Faculty of Forestry
and Wood Sciences

Inter-Action: Czech-American research cooperation

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The aims of the project

Genetic variability of hyperspectral reflectance in Scots pine ecotypes for selection of drought-resistant individuals

- Current climate change already has severe impacts on forests in Central Europe.
- One of the major limiting factors for the survival of forest stands under climate change is **drought**.
- Scots pine was considered a reasonable substitute for Norway Spruce, but this supposedly tolerant species already suffers many stress issues mainly due to the impact of drought.
- **Optical reflectance** data have shown their potential as **drought stress markers** in past studies.
- The main objectives of this project are extensive in situ data collection within distinct local **ecotypes of Scots pine** progeny trials, which will include both growth, spectral (laboratory spectroscopy), and biochemical (chlorophyll, proline) measurements.
- In the second step, controlled experiments in growth chambers with induced drought will be designed, and the material will be subsequently genotyped (SNP chip).
- The next phase will involve genetic evaluation of progeny trials and **chamber experiments**, where the **genetic correlation** of spectral parameters with growth traits will be predicted.
- Inference about the ecotypic variation underlying genetic variability of the measured traits will be drawn. In the last stage, **drone (UAV)-borne hyperspectral imagery** will be utilized to **upscale** the spectroscopical lab measurements

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Czech research background based on CULS / UK collaboration

Tree Physiology 36, 883–895
doi:10.1093/treephys/tpw028

883

Research paper

Genetic variability and heritability of chlorophyll *a* fluorescence parameters in Scots pine (*Pinus sylvestris* L.)

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Variable fluorescence heritability

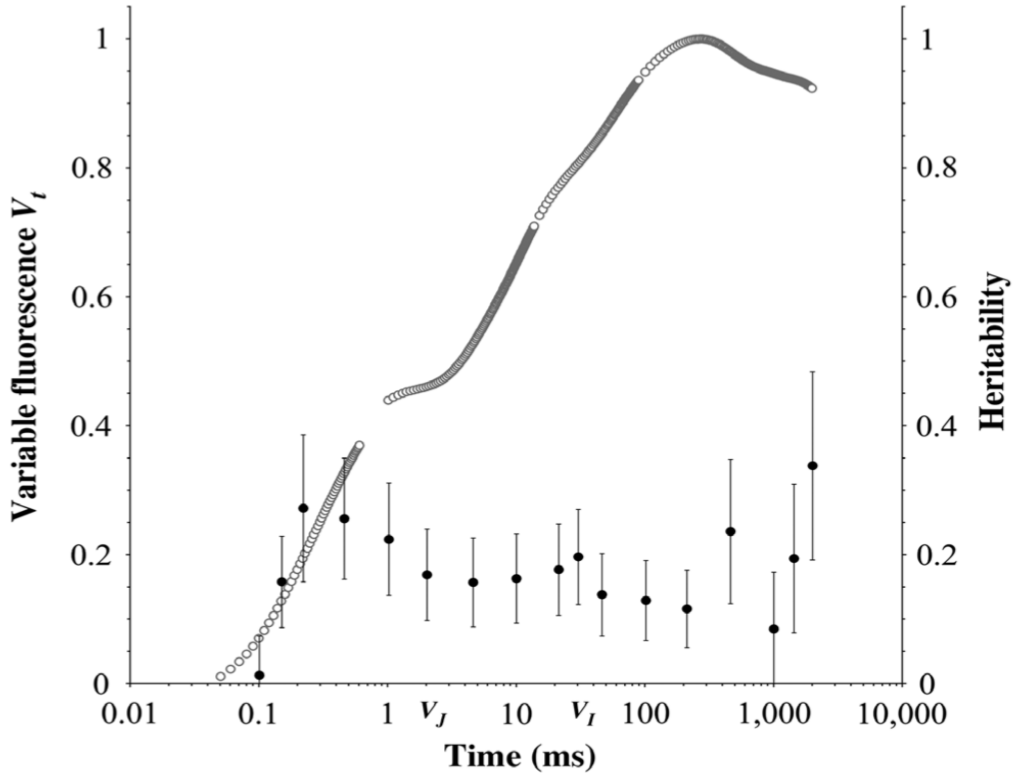

Figure 3. Mean variable ChlF (left *y*-axis) from both experimental sites with heritabilities (indicated by dots, right *y*-axis) for relative variable fluorescence at selected time points along with their respective SEs; *N* = 525.

Czech research background based on CULS / UK collaboration – needle spectral reflectance

Remote Sensing of Environment 219 (2018) 89–98

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Heritable variation in needle spectral reflectance of Scots pine (*Pinus sylvestris* L.) peaks in red edge

Check for updates

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ARTICLE INFO

ABSTRACT

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Single waveband heritability

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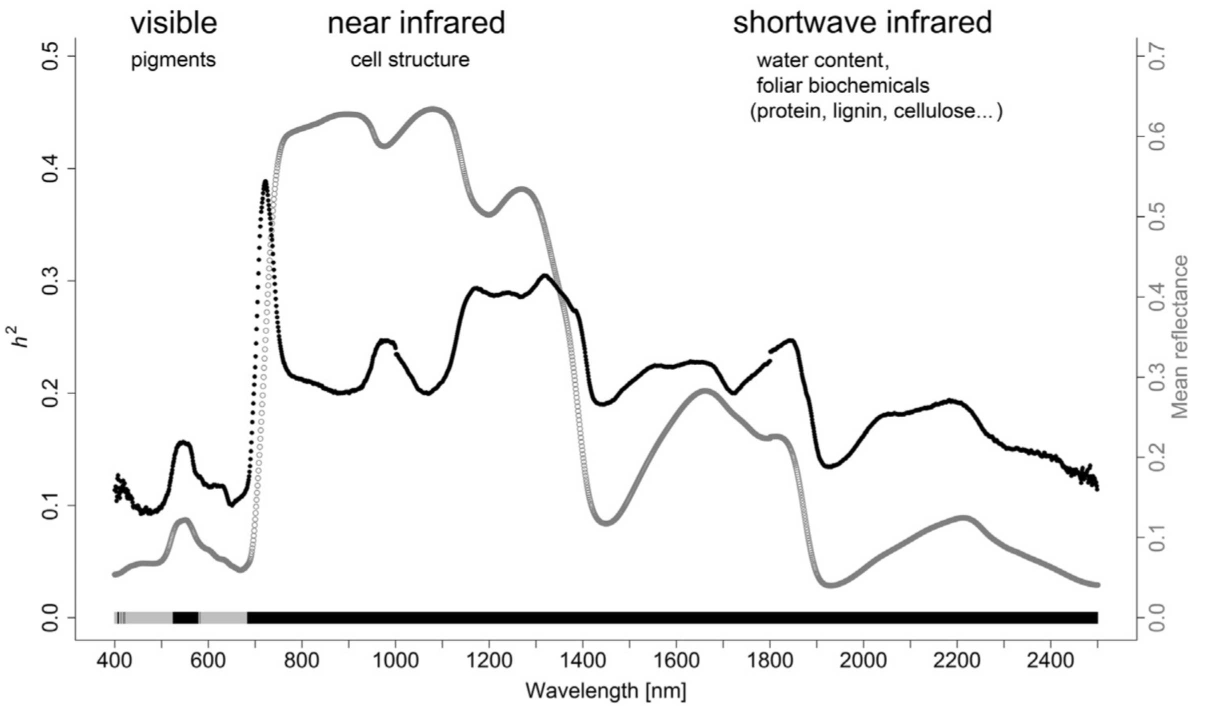
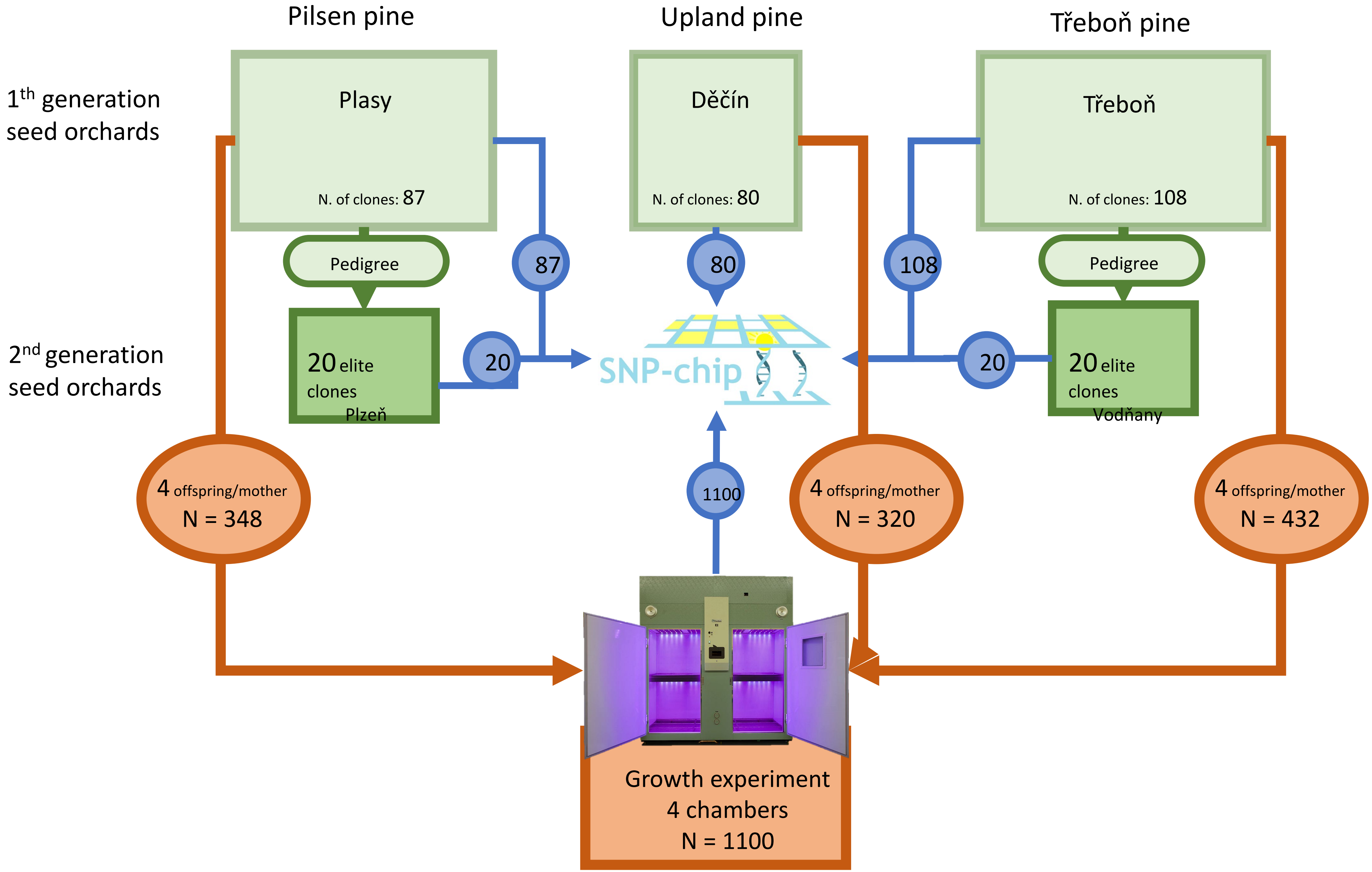


Fig. 1. Estimates of h^2 in 1 nm wavebands. Estimates of h^2 (right y-axis) for spectral reflectance at each wavelength are indicated by full black dots; region of significant h^2 at $\alpha = 0.05$ level is indicated by the black line on the x-axis; mean spectral reflectance for each wavelength from 400 nm to 2500 nm is indicated by grey circles, left y-axis. Main causal factors of foliar reflectance are indicated in the upper part of the plot.


Pilsen pine
Upland pine
Třeboň pine
1th generation seed orchards
2nd generation seed orchards
Plasy
N. of clones: 87
Děčín
N. of clones: 80
Třeboň
N. of clones: 108
Pedigree
Pedigree
87
80
108
20 elite clones
Plzeň
20
20
20 elite clones
Vodňany
SNP-chip
4 offspring/mother
N = 348
1100
4 offspring/mother
N = 320
4 offspring/mother
N = 432
Growth experiment
4 chambers
N = 1100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Walk-In FytoScope FS-

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Mimoň - the initial case study

Ř/S	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
2	30	31	32	33	34	35	36	37	38	40	41	42	43	44	45	46	48	49	50	51
3	53	54	55	57	58	59	60	62	63	64	65	66	67	68	69	70	71	73	75	76
4	77	78	79	80	81	82	83	84	85	87	88	10	11	12	13	14	15	16	17	18
5	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
6	40	41	42	43	44	45	46	48	49	50	51	53	54	55	57	58	59	60	62	63
7	64	65	66	67	68	69	70	71	73	75	76	77	78	79	80	81	82	83	84	85
8	87	88	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
9	28	29	30	31	32	33	34	35	36	37	38	40	41	42	43	44	45	46	48	49
10	50	51	53	54	55	57	58	59	60	62	63	64	65	66	67	68	69	70	71	73
11	75	76	77	78	79	80	81	82	83	84	85	87	88	10	11	12	13	14	15	16
12	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
13	37	38	40	41	42	43	44	45	46	48	49	50	51	53	54	55	57	58	59	60
14	62	63	64	65	66	67	68	69	70	71	73	75	76	77	78	79	80	81	82	83
15	84	85	87	88	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
16	26	27	28	29	30	31	32	33	34	35	36	37	38	40	41	42	43	44	45	46
17	48	49	50	51	53	54	55	57	58	59	60	62	63	64	65	66	67	68	69	70
18	71	73	75	76	77	78	79	80	81	82	83	84	85	87	88	10	11	12	13	14
19	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
20	35	36	37	38	40	41	42	43	44	45	46	48	49	50	51	53	54	55	57	58
21	59	60	62	63	64	65	66	67	68	69	70	71	73	75	76	77	78	79	80	81
22	82	83	84	85	87	88	10	11	12	13	14	15	16	17	18	19	20	21	22	23
23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	40	41	42	43	44
24	45	46	48	49	50	51	53	54	55	57	58	59	60	62	63	64	65	66	67	68
25	69	70	71	73	75	76	77	78	79	80	81	82	83	84	85	87	88	10	11	12
26	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
27	33	34	35	36	37	38	40	41	42	43	44	45	46	48	49	50	51	53	54	55
28	57	58	59	60	62	63	64	65	66	67	68	69	70	71	73	75	76	77	78	79
29	80	81	82	83	84	85	87	88	10	11	12	13	14	15	16	17	18	19	20	21
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31	43	44	45	46	48	49	50	51	53	54	55	57	58	59	60	62	63	64	65	66
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34	31	32	33	34	35	36	37	38	40	41	42	43	44	45	46	48	49	50	51	53
35	54	55	57	58	59	60	62	63	64	65	66	67	68	69	70	71	73	75	76	77
36	78	79	80	81	82	83	84	85	87	88										

- Half-sib progeny trials at three sites
- Measured annualy for growth traits
- 2019 – sampled in June and September – **hyperspectral reflectance; pigment content**

Our study revealed a relationship between pigment content and growth in a Scots pine breeding population sampled in two contrasting seasons. We identified specific wavebands and indices that may be predictive of pigment concentration and growth based on genetic correlations, providing evidence that spectral prediction models may be useful to predict traits associated with productivity.

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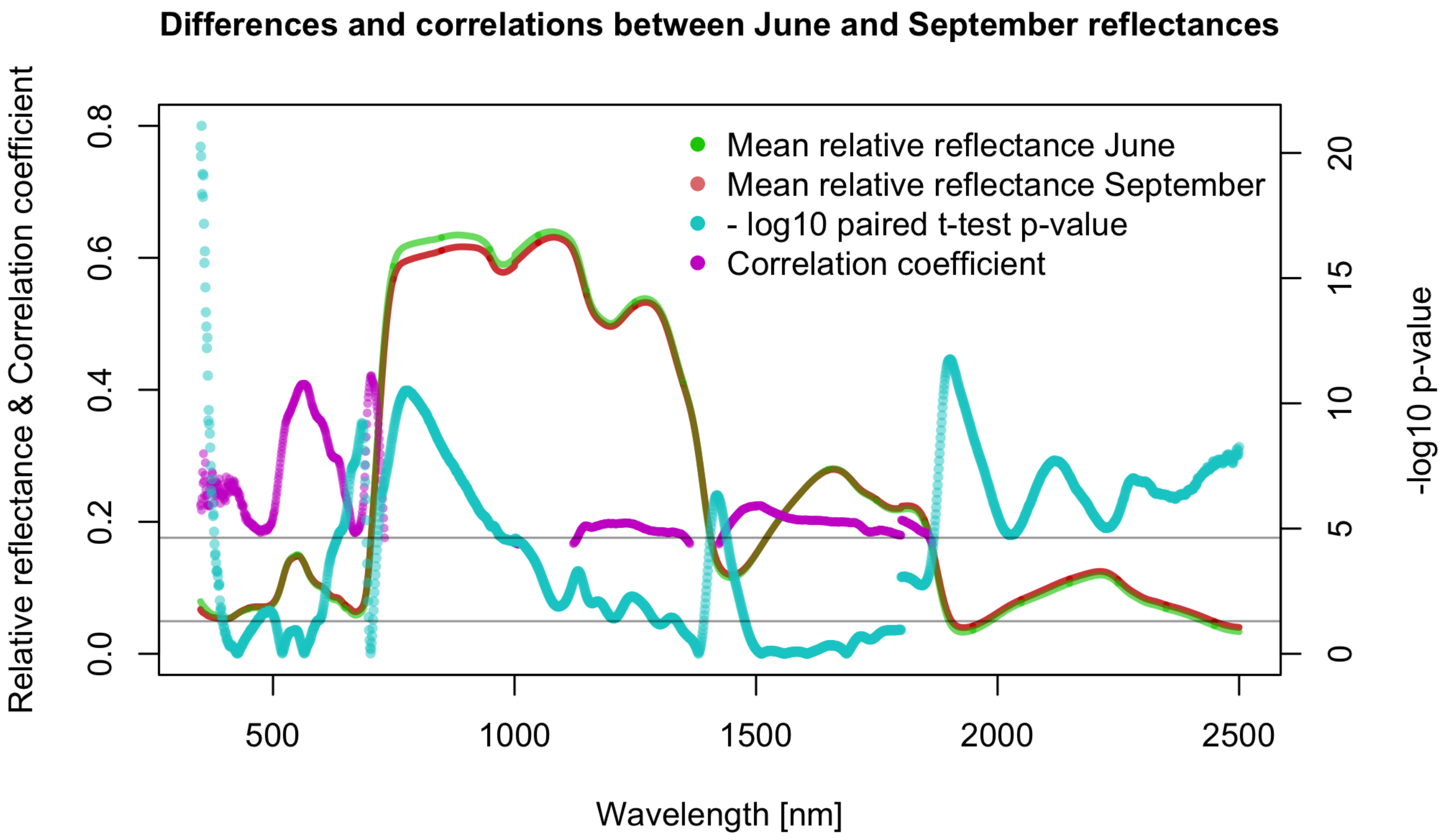

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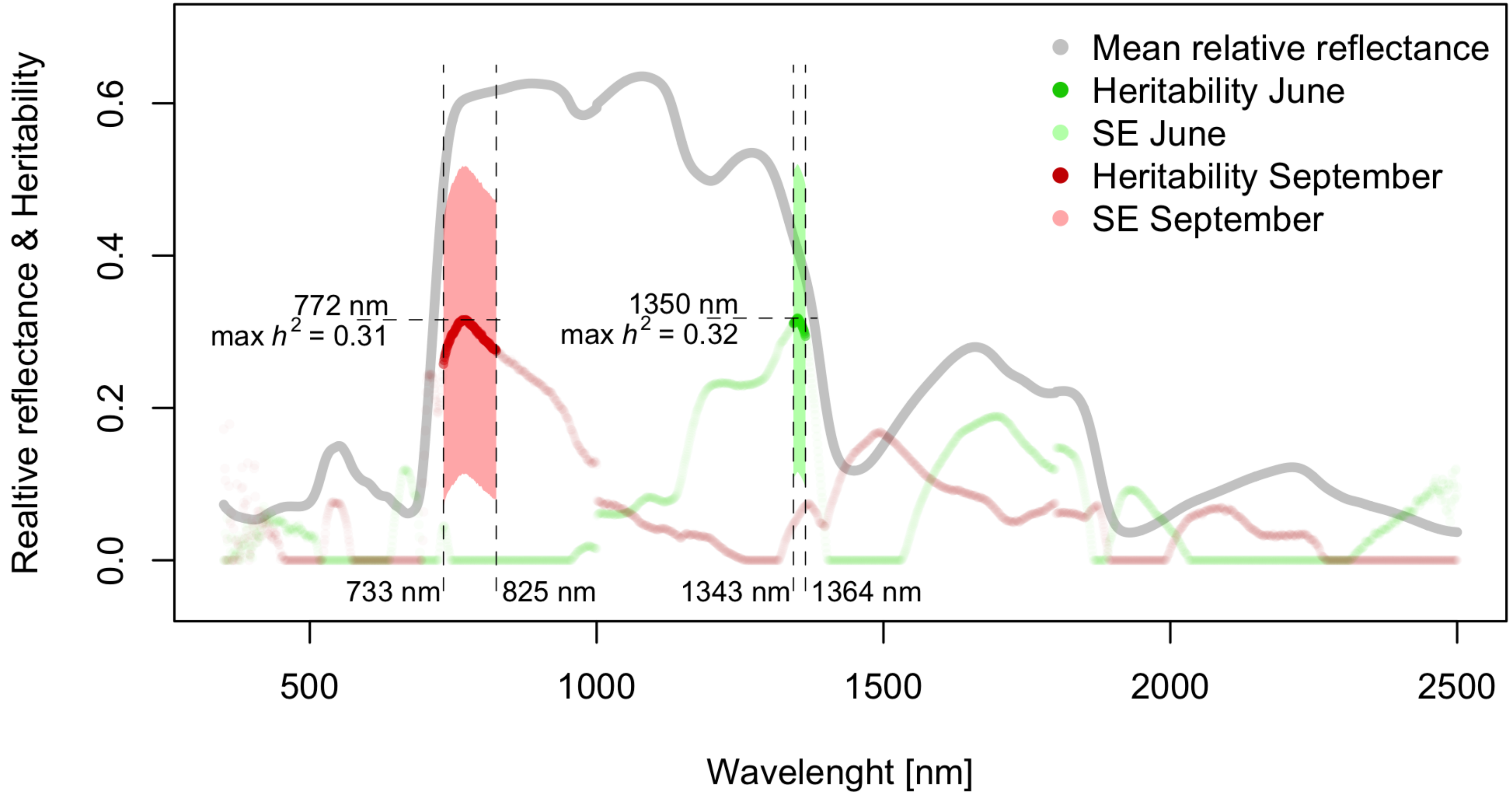


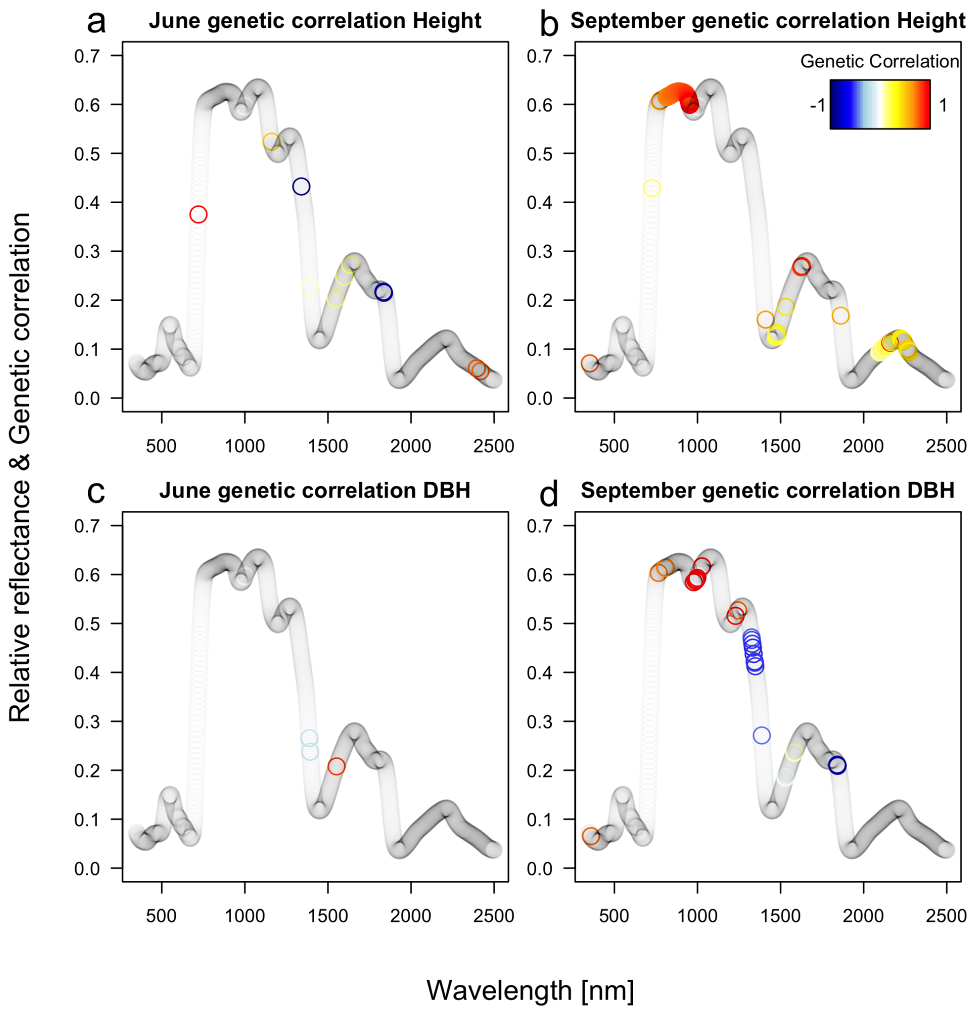
Response variable	h^2	Selected Model
Height	0.37 (0.12)	AR + polynomial
DBH	0.25 (0.11)	AR
chlorophyll-*b* September	0.31 (0.22)	AR + polynomial
WL1351 max June	0.31 (0.21)	AR + polynomial
WL772 max September	0.32 (0.20)	AR + polynomial

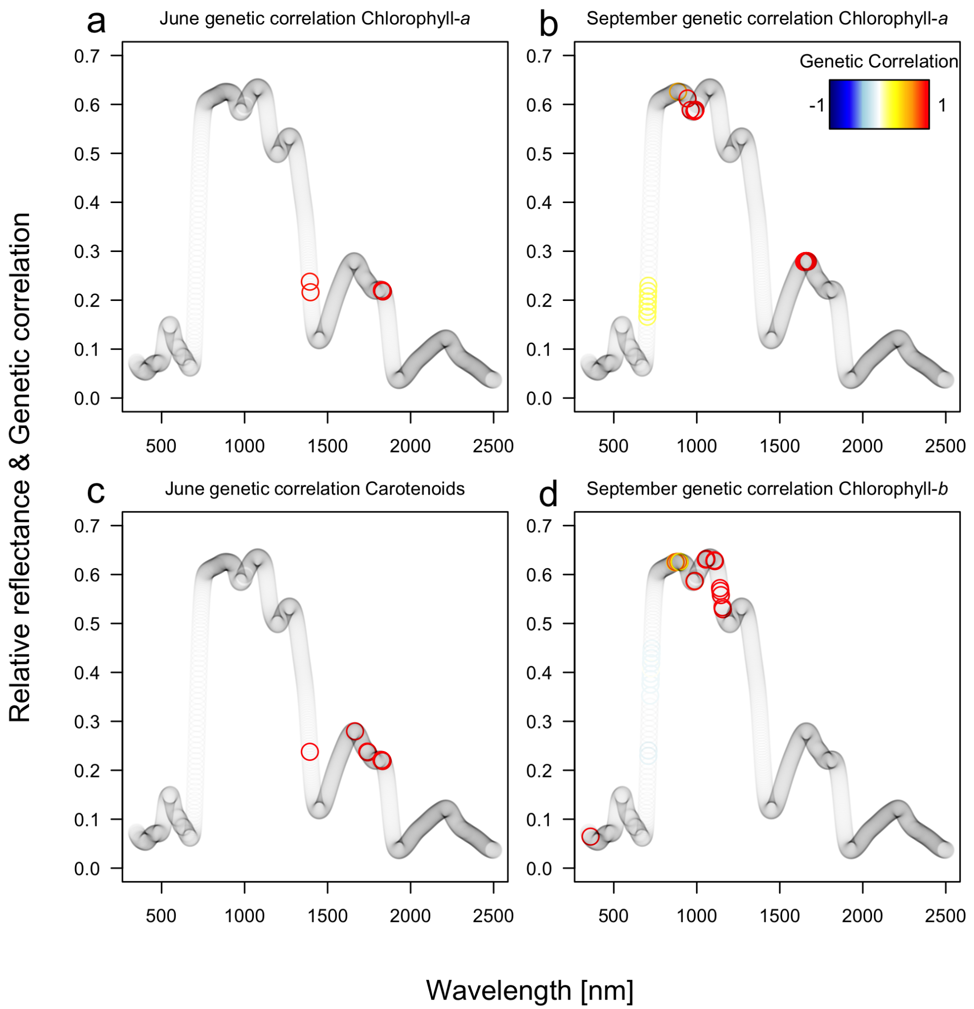
June

	WL	**max**	**SE**	**WL**	**min**	**SE**
height	1,160	0.8408	0.7640	2396	-0.2207	0.7762
DBH	1,388	-0.0195	0.6562	1552	-0.3974	0.7933
chlorophyll-*a*	1,832	0.9065	0.8185	1393	0.6693	0.9931
chlorophyll-*b*	NS	NS	NS	NS	NS	NS
carotenoids	1742	0.9921	0.6096	1665	0.7424	0.5390

September

	WL	**max**	**SE**	**WL**	**min**	**SE**
height	954	0.9743	0.5973	2101	0.1069	0.6698
DBH	994	0.9009	0.7976	1843	-0.1735	0.7611
chlorophyll-*a*	1,647	0.9096	0.9588	702	-0.9755	0.4946
chlorophyll-*b*	360	0.9727	0.6514	708	-0.9957	0.3680
carotenoids	NS	NS	NS	NS	NS	NS

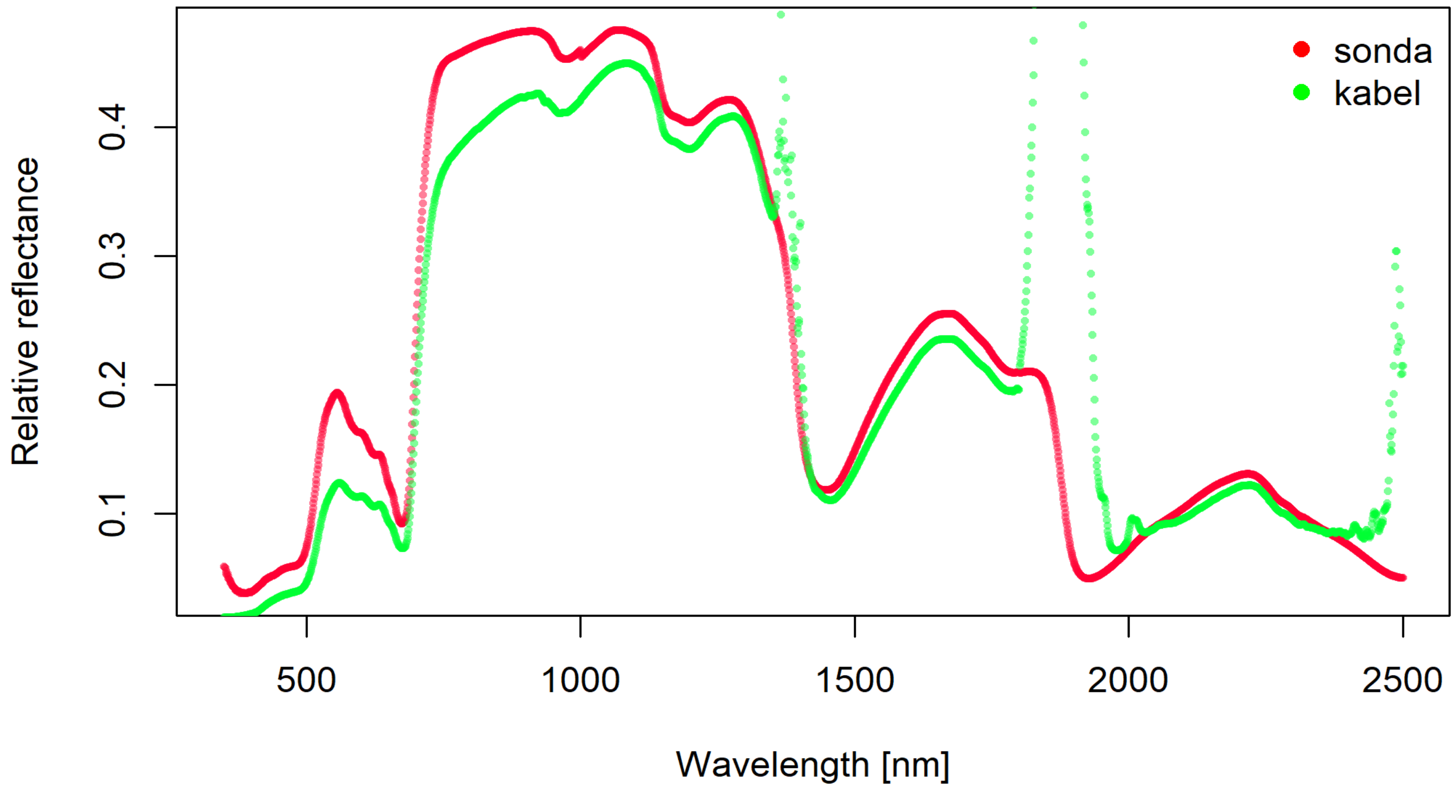

a June genetic correlation Height
b September genetic correlation Height
c June genetic correlation DBH
d September genetic correlation DBH
Genetic Correlation
-1
1
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
500
1000
1500
2000
2500
Relative reflectance & Genetic correlation
Wavelength [nm]

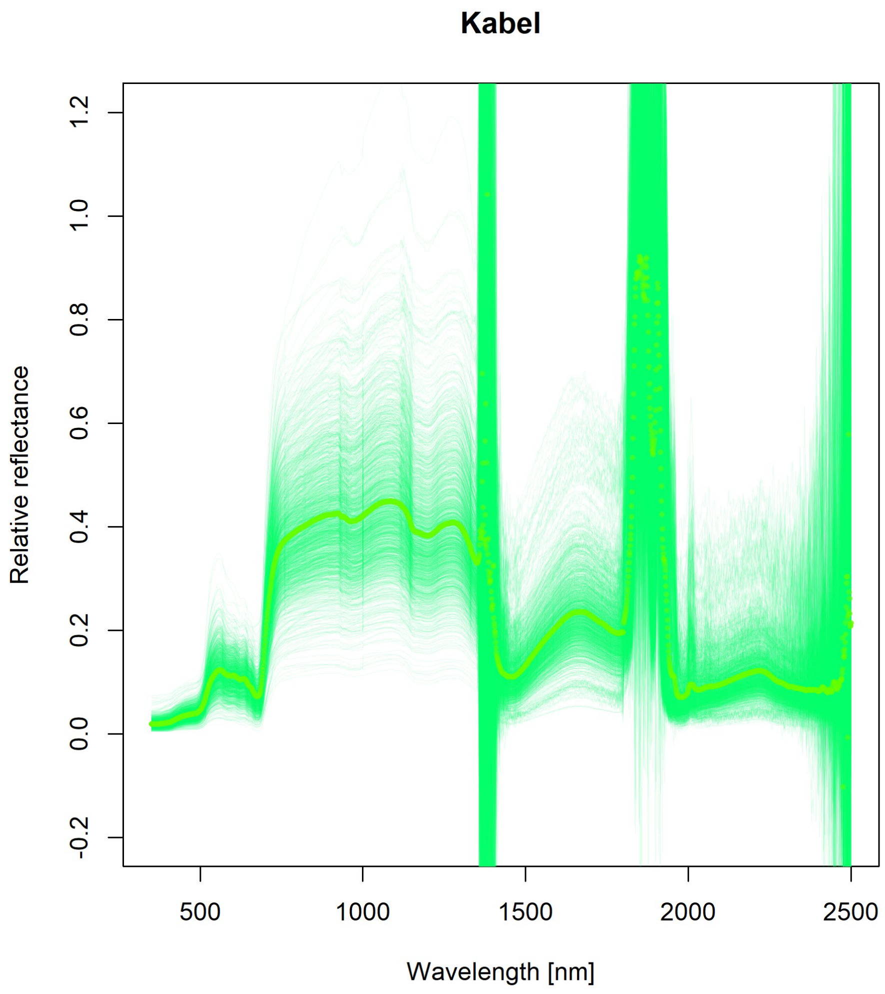

a June genetic correlation Chlorophyll-*a*
b September genetic correlation Chlorophyll-*a*
c June genetic correlation Carotenoids
d September genetic correlation Chlorophyll-*b*
Genetic Correlation
-1
1
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
500
1000
1500
2000
2500
Relative reflectance & Genetic correlation
Wavelength [nm]

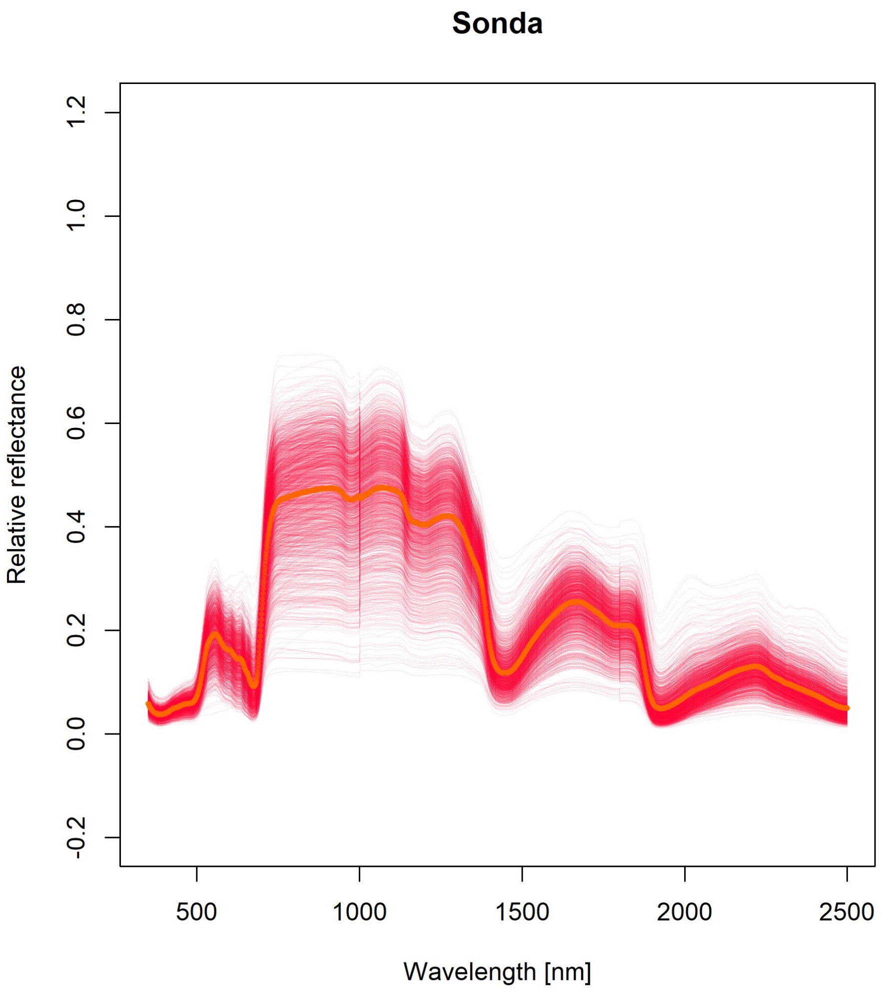
			Phenotypic correlations					Genetic correlations				
Index	*h^2*	SE	H	DBH	chl-*a*	chl-*b*	car	H	DBH	chl-*a*	chl-*b*	car
Boochs	0.369	0.213	-	-	-0.175	-0.264	-0.202	-	-	-	B	B
CAI	0.558	0.243	-	-	-0.203	-0.176	-0.136	-	-	-	**-0.667**	B
Carter	0.374	0.217	-	-	-0.245	-0.227	-0.181	B	B	B	B	B
Carter5	0.371	0.216	-	-	-0.322	-0.308	-0.296	**-0.601**	-	B	B	B
Datt	0.403	0.222	0.137	0.248	0.336	0.395	0.298	-	**0.882**	B	B	B
Datt2	0.330	0.212	0.146	0.258	0.289	0.350	0.236	-	**0.811**	B	B	B
Datt3	0.307	0.208	0.172	0.230	0.276	0.334	0.258	-	-	B	B	B
Datt4	0.297	0.208	-	-	0.280	0.349	0.296	-	-	B	B	B
Datt7	0.455	0.230	-	-	-	-0.168	-0.153	-	-	-	-	B
DD	0.339	0.214	-	0.257	0.347	0.387	0.279	**0.826**	B	B	B	-
DDn	0.319	0.211	-	-0.168	-0.285	-0.271	-0.199	**-0.864**	B	**-0.951**	-	B

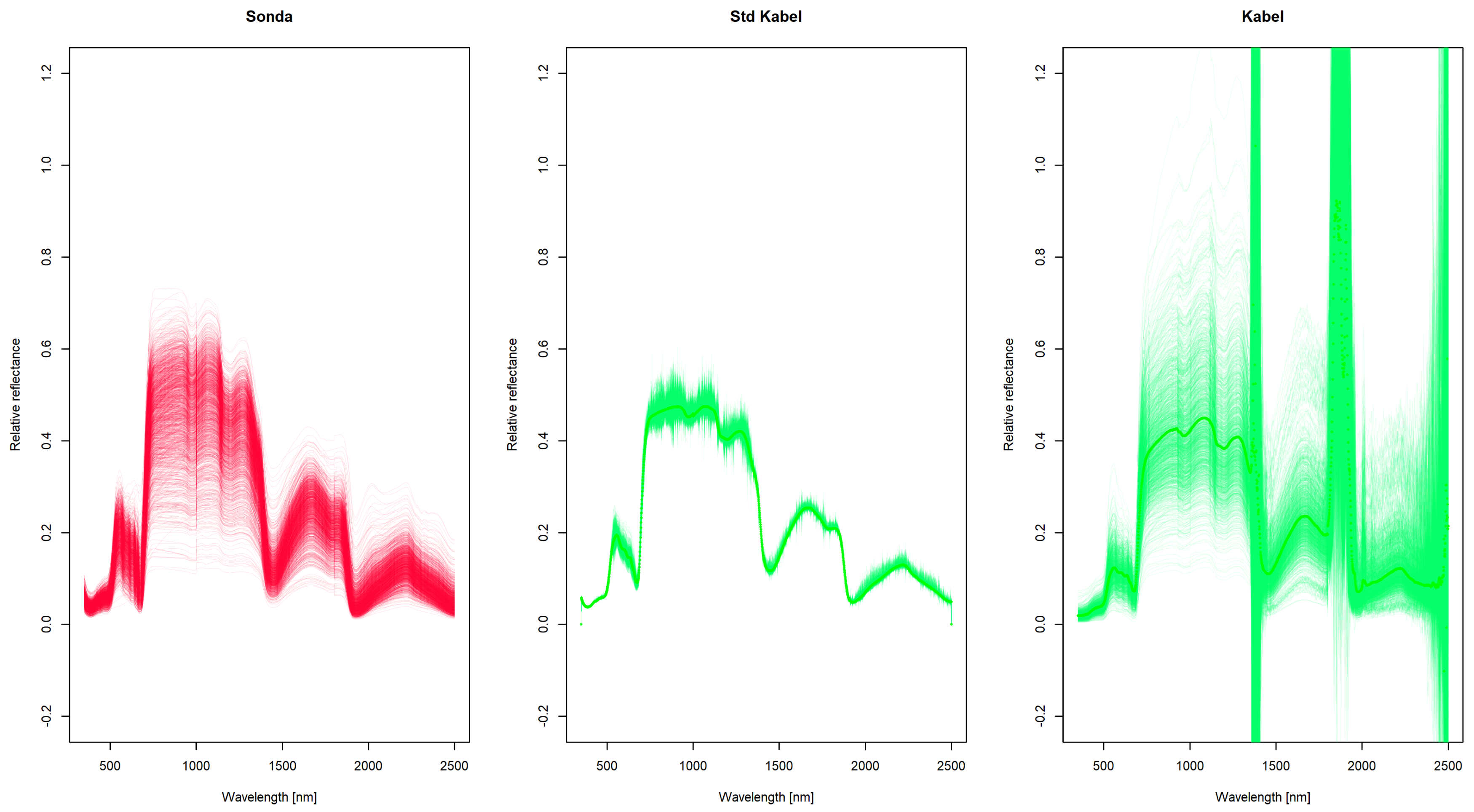
Sofronka arboretum - the first seedling avaluation

Sofronka - the first evaluation of seedlings




Kabel
Relative reflectance
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
1.2
500
1000
1500
2000
2500
Wavelength [nm]


Sonda
Relative reflectance
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
1.2
500
1000
1500
2000
2500
Wavelength [nm]


Sonda
Std Kabel
Kabel
Relative reflectance
Wavelength [nm]
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
1.2
500
1000
1500
2000
2500

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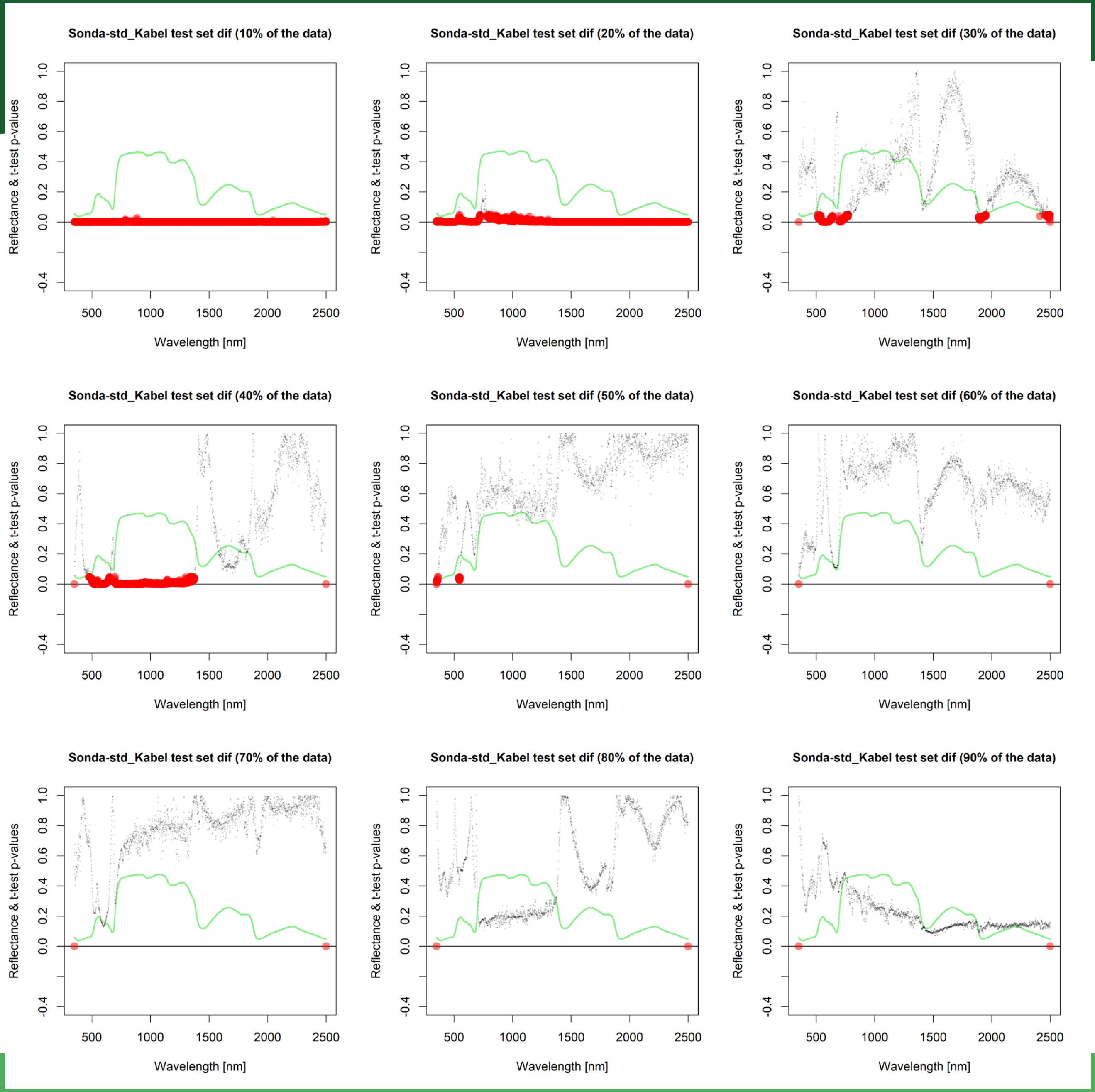

Next steps – multisite evaluation

3	17	53	39	29	15	14	21	1	33	35	42
48	30	33	23	35	6	24	45	29	28	51	17
38	54	20	4	2	27	4	38	43	12	44	41
51	24	21	31	36	42	26	31	52	32	19	25
8	25	40	52	7	10	8	13	6	39	36	30
9	18	1	50	46	28	3	53	10	47	2	11
19	13	44	43	11	45	16	9	34	22	20	49
5	49	47	26	37	22	5	23	15	46	18	48
12	14	16	34	32	41	50	27	40	54	37	7
22	14	9	54	36	20	17	33	26	4	46	9
47	27	11	52	16	40	18	40	7	50	29	38
8	7	49	43	41	13	19	47	11	35	32	13
45	28	48	34	21	29	14	52	31	48	23	12
5	17	6	12	44	23	20	44	43	36	41	10
15	53	51	4	37	30	25	15	27	45	8	54
32	50	46	39	18	38	42	2	37	6	30	5
42	3	19	35	2	26	21	49	16	28	39	1
33	25	31	24	1	10	34	53	24	3	51	22

Next steps – seed orchards as the substitute for clonal trials

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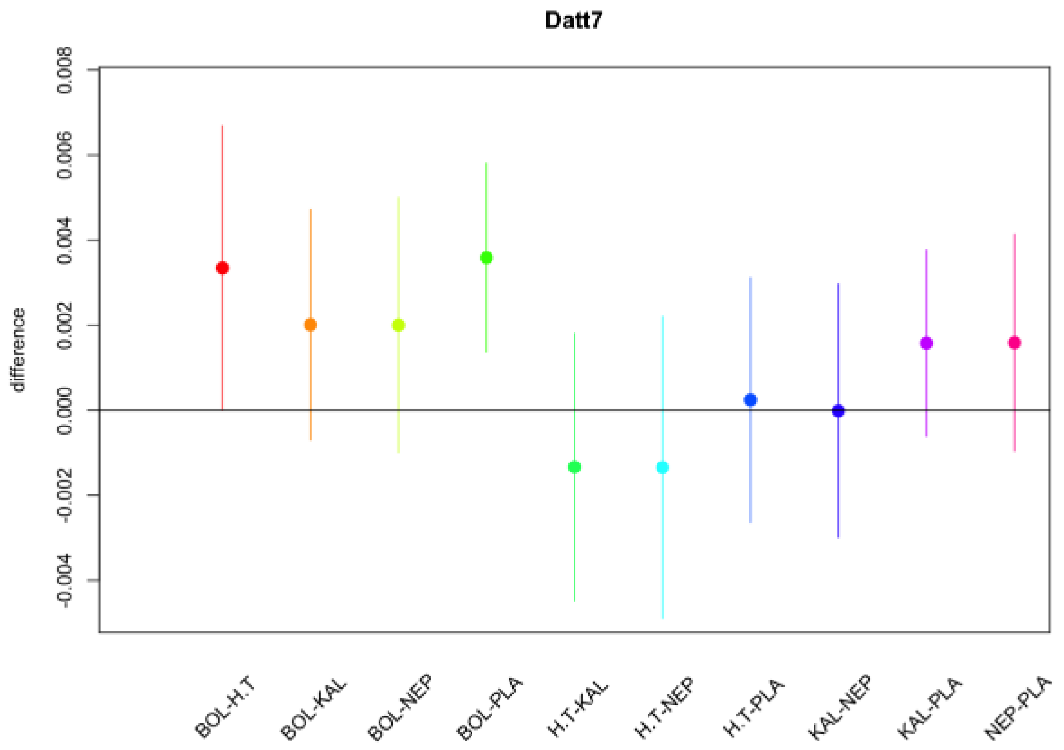
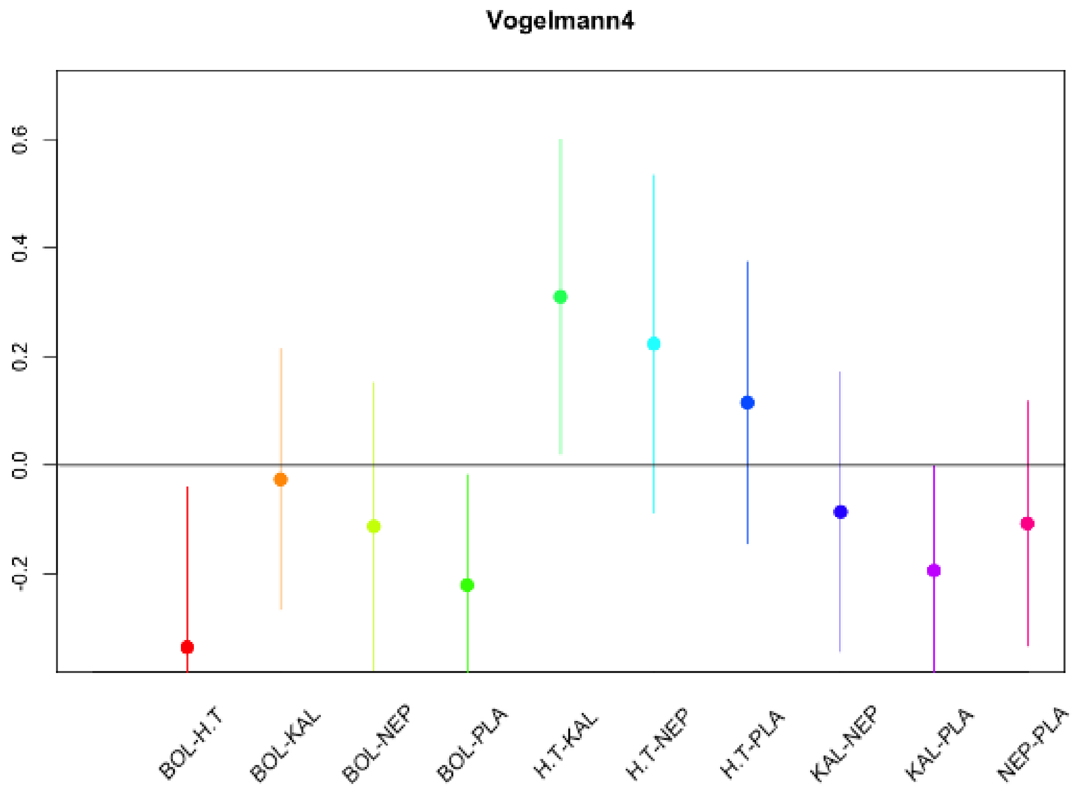
Next steps – seed orchards as the substitute for clonal trials





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