1.17	51.9±10.65	1.64±0.42	31.6
24	Yuzhnaya 12	KZ	0.75	230	70	10.25±0.42	18.00±0.94	43.70±8.06	1.50±0.22	34.28	0.7	222	95	10.86±0.81	19.3±1.34	56.1±3.9	1.98±0.27	35.29
25	Pirotriks 50	KZ	0.62	231	103	8.27±1.02	15.3±3.37	33.4±6.54	1.14±0.13	34.13	0.67	222	110	8.89±0.33	15.50±0.97	39.20±4.24	1.56±0.15	39.74
26	Daulet	KZ	0.64	224	115	11.66±0.86	18.90±1.52	38.80±3.08	1.39±0.19	35.82	0.64	225	113	7±0.53	13.9±1.1	33±5.12	0.92±0.3	27.88
27	Konditerskaya	KZ	0.58	226	60	9.32±0.95	16.1±1.52	43.7±9.25	1.95±0.39	44.62	0.64	222	85	9.29±0.96	16.80±0.63	41.00±2.00	1.44±0.05	35.15
28	428/MK-122A-1	KZ	0.76	229	96	9.20±0.53	19.80±0.63	46.90±4.58	2.00±0.22	42.64	0.72	222	105	10.05±0.68	21.9±0.88	46.6±4.58	2.13±0.29	45.71
29	Steklovidnaya 24	KZ	0.77	223	79	9.45±1.01	16.60±1.71	42.00±6.45	1.68±0.32	39.9	0.68	213	88	9.18±0.65	18.6±1.9	53.5±6.36	2.27±0.28	42.43
30	Sultan 2	KZ	0.83	228	115	13.88±2.5	24.5±3.1	70.8±13.88	3.01±0.83	42.51	0.75	220	111	13.75±0.95	20.90±2.18	50.90±6.57	1.68±0.26	32.99
31	Naz/Immun 78	KZ	0.74	223	87	7.62±0.64	19.8±1.75	47.7±7.27	1.85±0.38	38.78	0.73	217	93	6.68±0.40	15.50±0.97	39.90±4.04	1.52±0.12	41.3
32	Naz/GF 55-2	KZ	0.78	228	125	10.66±0.43	18.20±0.42	40.10±3.31	1.50±0.16	37.31	0.69	222	128	12.11±1.16	21.7±1.16	46.3±6.82	1.68±0.35	36.29
33	Naz/GF 55-3	KZ	0.74	224	86	9.78±0.73	19.1±1.73	41.2±7.05	1.62±0.25	39.32	0.69	221	90	9.16±0.47	16.40±0.97	34.70±12.24	1.41±0.28	40.75
34	Naz/GF 55-5	KZ	0.81	225	106	10.7±0.86	19.9±1.2	39.5±3.63	1.4±0.27	35.44	0.73	222	98	9.20±0.74	14.80±0.79	38.30±5.29	1.47±0.30	38.46
35	Yr/Octyabrina	KZ	0.8	227	112	11.37±1.1	20.1±2.02	43.1±9.19	1.72±0.48	39.91	0.73	222	115	9.49±0.59	16.80±1.23	37.10±4.89	1.52±0.13	40.92
36	425/Obri	KZ	0.86	230	119	11.35±0.61	17.90±0.88	41.80±4.85	1.55±0.17	37.02	0.78	225	125	12±1.82	20.5±1.72	47.9±8.88	1.74±0.45	36.33
37	Alihan	KZ	0.67	221	79	8.00±0.58	16.10±1.10	38.10±4.86	1.78±0.18	46.77	0.69	212	102	8.45±0.95	17.6±2.41	44.2±6.36	2.1±0.5	47.51
38	Anar	KZ	0.75	230	86	9.50±0.47	17.00±0.82	37.10±4.33	1.48±0.18	39.76	0.72	219	77	11.61±0.9	22.2±1.55	49.9±5.95	1.96±0.33	39.28
39	Derbes	KZ	0.62	221	84	8.25±0.42	17.50±1.43	30.40±5.17	1.00±0.26	32.73	0.68	215	107	8.29±0.45	17.30±1.06	36.5±3.87	1.29±0.29	35.21
40	Krasnovodapadskaya 210	KZ	0.61	225	74	9.35±0.72	19.10±1.52	46.90±6.40	1.69±0.46	35.97	0.73	226	85	8.62±0.68	16.6±1.58	33.8±7.74	1.23±0.14	36.39
41	APK/Progress	KZ	0.79	225	102	10.07±0.43	18.70±0.67	42.50±3.78	1.75±0.11	41.13	0.73	222	108	10.26±0.93	21.3±1.89	45.7±5.64	1.86±0.14	40.77
42	Almaly/Orbij	KZ	0.76	225	91	8.29±0.52	19.5±2.07	42.3±5.17	1.94±0.27	45.86	0.75	221	94	8.27±0.85	17.20±1.23	39.30±5.79	1.54±0.25	39.29
43	Gozgon	IWWIP	0.62	224	86	8.93±0.62	16.60±1.07	42.90±5.65	2.05±0.19	47.69	0.75	223	91	9.46±0.59	18.7±1.64	45.5±7.88	2.15±0.33	47.25
44	Bunyodkor	IWWIP	0.64	223	85	9.18±0.30	18.50±0.53	36.70±6.15	1.49±0.22	40.71	0.8	215	90	9.89±1.16	20.5±2.01	45.2±10.63	1.72±0.58	38.05
45	Faravon	IWWIP	0.69	227	92	9.18±0.62	17.70±0.67	50.20±6.68	2.12±0.13	42.25	0.75	221	93	9.2±0.79	19.2±1.93	51.9±9.17	2.09±0.14	40.33
46	Hazrati Bashir	IWWIP	0.61	221	73	10.48±0.56	17.30±0.67	50.00±8.04	1.57±0.17	31.32	0.7	214	77	10.48±0.56	17.3±0.67	50±8.04	1.57±0.17	31.4
47	Hisorok	IWWIP	0.63	227	69	8.96±0.64	19.60±1.35	48.40±6.11	2.09±0.11	43.24	0.7	220	73	9.49±1.06	20.5±2.32	51.1±9.96	2.15±0.38	42.07

48	Layagatlii 80	IWWIP	0.64	225	109	11.62±0.37	22.2±1.03	62.8±5.96	2.54±0.24	40.45	0.73	216	103	10.13±0.86	19.50±1.08	49.60±8.50	1.61±0.34	32.54
49	Shafag 2	IWWIP	0.62	225	103	11.95±0.6	21±0.94	58.6±3.75	2.47±0.29	42.15	0.69	225	97	9.46±0.67	18.10±1.10	43.20±4.73	1.65±0.22	38.17
50	Egana	IWWIP	0.64	224	80	8.07±0.46	17.30±1.25	44.20±7.04	1.86±0.19	41.97	0.7	224	85	8.67±0.45	17.20±1.14	55.1±6.61	2.34±0.32	42.47
51	415-SP-2	KZ/C	0.71	224	88	10.12±0.75	19.40±0.89	46.1±3.31	1.75±0.26	37.96	0.62	220	77	11.73±1.13	19.71±1.70	47.90±4.23	2.08±0.24	43.32
52	416-SP-2	KZ/C	0.71	224	88	9.70±1.59	15.57±2.70	42.30±3.77	1.55±0.21	36.74	0.57	218	74	10.65±1.02	16.29±2.43	44.30±6.20	1.98±0.22	44.65
53	2-CP	KZ/C	0.73	223	85	8.86±1.02	17.60±1.26	43.60±10.17	1.63±0.46	37.45	0.73	212	94	10.39±0.62	20.60±1.78	56.30±5.54	1.80±0.31	31.90
54	3-CP	KZ/C	0.76	227	115	9.55±0.78	18.70±1.25	33.50±5.93	1.30±0.32	38.81	0.77	224	137	11.60±1.02	20.60±1.17	52.60±6.02	2.52±0.58	47.95
55	4-CP	KZ/C	0.7	218	96	8.51±0.94	14.40±1.51	33.89±6.85	1.31±0.26	38.60	0.69	210	120	9.64±0.61	18.10±0.99	43.10±5.74	2.06±0.19	47.68
56	5-CP	KZ/C	0.73	224	98	9.97±0.31	18.10±0.74	42.60±4.62	1.91±0.31	44.93	0.76	220	115	10.92±0.49	20.60±0.70	48.70±4.06	2.14±0.20	43.94
57	6-CP	KZ/C	0.71	224	97	9.64±0.93	15.80±1.14	36.90±5.61	1.51±0.21	41.00	0.74	218	125	11.30±0.80	18.80±1.03	46.00±6.18	2.21±0.32	47.93
58	7-CP	KZ/C	0.7	228	94	11.16±0.66	18.80±1.23	44.80±3.77	1.95±0.21	43.42	0.74	221	127	12.13±0.77	20.80±1.14	48.10±3.41	2.39±0.22	49.65
59	8-CP	KZ/C	0.74	227	86	8.79±0.63	18.90±1.45	33.70±4.06	1.08±0.26	32.08	0.73	217	107	8.96±0.26	19.40±1.17	39.50±5.28	1.39±0.18	35.16
60	9-CP	KZ/C	0.47	226	87	9.16±0.70	19.40±1.43	45.50±4.45	2.07±0.27	45.49	0.72	217	137	8.89±0.44	20.50±.43	44.60±3.47	2.01±0.39	45.09
61	10-CP	KZ/C	0.77	226	120	10.11±0.86	20.20±2.10	46.60±3.60	1.93±0.13	41.42	0.79	218	110	9.66±0.57	20.20±2.49	38.80±9.45	1.68±0.29	43.27
62	11-CP	KZ/C	0.74	228	87	10.22±0.70	19.44±1.33	46.78±8.27	1.93±0.53	41.26	0.71	218	102	10.23±0.55	20.80±1.23	48.10±4.63	1.79±0.32	37.19
63	12-CP	KZ/C	0.75	225	97	10.30±0.72	20.50±1.58	42.80±5.07	1.52±0.26	35.58	0.7	221	135	12.24±0.63	23.90±1.32	64.50±10.90	2.64±0.61	40.98
64	13-CP	KZ/C	0.71	219	94	7.54±1.27	17.20±2.04	44.30±5.76	1.82±0.25	41.02	0.75	217	129	9.73±1.84	20.70±1.06	49.80±6.34	2.00±0.29	40.16
65	14-CP	KZ/C	0.7	222	115	10.07±0.97	18.90±1.37	46.10±7.81	1.65±0.31	35.86	0.66	209	110	12.50±0.94	21.50±2.01	54.50±5.34	2.24±0.30	41.17
66	15-CP	KZ/C	0.75	222	101	10.90±0.97	22.20±1.32	37.90±2.64	1.46±0.12	38.47	0.75	219	128	11.45±0.66	21.50±1.51	52.90±3.14	1.96±0.42	36.98
67	16-CP	KZ/C	0.73	224	108	10.15±0.56	19.00±1.94	36.90±2.56	1.38±0.15	37.32	0.7	218	110	9.69±0.65	19.30±0.95	42.60±2.99	1.67±0.12	39.10
68	17-CP	KZ/C	0.67	221	97	11.95±0.90	20.30±1.49	41.20±6.46	1.59±0.50	38.52	0.76	222	125	11.92±0.55	20.80±1.03	44.30±4.42	1.58±0.27	35.69
69	18-CP	KZ/C	0.73	218	115	10.09±0.45	21.00±0.67	34.80±3.94	1.10±0.36	31.58	0.75	218	131	9.63±0.23	21.10±0.57	43.60±4.67	1.43±0.12	32.72
70	19-CP	KZ/C	0.61	226	94	9.52±1.21	19.40±1.96	33.90±6.95	1.15±0.30	33.89	0.77	225	85	10.56±1.25	19.40±2.22	45.50±7.21	1.32±0.22	29.08

Note: KZ – Kazakhstan; IWWIP (International Winter Wheat Improvement Program) developed by CIMMYT-ICARDA; KZ/C – Kazakhstan-CIMMYT breeding program; NDVI - normalized difference vegetation index; PH, cm - plant height, DH - days to heading, SL, cm - spike lengths, SS - the mean number of spikelets/spike, GS - grains/spike, WGS, g - the weight of grain/spike, TKW, g - thousand kernel weights

Table S3. Pedigree of promising winter wheat lines, originating from Kazakhstan-CIMMYT breeding program.

#	Name	Pedigree
51	415-SP-2	1454/309/1018(104(N91/5347)/ Mereke))//Mereke/1101-17/309
52	416-SP-2	1454/309/1018(104(N91/5347)/Mereke))//Mereke/1101-17/309
53	2-CP	1300(93.AUS 4930.7/2*PASTOR/4/338-K1-1// ANB/BUC/3/GS50A/5/TAM200/KAUZ/Naz/367/113/DO-4 DS/366
54	3-CP	23/Kupava//1774/23
55	4-CP	23/Kupava//1774/23
56	5-CP	20/Umanka//1773/22
57	6-CP	23/Kupava//1773/22
58	7-CP	179/ 1760
59	8-CP	179/586(Bermet)// RWKLDN9
60	9-CP	Ramin/1736/1594 (1013(97(N20 /Umanka)/ Egemen)//Brundage 96/23 Brundage 96
61	10-CP	1777Darya/1724 /1581/ (807 (Naz/Umanka)/Almaly)//Zimorodok/Almaly
62	11-CP	1777Darya/1737/1014 (99(Madsen/Cm.24)/Arap)//Brundage 96/23Brundage 96
63	12-CP	1772Viza/Almaly//Viza
64	13-CP	23/Kupava//Ulugbek/Yr4/Mereke/197
65	14-CP	1320 (113.338-K1-1//ANB/BUC/3/GS50A/4 /TREGO/JGR 8W/5/TX69A509-2//BBY2/ FOX/3/PKL70/LIRA/4/YMH/TOB// MCD/3/LIRA)/Tungysh)//323
66	15-CP	1214. MV10-2000/4/AGRI/NAC// KAUZ/3/ 1D13.1/MLT//Tungysh/Egemen
67	16-CP	11Fielder/269//88
68	17-CP	1046 DALNITSKAYA/4/AGRI/NAC//KAUZ/3/1D13.1/MLT/5/F10S-1//ATAY/GAL-VEZ87//Amigo
69	18-CP	845/ Kupava/1654/1022 (108 (Vabah 1(5351)/133)/Arap)/Arap)//Arap
70	19-CP	1286(79 (ARDEAL/BOEMA//F135U2-1/5/ TX69A509-2//BBY2/FOX/3/PKL70 /LIRA/4/YMH/TOB//MCD/3/LIRA)/Naz)/Naz//296 W2691SrTt-1 Cl 17385

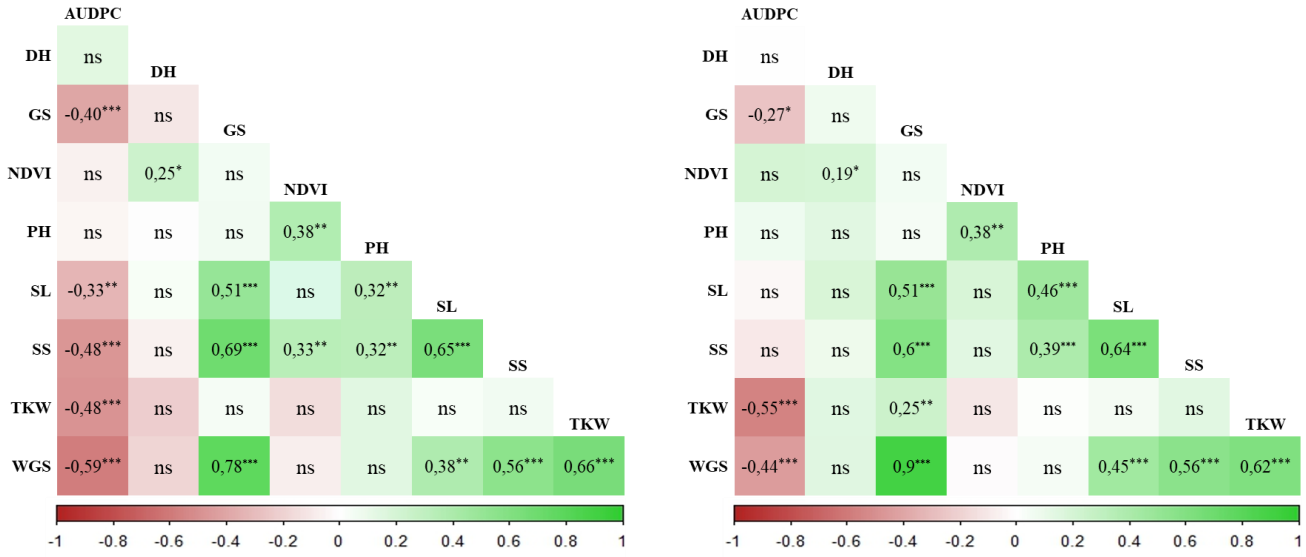
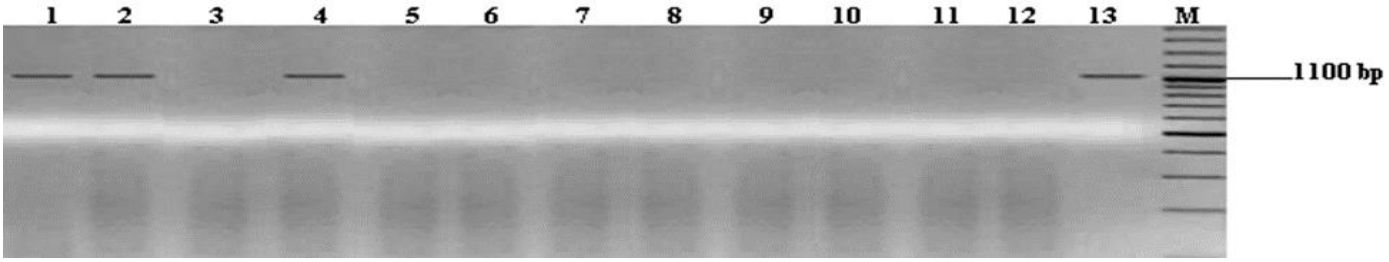
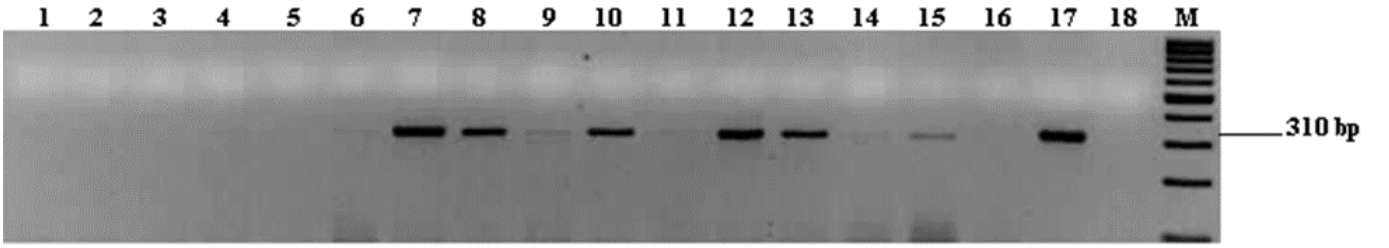


Figure S1. Pearson correlation analysis between the disease progression value (AUDPC) and the main indicators of wheat productivity in 2021 (a) and 2022 (b).
Note: *** – p<0.001; ** – p<0.01; * – p<0.05; ns – not significant.



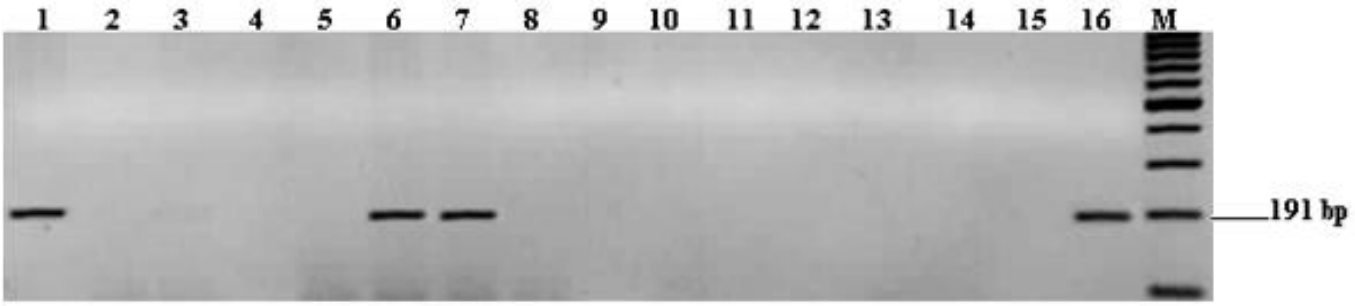
1-Anar, 2-Mataj, 3-Alatau, 4-Raminal, 5-Almaly, 6-Aliya, 7-Akbidaj, 8-Batyr, 9-Egemen 20, 10-Farabi, 11-Kyzyl bidaj, 12-ddH2O (negative control), 13- Transfer/6*TC (positive control), M - molecular weight marker (Gene Ruler, 100 bp DNA Ladder)

Figure S2. DNA amplification products of wheat entries using primers to the STS J13 locus linked with the *Lr9* resistance gene. The sizes of the bands for *Lr9* are 1100 bp. The arrows show the band size of *Lr9*-carrying germplasm (1, 2, 4 and 13 – positive control).



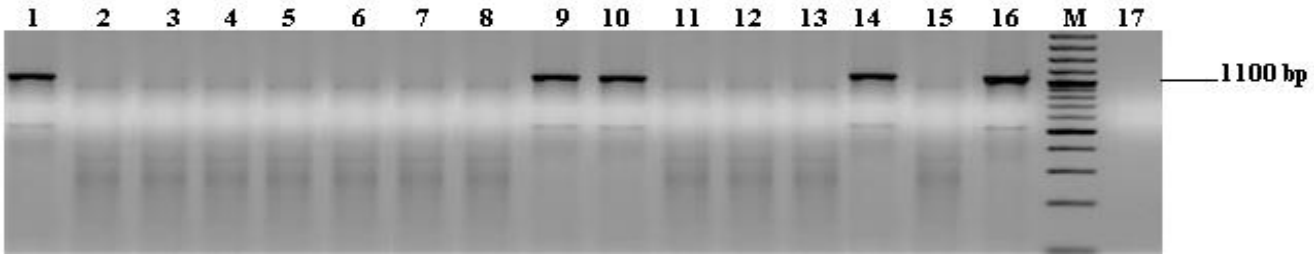
1-Alatau, 2-Almaly, 3-Azharly, 4-Akbidaj, 5-Batyr, 6-Egemen 20, 7-Aliya, 8-Hazrati Bashir, 9-Farabi, 10-Layagatlii 80, 11-Mataj, 12-Egana, 13-Hisorok, 14-Koksu, 15-Yr/Octyabrina, 16-Kyzyl Bidaj, 17- TC*6/Exchange (positive control), 18- ddH2O (negative control), M - molecular weight marker (Gene Ruler, 100 bp DNA Ladder)

Figure S3. DNA amplification products of wheat entries using primers to the STS *Lr 10* locus linked with the *Lr10* resistance gene. The sizes of the bands for *Lr10* are 310 bp. The arrows show the band size of *Lr10*-carrying germplasm (7, 8, 10, 12, 13, 15 and 17-positive control).



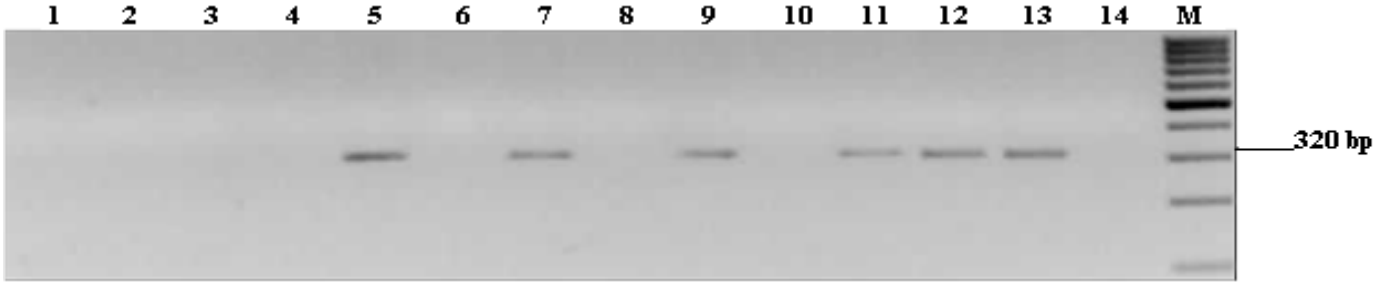
1-Kyzyl bidaj, 2-Zhalyn, 3-Koksu, 4-Kokbidaj, 5-Karaspan, 6-Keremet, 7-Hisorok, 8-Karlygash, 9-Kazakhstanskaya 10, 10-Progress, 11-Prezident, 12-Raminal, 13-Rasad, 14-Rausin, 15- ddH2O (negative control), 16- TC*7/Tr (positive control), M - molecular weight marker (Gene Ruler, 100 bp DNA Ladder)

Figure S4. DNA amplification products of wheat entries using primers to the STS PSY_EF2/PSY_ER4 locus linked with the *Lr19* resistance gene. The sizes of the bands for *Lr19* are 191 bp. The arrows show the band size of *Lr19*-carrying germplasm (1,6,7 and 16-positive control).



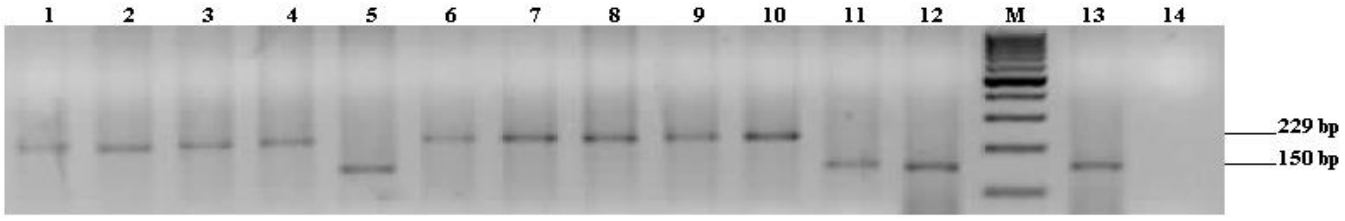
1-Keremet, 2-Koksu, 3-Kokbidaj, 4-Karaspan, 5-Karlygash, 6-Kazakhstanskaya 10, 7-Progress, 8-Prezident, 9-Bunyogkor, 10-Layagatlii 80, 11-Raminal, 12-Rasad, 13-Rausin, 14-Shafag 2, 15-Reke, 16- TC*6/ST-1-25 (positive control), M- molecular weight marker (Gene Ruler, 100 bp DNA Ladder), 17- ddH2O (negative control)

Figure S5. DNA amplification products of wheat entries using primers to the STS Iag 95 locus linked with the *Lr26* resistance gene. The sizes of the bands for *Lr26* are 1100 bp. The arrows show the band size of *Lr26*-carrying germplasm (1, 9, 10, 14 and 16-positive control).



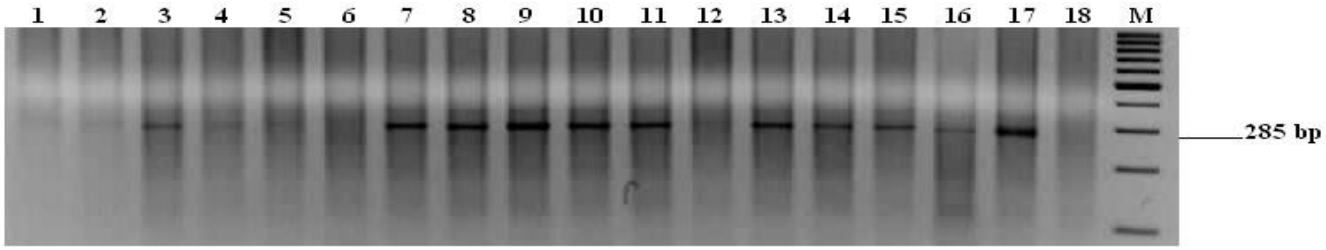
1-Batyr, 2-Zhalyn, 3-Daulet, 4-Yuzhnaya 12, 5-Aliya, 6-Gozgon, 7-Pirotriks 50, 8-Hazrati Bashir, 9-Reke, 10-Egana, 11-Konditerskaya, 12-425/Obri, 13- CS2D-2M (positive control), 14-ddH2O (negative control), M- molecular weight marker (Gene Ruler, 100 bp DNA Ladder)

Figure S6. DNA amplification products of wheat entries using primers to the SSR wmc313 locus linked with the *Lr28* resistance gene. The sizes of the bands for *Lr28* are 320 bp. The arrows show the band size of *Lr28*-carrying germplasm (5, 7, 9, 11, 12 and 13-positive control).



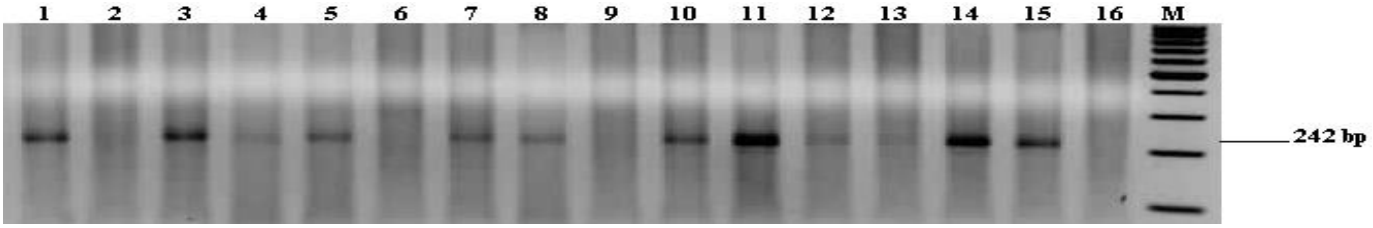
1- Naz/GF-55-2, 2-Naz/GF-55-3, 3-Yr/Octyabrina, 4-Alihan, 5-Almaly, 6-425/Obri, 7-Anar, 8-Derbes, 9-Krasnovodopadskaya 210, 10-Almatinskaya polukarlikovaya/Progress, 11-Karaspan, 12-Karlygash, M- molecular weight marker (Gene Ruler, 100 bp DNA Ladder), 13- TC*6/PI58548 (positive control), 14- ddH2O (negative control)

Figure S7. DNA amplification products of wheat entries using primers to the STS csLV34 locus linked with the *Lr34* resistance gene. The arrows show the band size of *Lr34*-carrying and *Lr34*-none-carrying. The sizes of the bands are 150 bp for *Lr34* (5, 11, 12 and 13-positive control) and 229 bp for non-carryes of *Lr34* (1, 2, 3, 4, 6, 7, 8, 9, 10)



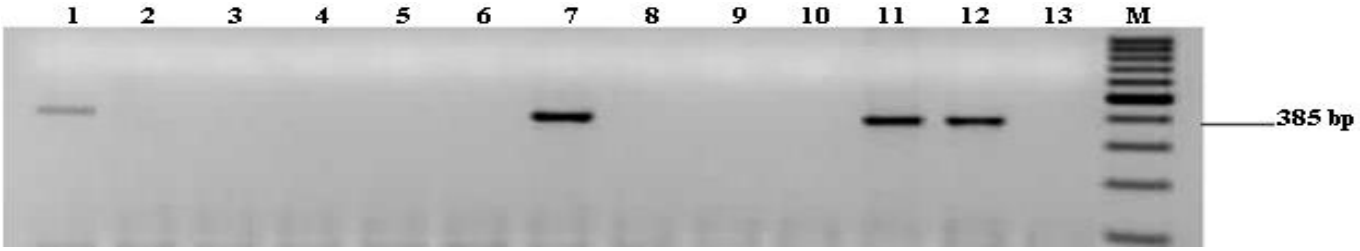
1- Shafag 2, 2-Egana, 3-Aliya, 4-Egemen 20, 5-Steklovidnaya 24, 6-Sultan 2, 7-Mataj, 8-Kyzyl bidaj, 9-Keremet, 10-Kokbidaj, 11-Rasad, 12-Naz/Immun 78, 13-Reke, 14-Hisorok, 15-Alihan, 16-Krasnovodopadskaya 210, 17- TC*6/VPM (positive control), 18-ddH2O (negative control), M - molecular weight marker (Gene Ruler, 100 bp DNA Ladder)

Figure S8. DNA amplification products of wheat entries using primers to the CAPS URIC-LN2 linked with the *Lr37* resistance gene. The sizes of the bands for *Lr37* are 285 bp. The arrows show the band size of *Lr37*-carrying germplasm (3, 7, 8, 9, 10, 11, 13, 14, 15, 16 and 17-positive control).



1-Alatau, 2-Alihan, 3-Azharly, 4-Anar, 5-Akbidaj, 6-Derbes, 7-Batyr, 8-Farabi, 9-Krasnovodopadskaya 210, 10-Mataj, 11-Keremet, 12-Almatinskaya polukarlikovaya/Progress, 13-Almaly/Obri, 14-Koksu, 15- Pavon 76 (positive control), 16- ddH2O (negative control), M - molecular weight marker (Gene Ruler, 100 bp DNA Ladder)

Figure S9. DNA amplification products of wheat entries using primers to the STS Xwmc 44 locus linked with the *Lr46* resistance gene. The sizes of the bands for *Lr46* are 242 bp. The arrows show the band size of *Lr46*-carrying germplasm (1, 3, 5, 7, 8, 10, 11, 14 and 15-positive control).



1-Almaly/Obri, 2-Azharly, 3-Koksu, 4-Kokbidaj, 5-Karaspan, 6-Zhalyn, 7-Naz/GF-55-3, 8-Karlygash, 9-Kazakhstanskaya 10, 10-Progress, 11-Alihan, 12- Parula (positive control), 13-ddH2O (negative control), M - molecular weight marker (Gene Ruler, 100 bp DNA Ladder)

Figure S10. DNA amplification products of wheat entries using primers to the STS csGS F1 csGS R-1 locus linked with the *Lr68* resistance gene. The sizes of the bands for *Lr68* are 385 bp. The arrows show the band size of *Lr68*-carrying germplasm (1, 7, 11 and 12-positive control)