Yield of *Elymus elongatus* and *Secale cereanum* on marginal soils in Central Europe

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Table S1 Average content of nutrients in the soil (0–30 cm) within the experiment with tall wheatgrass and perennial rye, values/categories determined according to the Mehlich 3 method, initial status of 2016

Site – parameter	N_t (mg.kg^{-1})	P (mg.kg^{-1})	K (mg.kg^{-1})	Ca (mg.kg^{-1})	Mg (mg.kg^{-1})	pH/KCl	C_{ox} (%)	Humus (%)	C/N
Site-1	597	89.3	226.1	1,066.2	133.2	4.82	0.623	1.07	10.71
		suitable	middle	suitable	suitable	strongly acidic		low	*middle
Site-2	1,548	79.8	277.5	4,613.6	834.4	5.03	1.652	2.85	10.73
		middle	middle	high	very high	strongly acidic		middle	*middle
Site-3	1,606	28.8	259.4	3,626.6	539.1	4.91	1.684	2.90	10.48
		low	suitable	middle	very high	strongly acidic		middle	*middle
Site-4	1,387	59.8	387.9	4,683.0	667.4	5.80	1.489	2.57	10.76
		suitable	high	high	very high	weakly acidic		middle	*middle

*middle - middle nitrogen content in relation to carbon content, N_t – total nitrogen

Table S2 Weather conditions after sowing date in autumn of 2016, within the experiment with tall wheatgrass and perennial rye, data from the SHMÚ network stations closest to the experiment sites

Month	Parameter	Site-1	Site-2	Site-3	Site-4
August	average daily temperature (°C)	20.2	19.9	20.2	18.4
	sum of precipitations (mm)	48.1	80.6	74.2	89.4
September	average daily temperature (°C)	17.8	17.7	17.6	16.2
	sum of precipitations (mm)	46.5	42.0	35.8	29.4
October	average daily temperature (°C)	9.2	9.0	9.1	7.6
	sum of precipitations (mm)	105.6	117.4	140.6	130.7
November	average daily temperature (°C)	4.3	4.1	4.4	2.9
	sum of precipitations (mm)	62.8	70.1	69.2	54.1
December	average daily temperature (°C)	-1.6	-1.6	-1.9	-3.5
	sum of precipitations (mm)	9.8	5.5	24.7	13.5

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Table S3 The data of weather and soil conditions, during the main vegetation period (from April till harvest) of the experiment with tall wheatgrass and perennial rye

Site/soil-climate	Crop	Weather condition		Soil conditions, depth 15 cm			Soil conditions, depth 45 cm		
Parameter		AT (°C)	SP (mm)	M (% VWC)	T (°C)	EC (mS.cm^{-1})	M (% VWC)	T (°C)	EC (mS.cm^{-1})
2017									
Site-1	TW	18.2	236	21.0	19.7	0.065	14.1	18.6	0.051
	PR	16.5	107	22.4	17.4	0.062	17.3	16.1	0.059
Site-2	TW	18.1	301	34.4	18.7	0.330	40.9	17.4	0.439
	PR	16.3	97	35.2	16.0	0.330	42.3	14.6	0.457
Site-3	TW	18.4	288	24.3	17.4	0.119	31.7	16.2	0.299
	PR	16.6	80	25.3	15.5	0.114	33.7	14.3	0.311
Site-4	TW	16.6	363	41.4	17.2	0.623	46.9	15.5	1.074
	PR	14.8	148	44.1	14.9	0.667	49.6	13.0	1.178
2018									
Site-1	TW	20.0	202	19.9	22.8	0.081	14.1	21.0	0.056
	PR	18.4	133	22.4	20.7	0.087	17.4	18.8	0.061
Site-2	TW	20.0	235	32.8	20.2	0.268	40.7	18.3	0.478
	PR	18.3	155	35.0	17.6	0.301	42.7	15.7	0.489
Site-3	TW	20.0	221	20.7	19.9	0.067	28.7	17.4	0.274
	PR	18.2	159	21.2	18.6	0.084	31.6	15.7	0.294
Site-4	TW	18.6	259	34.7	18.8	0.395	43.7	16.5	0.802
	PR	16.8	181	36.6	16.9	0.461	49.5	14.4	0.932
2019									
Site-1	TW	19.5	340	21.4	19.9	0.083	15.6	18.7	0.049
	PR	18.2	256	25.3	17.5	0.093	19.4	16.3	0.059
Site-2	TW	19.5	308	33.4	17.5	0.231	29.8	16.1	0.281
	PR	18.2	222	36.0	15.5	0.286	32.0	13.8	0.344
Site-3	TW	18.4	445	32.3	17.5	0.165	28.3	16.1	0.273
	PR	16.5	298	32.5	15.7	0.159	28.6	14.2	0.273
Site-4	TW	16.8	516	41.6	17.9	0.555	39.5	15.9	0.75
	PR	14.8	279	44.5	15.9	0.656	46.0	13.6	0.881
2020									
Site-1	TW	16.9	339	20.9	18.9	0.112	15.6	17.8	0.042
	PR	14.6	162	20.9	16.2	0.108	16.3	15.2	0.041
Site-2	TW	16.9	439	30.1	17.5	0.200	40.0	16.2	0.416
	PR	14.6	252	28.4	15.1	0.158	38.7	13.5	0.359
Site-3	TW	17.3	388	28.2	17.4	0.150	32.8	16.0	0.255
	PR	14.8	246	26.7	14.5	0.140	33.1	13.1	0.249
Site-4	TW	16.0	468	31.6	17.3	0.702	46.9	15.5	1.086
	PR	13.4	211	32.1	14.9	0.731	48.8	12.9	1.127
Average	TW	18.2	334	29.3	18.7	0.259	31.8	17.1	0.414
	PR	16.3	187	30.5	16.4	0.277	34.2	14.7	0.445

AT – average day air temperature, SP – sum of precipitation, M – moisture, T – temperature, EC – electrical conductivity

Table S4   Crop harvest dates of the experiment with tall wheatgrass and perennial rye

Site/harvest day	Site-1	Site-2	Site-3	Site-4
2017				
Kriszta and Gergő	7 July	7 July	12 July	12 July
Szarvasi-1 and Alkar	30 August	30 August	12 September	12 September
2018				
Kriszta and Gergő	3 July	3 July	4 July	4 July
Szarvasi-1 and Alkar	22 August	22 August	23 September	23 August
2019				
Kriszta and Gergő	03 July	03 July	02 July	15 July
Szarvasi-1 and Alkar	13 August	13 August	12 August	13 August
2020				
Kriszta and Gergő	15 July	15 July	15 July	12 July
Szarvasi-1 and Alkar	12 August	12 August	12 September	13 August

Table S5   Plant height (cm) within the experiment with tall wheatgrass and perennial rye

Site/variety year/treatment		Site-1			Site-2			Site-3			Site-4		
		Int.	Sem.	Con.	Int.	Sem.	Con.	Int.	Sem.	Con.	Int.	Sem.	Con.
Szarvasi-1	2017	102	81	78	118	91	76	133	132	125	85	73	39
	2018	156	134	112	169	147	138	139	135	131	131	95	92
	2019	135	119	107	162	148	145	173	165	149	153	148	114
	2020	163	148	115	163	149	57	153	148	134	163	152	108
Alkar	2017	121	83	69	118	92	83	144	141	129	86	51	42
	2018	145	143	93	144	139	127	145	138	131	125	118	95
	2019	144	135	103	135	133	132	163	161	155	164	158	116
	2020	156	149	118	172	163	151	155	149	141	163	154	111
Kriszta	2017	184	175	162	171	141	136	175	158	143	172	141	125
	2018	112	95	92	154	122	115	162	155	133	165	136	123
	2019	165	154	117	183	171	168	178	169	163	193	118	112
	2020	176	139	106	165	143	92	183	179	142	165	132	79
Gergő	2017	182	171	158	143	118	115	172	145	138	175	154	127
	2018	133	128	106	117	104	94	153	151	114	163	141	138
	2019	175	165	137	163	134	125	183	178	146	184	121	105
	2020	172	123	111	152	101	94	181	175	139	163	132	74

Int. – intensive nutrition, Sem. – semi-intensive nutrition, Con. – untreated control

Table S6   Crop coverage (%) within the experiment with tall wheatgrass and perennial rye

Site/variety year/treathment		Site-1			Site-2			Site-3			Site-4		
		Int.	Sem.	Con.	Int.	Sem.	Con.	Int.	Sem.	Con.	Int.	Sem.	Con.
Szarvasi-1	2017	62	43	39	76	41	38	68	61	55	77	61	54
	2018	84	55	41	100	92	88	100	96	85	93	85	79
	2019	86	79	58	84	79	76	100	100	100	83	69	67
	2020	83	71	29	83	78	63	100	95	78	98	95	63
Alkar	2017	66	45	38	85	41	38	93	74	53	86	54	52
	2018	72	68	31	100	100	98	100	99	86	96	78	71
	2019	93	81	57	85	81	62	100	100	100	93	89	74
	2020	84	79	13	83	79	61	100	98	77	100	98	59
Kriszta	2017	46	38	23	27	19	16	56	48	33	96	18	7
	2018	51	29	24	45	26	18	39	33	8	33	7	4
	2019	92	89	18	62	33	28	78	54	49	88	23	21
	2020	83	69	7	61	52	4	91	82	18	31	3	1
Gergő	2017	78	56	37	24	10	10	63	58	44	99	61	26
	2018	42	39	28	54	28	13	43	25	8	38	9	7
	2019	91	89	17	35	17	7	73	51	45	81	18	13
	2020	85	68	9	29	12	3	92	81	17	31	3	1

Int. – intensive nutrition, Sem. – semi-intensive nutrition, Con. – untreated control

Table S7   Dry matter content at harvest (%) within the experiment with tall wheatgrass and perennial rye

Site/variety year/treathment		Site-1			Site-2			Site-3			Site-4		
		Int.	Sem.	Con.	Int.	Sem.	Con.	Int.	Sem.	Con.	Int.	Sem.	Con.
Szarvasi-1	2017	65.2	60.5	50.5	56.8	56.9	58.5	46.6	39.3	47.7	483	49.8	49.7
	2018	70.1	74.3	66.1	65.0	62.2	64.9	64.2	67.2	61.7	59.5	62.0	60.8
	2019	72.5	85.2	66.1	57.3	59.2	59.4	50.4	49.1	52.8	50.0	52.5	48.7
	2020	64.2	59.9	57.0	53.0	51.5	52.7	50.7	50.4	51.6	50.5	50.0	52.1
Alkar	2017	73.3	63.7	56.2	54.6	56.8	52.4	46.5	45.7	34.3	45.6	52.5	49.2
	2018	67.4	71.6	65.9	62.9	66.4	69.0	58.7	65.2	64.4	54.8	57.8	59.1
	2019	69.7	71.2	72.1	59.2	56.2	56.5	51.2	47.1	50.9	48.5	51.3	48.6
	2020	65.6	59.9	54.1	51.3	53.6	50.3	48.8	49.3	49.7	46.3	47.8	46.7
Kriszta	2017	66.9	65.3	60.1	58.1	58.8	58.9	52.5	55.3	53.6	54.2	60.3	62.4
	2018	56.5	57.4	66.4	62.4	57.8	51.4	54.5	61.8	61.4	51.3	52.8	53.5
	2019	48.8	55.4	60.2	55.6	54.5	55.2	46.8	47.7	50.7	50.2	52.8	52.9
	2020	52.9	49.4	50.5	61.2	58.3	58.5	56.0	55.1	57.9	55.2	54.5	53.1
Gergő	2017	70.8	72.4	75.2	57.1	55.7	56.0	55.1	53.1	55.5	54.0	62.7	62.6
	2018	58.0	67.3	76.3	59.3	54.9	52.4	53.9	55.5	64.4	49.8	52.6	53.7
	2019	51.8	57.3	71.2	59.9	54.1	59.8	47.8	48.3	49.5	53.3	50.6	49.9
	2020	61.0	45.7	61.7	65.0	61.4	57.2	55.9	56.3	59.0	50.5	54.6	51.8

Int. – intensive nutrition, Sem. – semi-intensive nutrition, Con. – untreated control

Table S8 Reliability index (R2) of second-order polynomic dependence of dry matter yield of tall wheatgrass cv. Szarvasi-1 and Alkar and perennial rye cv. Kriszta and Gergő on weather and soil-climate parameters, determination index (r2) respectively for the precipitations valuated by a linear dependence

| Variety/treatment/ parameter	Szarvasi-1			Alkar			Kriszta			Gergő		
	intensive	semi-intensive	control	intensive	semi-intensive	control	intensive	semi-intensive	control	intensive	semi-intensive	control
Weather												
Temperature	0.090	0.020	0.240	0.138	0.100	0.097	0.435	0.258	0.440	0.350	0.270	0.396
Precipitations	0.116	0.167	0.005	0.189	0.175	0.010	0.001	0.007	0.052	0.167	0.007	0.061
Soil-climate and conductivity												
Temperature*	0.171	0.198	0.006	0.312	0.153	0.043	0.437	0.105	0.077	0.210	0.010	0.154
Temperature**	0.155	0.187	0.041	0.305	0.153	0.080	0.288	0.092	0.148	0.074	0.052	0.082
Moisture*	0.248	0.353	0.180	0.322	0.287	0.197	0.172	0.116	0.057	0.085	0.243	0.069
Moisture**	0.218	0.426	0.445	0.334	0.253	0.501	0.025	0.415	0.248	0.053	0.379	0.220
Conductivity*	0.008	0.071	0.126	0.032	0.071	0.126	0.181	0.325	0.185	0.163	0.453	0.212
Conductivity**	0.067	0.295	0.305	0.190	0.109	0.369	0.108	0.340	0.204	0.158	0.422	0.207

* depth of 15 cm; ** depth of 45 cm
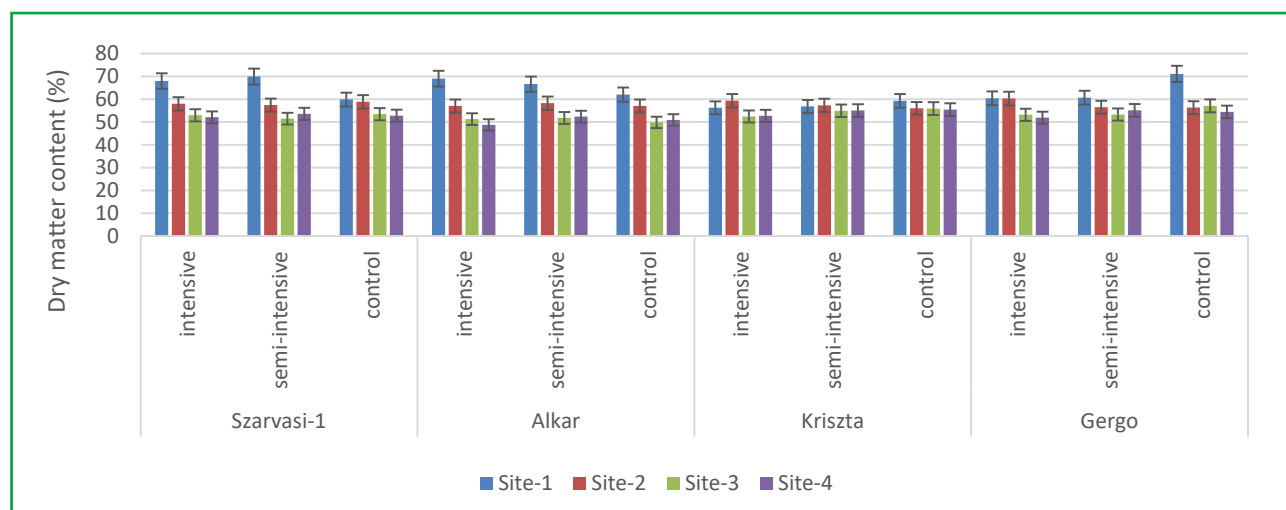
Figure S1 The dry matter content of tall wheatgrass and perennial rye green phytomass at harvest, mean values by sites, varieties and nutrition
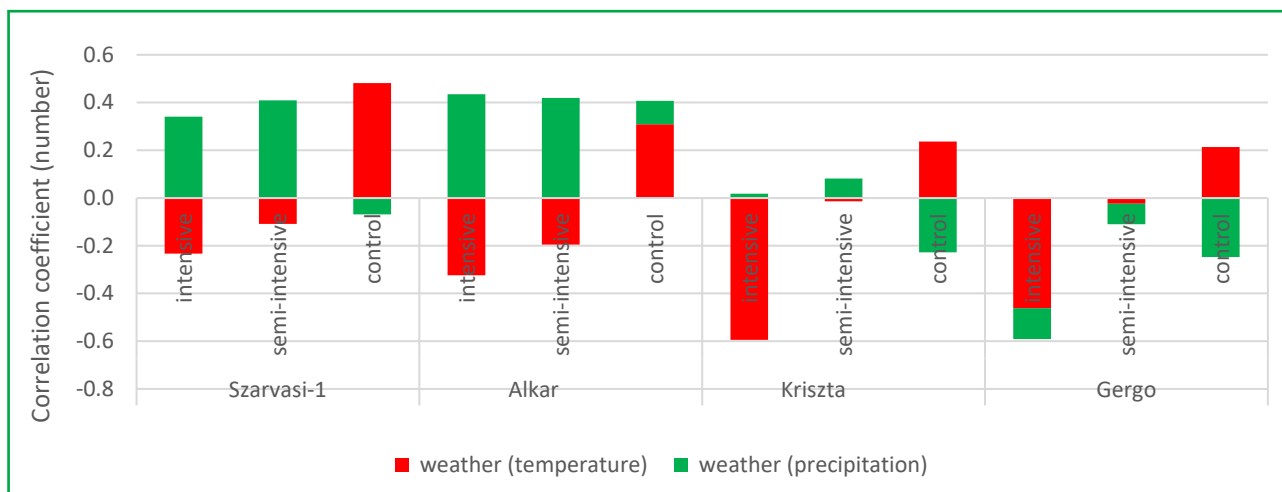
Figure S2 The correlation coefficients of yield of tall wheatgrass and perennial rye and weather condition relations
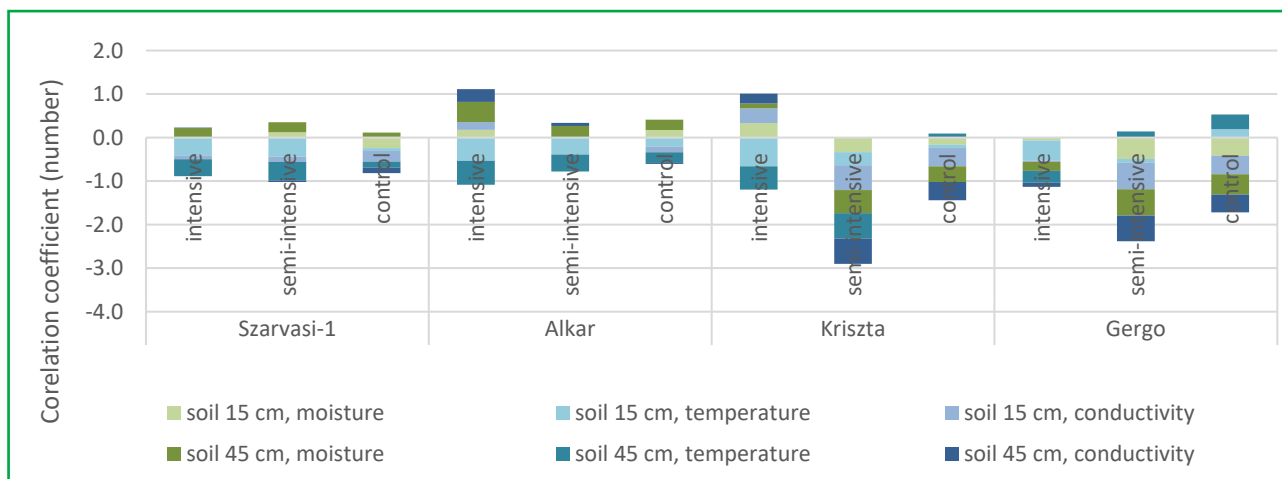

Figure S3 The correlation coefficients of yield of tall wheatgrass and perennial rye and soil condition relations
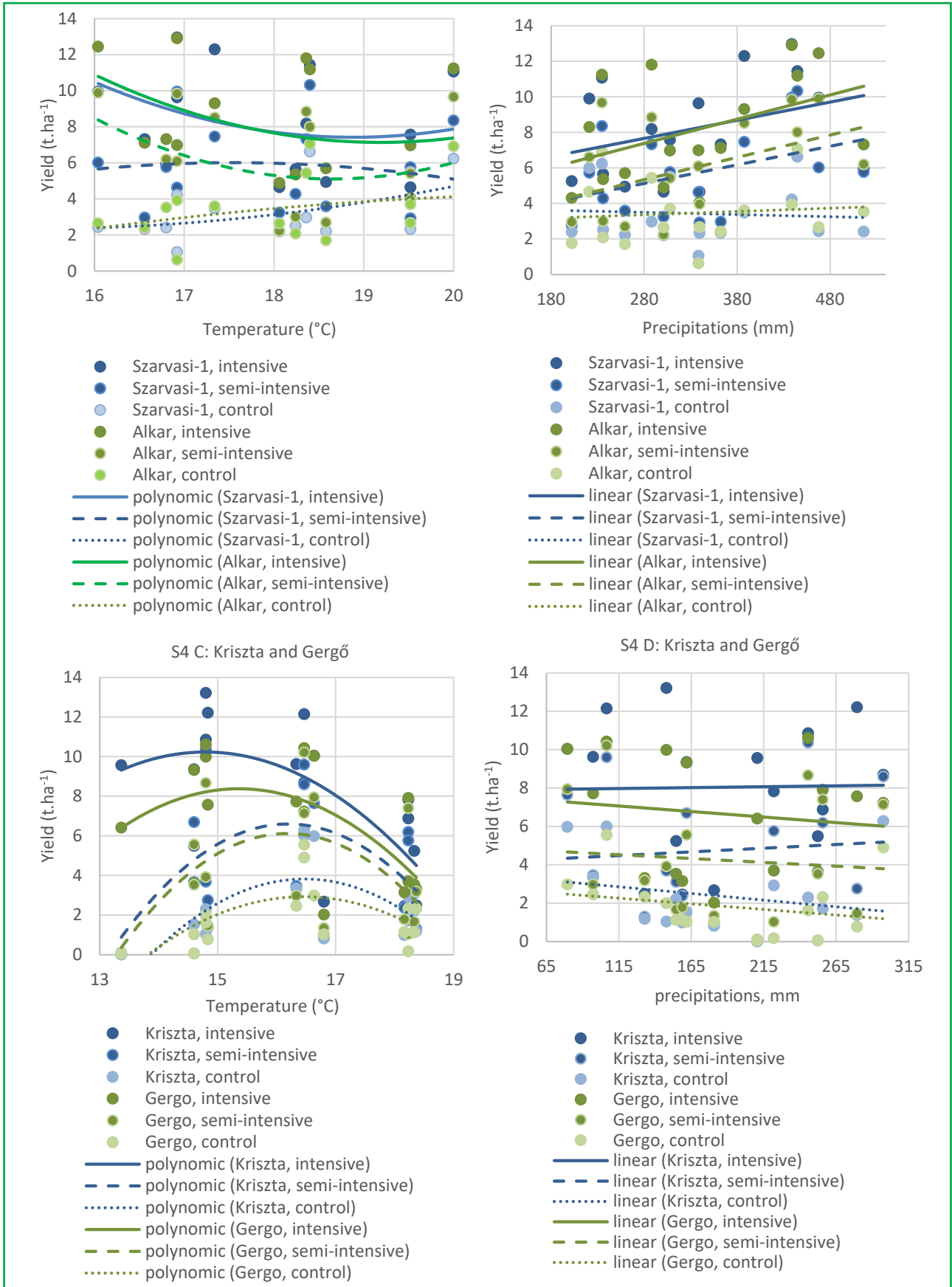
Figure S4 The polynomic course of dependence of yield of tall wheatgrass cv. Szarvasi-1 and Alkar and perennial rye cv. Kriszta and Gergő on air temperature – A/C and the linear course of dependence of the yield on precipitations – B/D
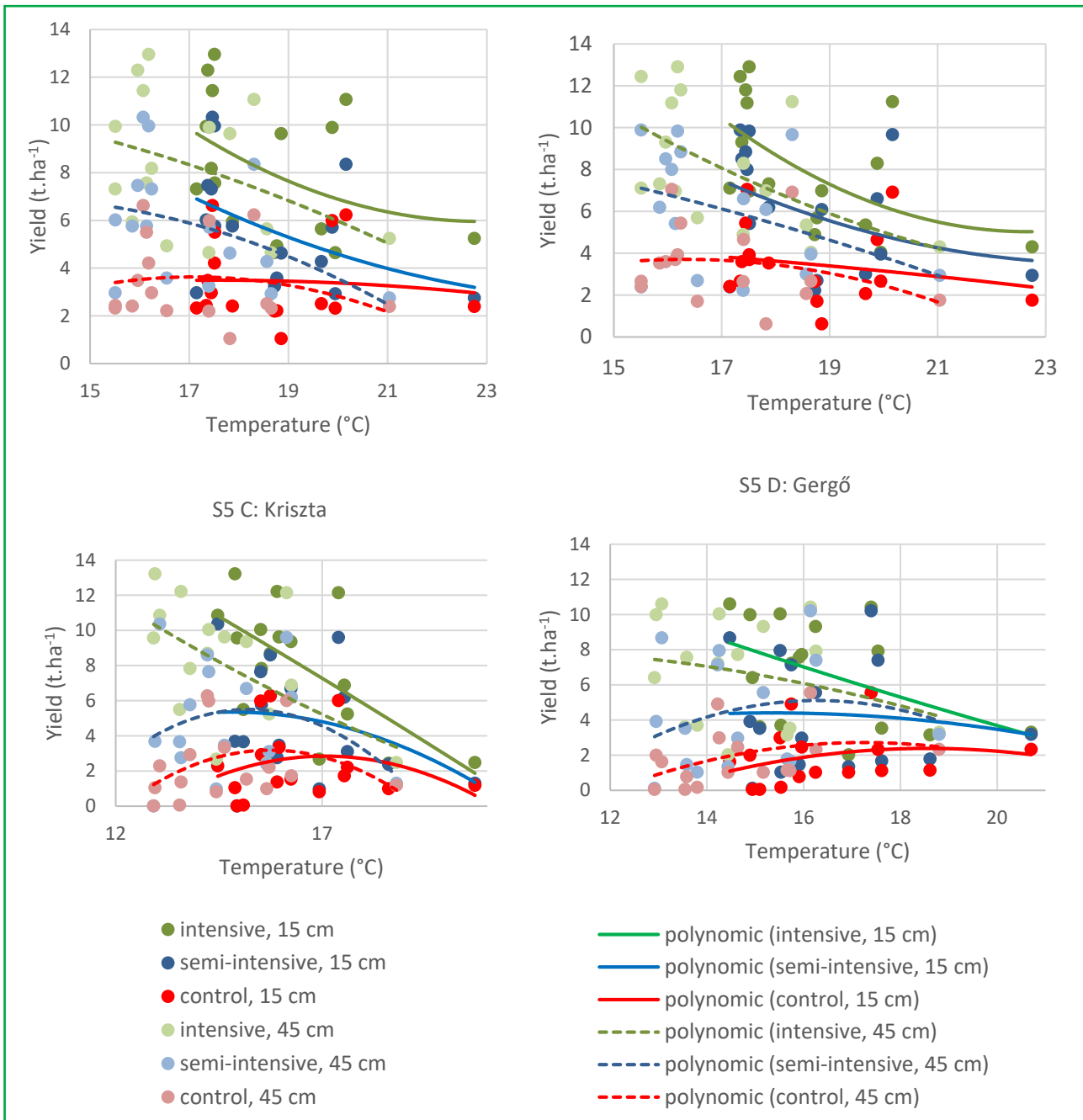
Figure S5 The polynomic course of dependence of yield of tall wheatgrass cv. Szarvasi-1 and Alkar and perennial rye cv. Kriszta and Gergő on soil temperature (depths of 15 cm and 45 cm)

Figure S6 The polynomic course of dependence of yield of tall wheatgrass cv. Szarvasi-1 and Alkar and perennial rye cv. Kriszta and Gergő on soil moisture (depths of 15 cm and 45 cm)

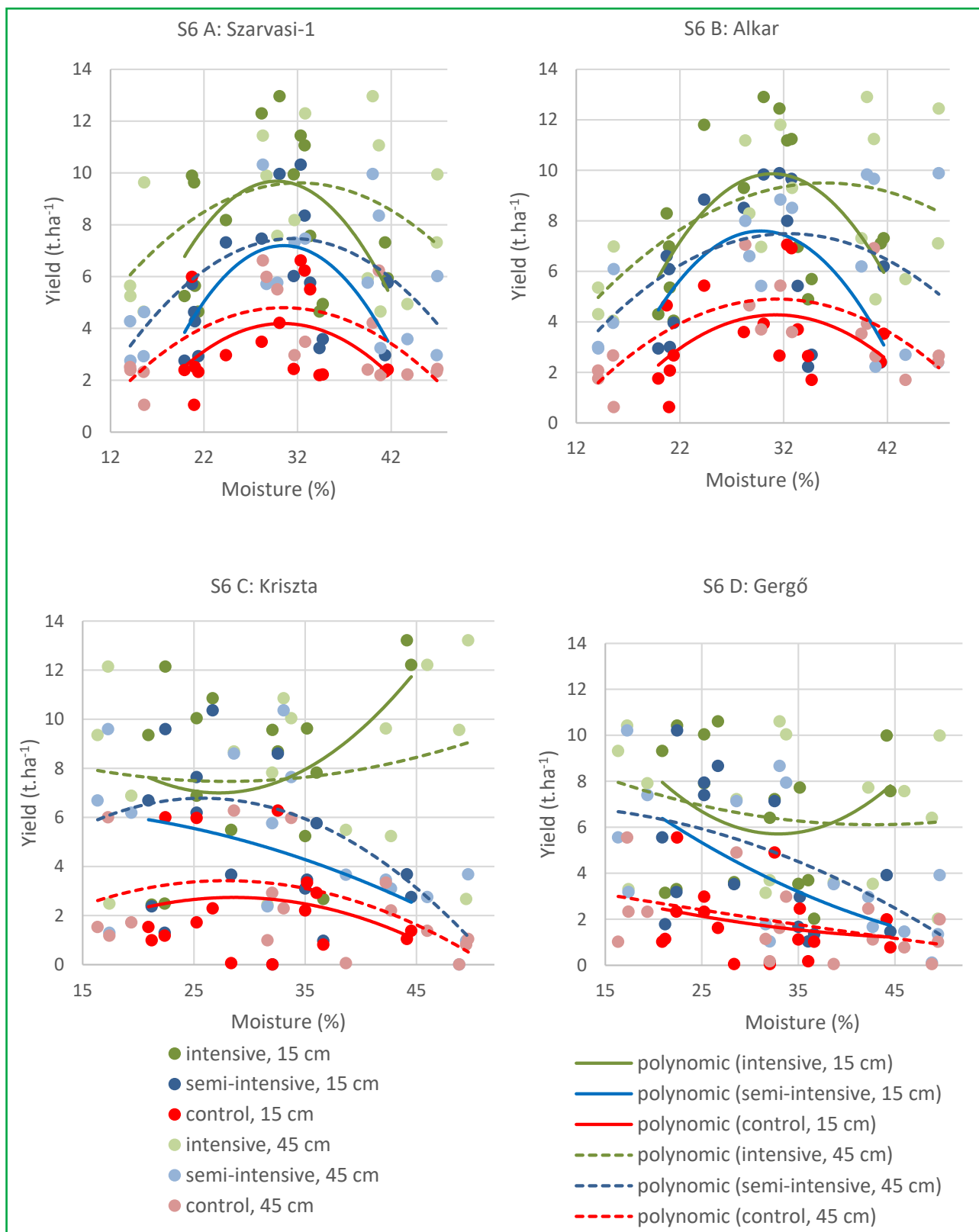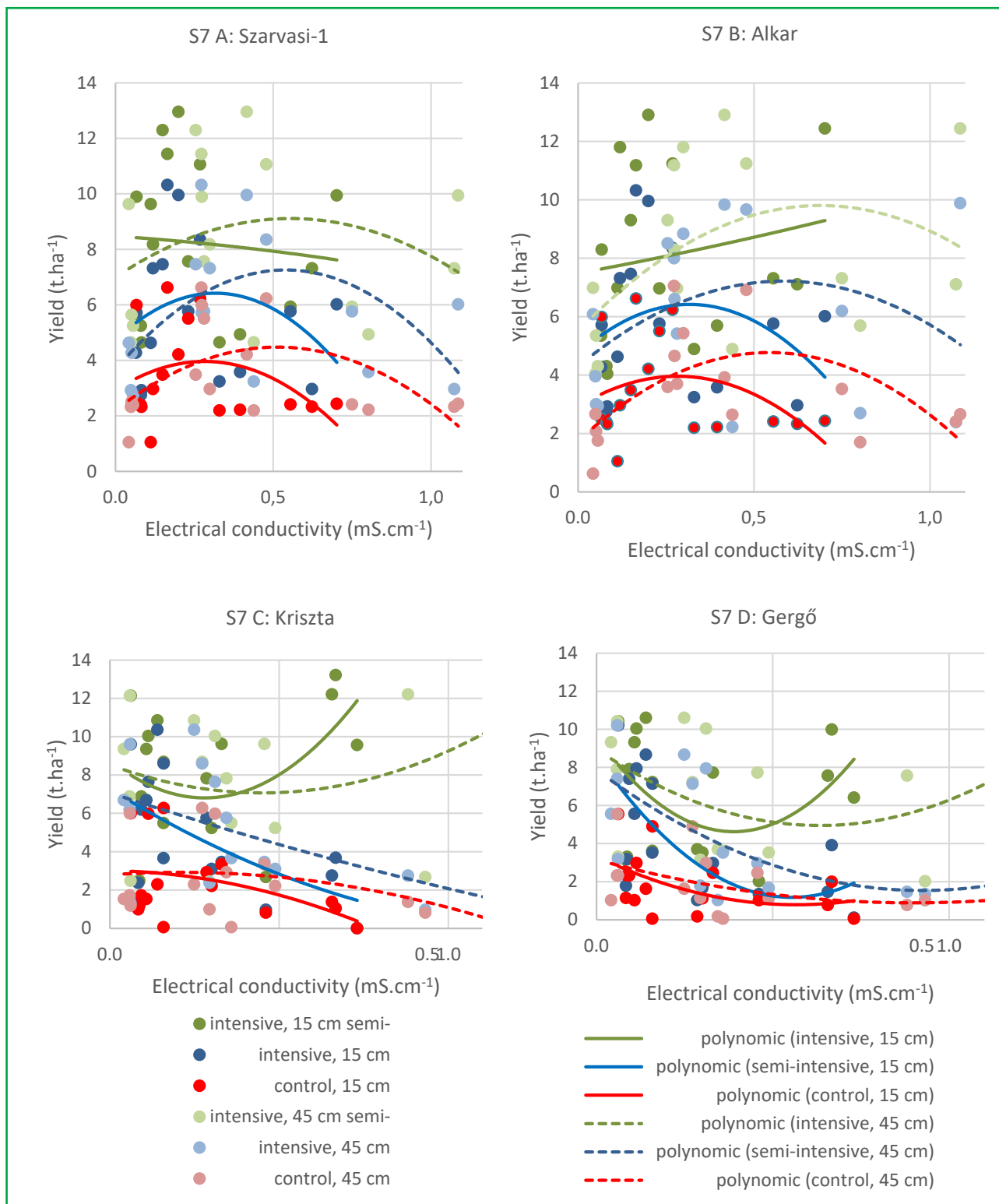**Figure S7** The polynomic course of dependence of yield of tall wheatgrass cv. Szarvasi-1 and Alkar and perennial rye cv. Kriszta and Gergő on soil electrical conductivity (depths of 15 cm and 45 cm)
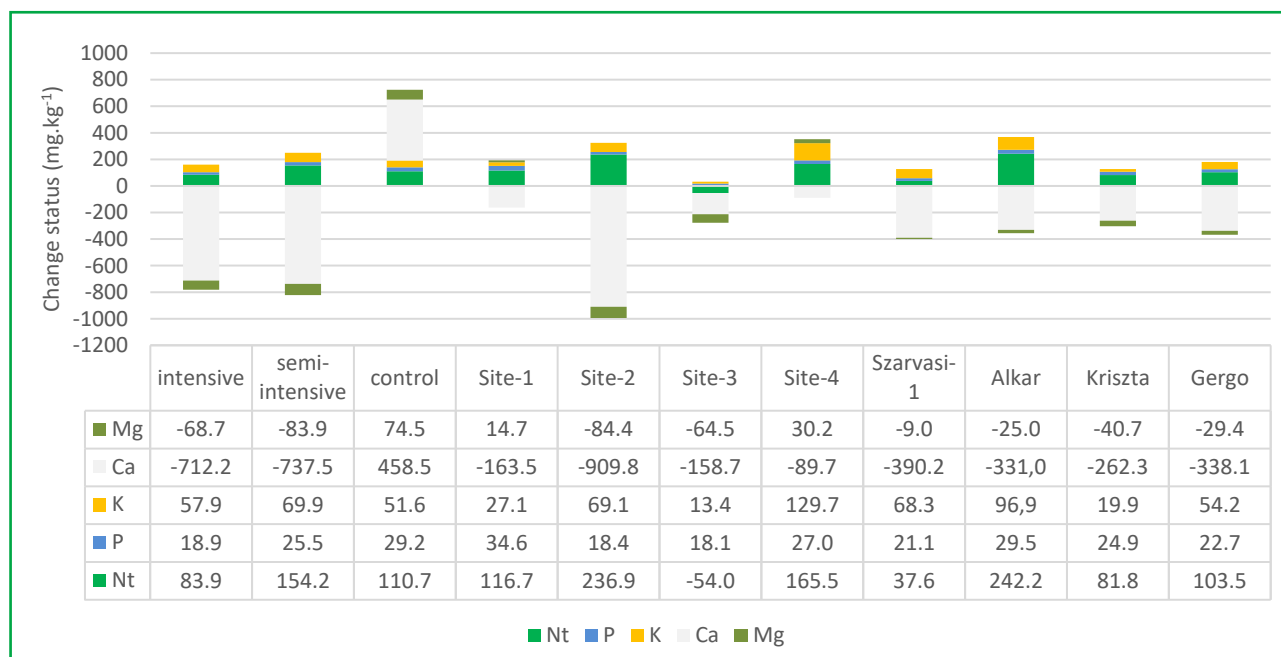
	intensive	semi-intensive	control	Site-1	Site-2	Site-3	Site-4	Szarvasi-1	Alkar	Kriszta	Gergo
Mg	-68.7	-83.9	74.5	14.7	-84.4	-64.5	30.2	-9.0	-25.0	-40.7	-29.4
Ca	-712.2	-737.5	458.5	-163.5	-909.8	-158.7	-89.7	-390.2	-331,0	-262.3	-338.1
K	57.9	69.9	51.6	27.1	69.1	13.4	129.7	68.3	96,9	19.9	54.2
P	18.9	25.5	29.2	34.6	18.4	18.1	27.0	21.1	29.5	24.9	22.7
Nt	83.9	154.2	110.7	116.7	236.9	-54.0	165.5	37.6	242.2	81.8	103.5

Figure S8   The change of main plant nutrient content (total nitrogen Nt, P, K, Ca, Mg) in the soil, in mg/kg within the experiment with tall wheatgrass cv. Szarvasi-1 and Alkar and perennial rye cv. Kriszta and Gergő
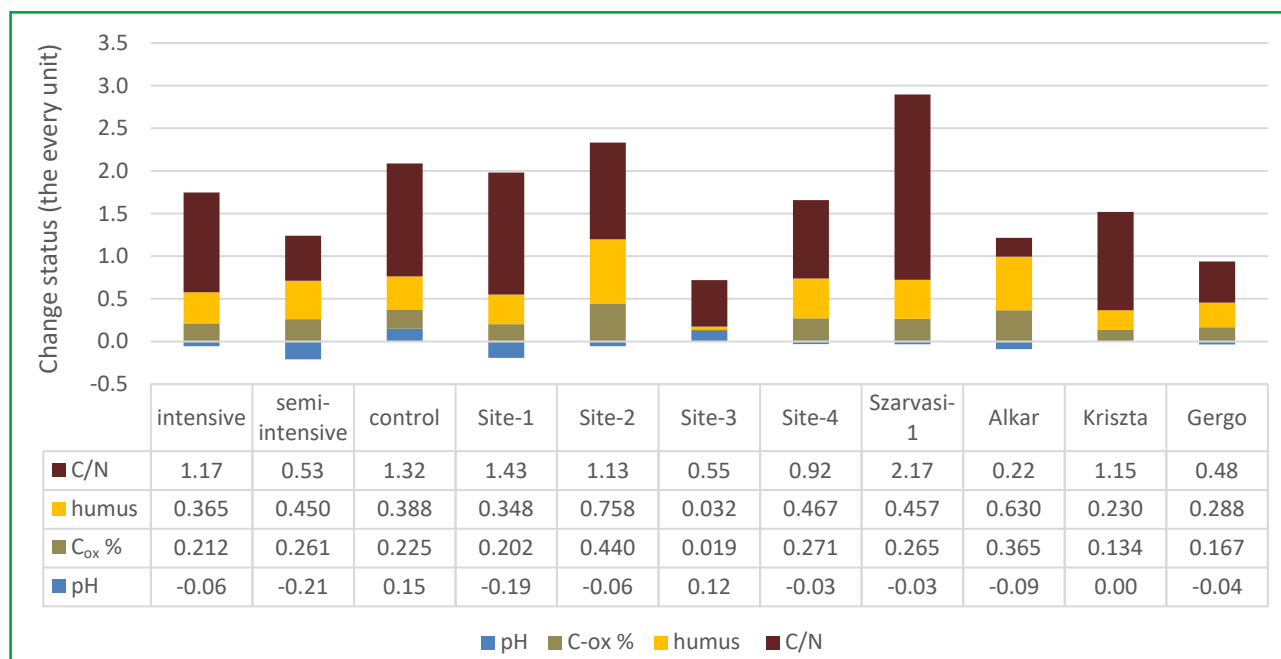

	intensive	semi-intensive	control	Site-1	Site-2	Site-3	Site-4	Szarvasi-1	Alkar	Kriszta	Gergo
C/N	1.17	0.53	1.32	1.43	1.13	0.55	0.92	2.17	0.22	1.15	0.48
humus	0.365	0.450	0.388	0.348	0.758	0.032	0.467	0.457	0.630	0.230	0.288
C_{ox} %	0.212	0.261	0.225	0.202	0.440	0.019	0.271	0.265	0.365	0.134	0.167
pH	-0.06	-0.21	0.15	-0.19	-0.06	0.12	-0.03	-0.03	-0.09	0.00	-0.04

Figure S9   The change of the C_{ox} (%), C/N ratio, humus (%) and soil pH/KCl in the experiment with tall wheatgrass cv. Szarvasi-1 and Alkar and perennial rye cv. Kriszta and Gergő