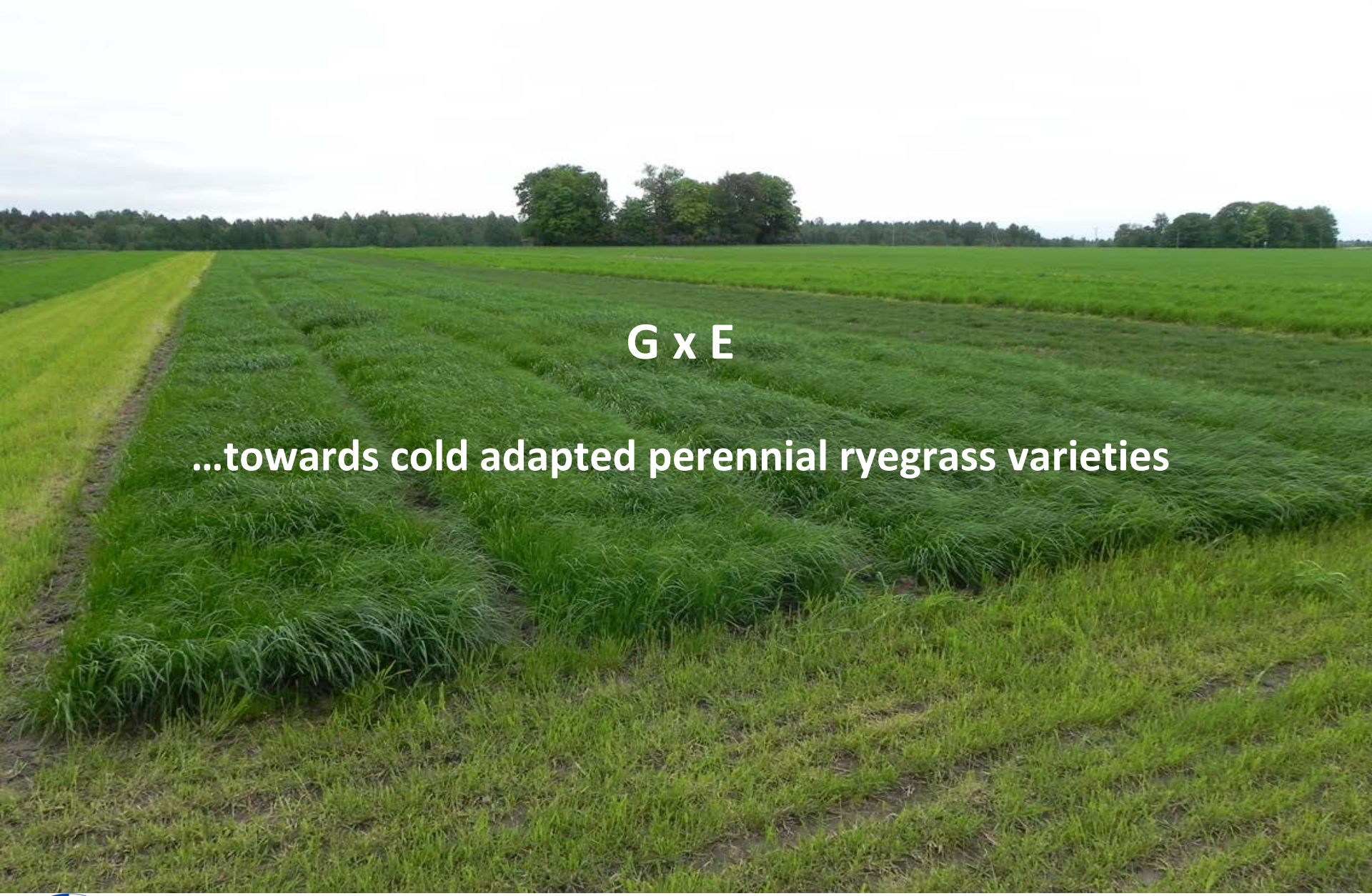
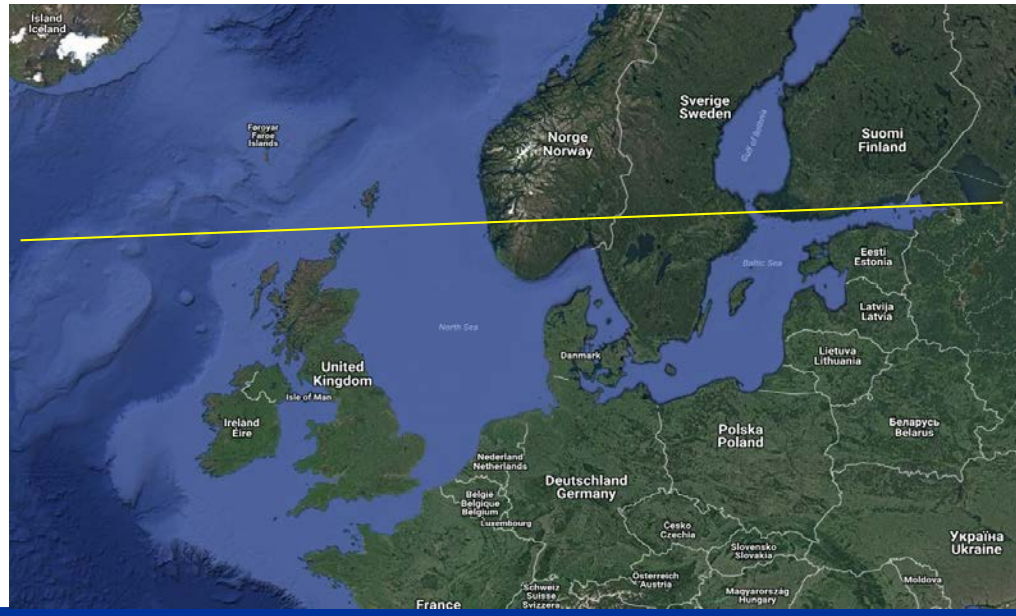

G x E
…towards cold adapted perennial ryegrass varieties

Perennial ryegrass (*Lolium perenne* L.)

- susceptibility to low-temperature pathogens
- inadequate growth cessation in autumn to allow for sufficient cold hardening and for good winter survival
- can de-harden too early with increased risk of frost injury in spring
- at present is at its adaptation border when grown north of a line Oslo to Helsinki



Perennial ryegrass (*Lolium perenne* L.)

Predicted climate changes:

- annual photoperiod-temperature regimes change with increasing temperature
- longer growth seasons
- changing precipitation patterns

Need for new types of cultivars!

The available germplasms and active breeding populations – are they sufficiently broad?

Public Private Partnership (PPP) for pre-breeding in perennial ryegrass

Norwegian University of Life Sciences

Agricultural University of Iceland

AARHUS UNIVERSITY

Jõgeva Plant Breeding Institute
Jõgeva Sordiaretuse Instituut

DLF SEEDS & SCIENCE

Lantmännen

Boreal ETUSIVU

Graminor

Public Private Partnership (PPP) for pre-breeding in perennial ryegrass

Aims:

- identify and select new plant material for development of cultivars with suitable adaptation to future climates

- recombine exotic material with existing germplasm to create new genetic resources

PPP for pre-breeding in perennial ryegrass

Country	Wild	Cultivars/ breeding lines	Unknown	Total
Austria		1	1	2
Belgium		1		1
Canada			1	1
Czech Rep	9	1	4	14
Denmark		28		28
Estonia	2	7		9
Finland	2	3		5
France	33	5		38
Germany	32	7		39
Holland		6		6
Hungary	12	2	1	15
Italy	6			6
Japan		3		3
Kirgizstan		1		1
Latvia	2	16	2	20
Lithuania	16	15		31
Moldova	1			1
Norway	5	13		18
Poland	24	11	7	42
Romania	15			15
Russia	2	7	3	12
Switzerland	9	3		12
Slovakia	2	1		3
Slovenia		1		1
Sweden	9	17	2	28
Turkey	9			9
UK	5	6		11
Ukraine	4	2		6
USA		2	1	3
Total	199	159	22	380

PPP for pre-breeding in perennial ryegrass

Country	Wild	Cultivars/ breeding lines	Unknown	Total
Austria		1	1	2
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Canada			1	1
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Denmark		28		28
Estonia	2	7		9
Finland	2	3		5
France	33	5		38
Germany	32	7		39
Holland		6		6
Hungary	12	2	1	15
Italy	6			6
Japan		3		3
Kirgizstan		1		1
Latvia	2	16	2	20
Lithuania	16	15		31
Moldova	1			1
Norway	5	13		18
Poland	24	11	7	42
Romania	15			15
Russia	2	7	3	12
Switzerland	9	3		12
Slovakia	2	1		3
Slovenia		1		1
Sweden	9	17	2	28
Turkey	9			9
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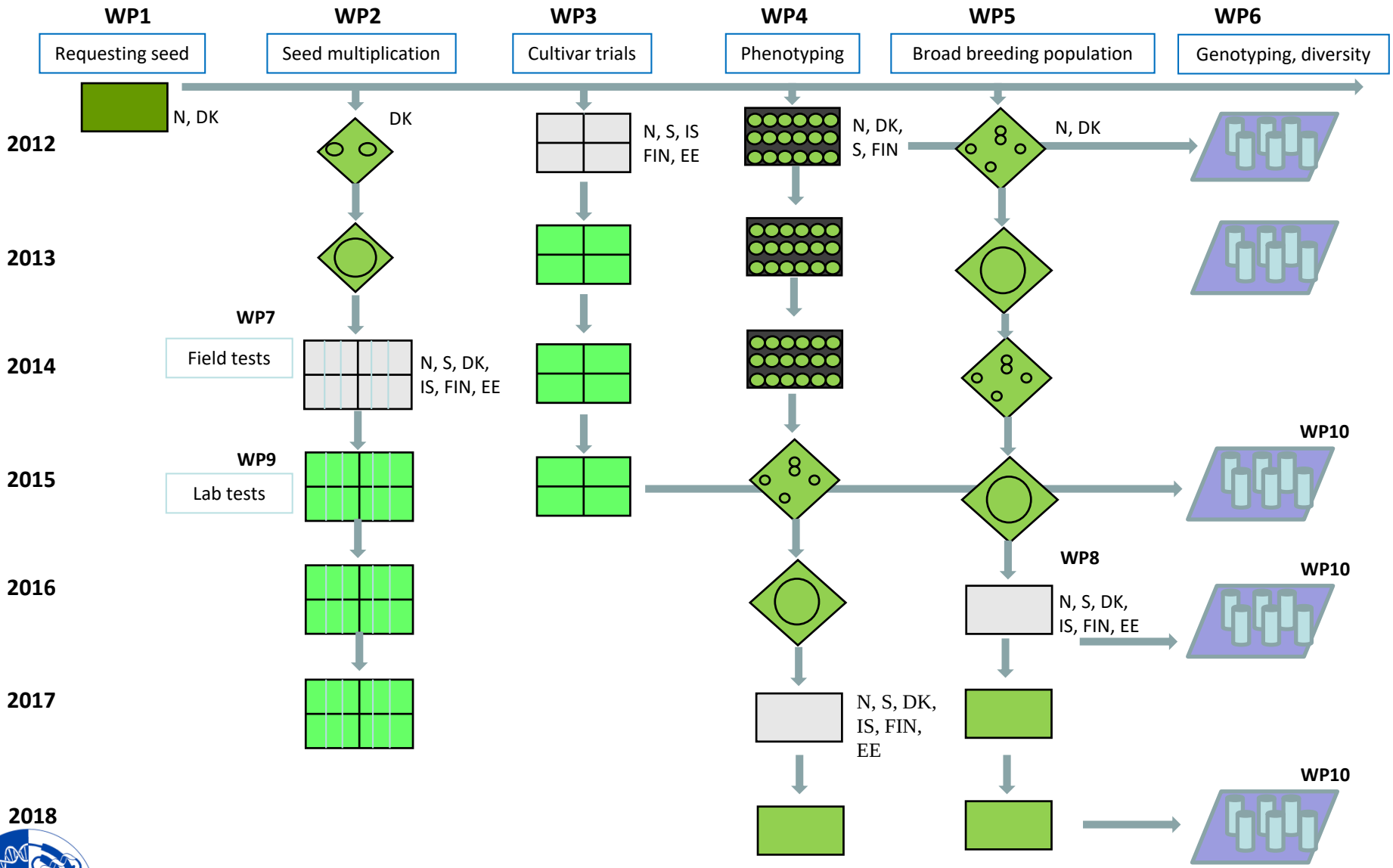
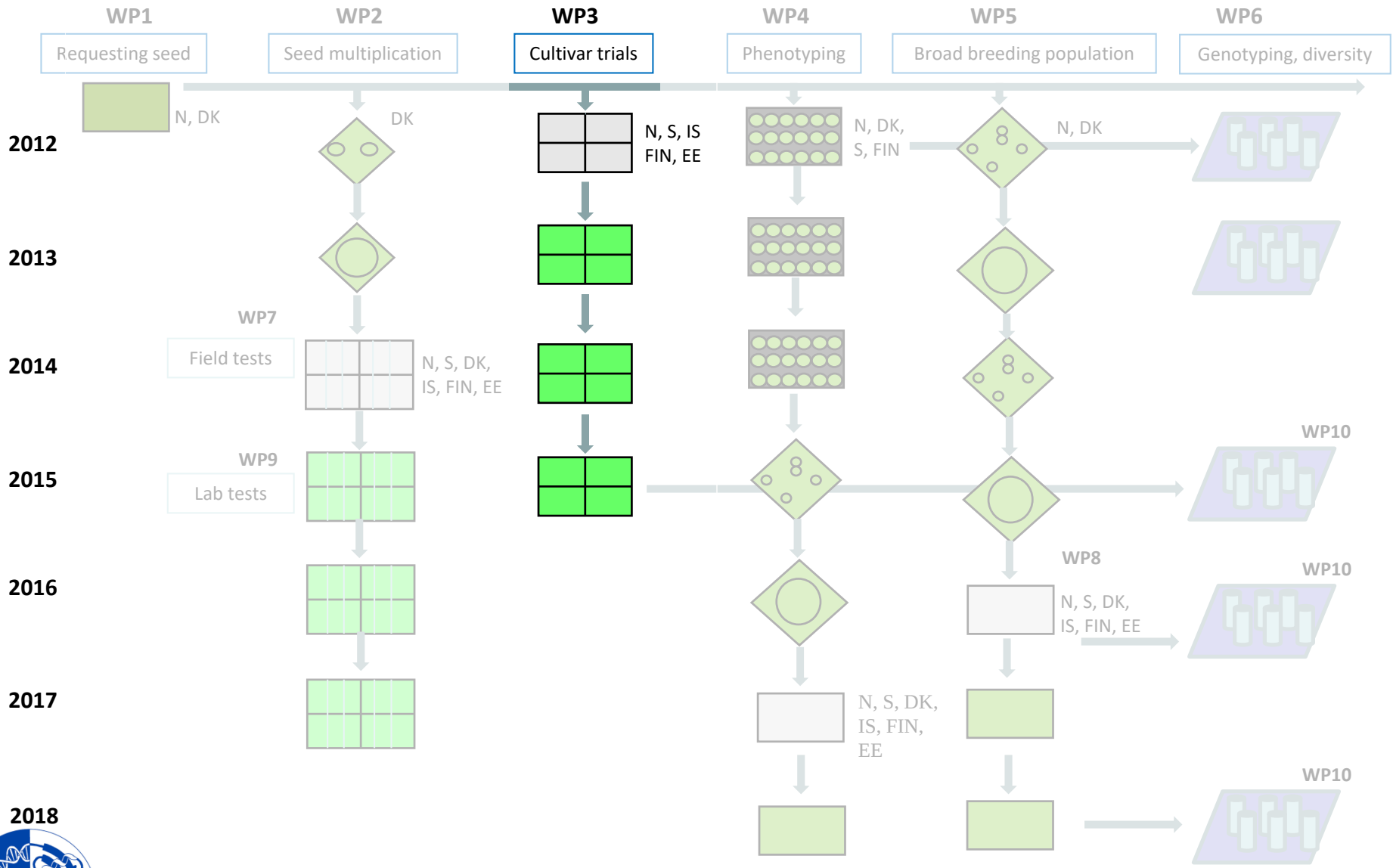
Total	199	159	22	380

PPP for pre-breeding in perennial ryegrass



PPP for pre-breeding in perennial ryegrass



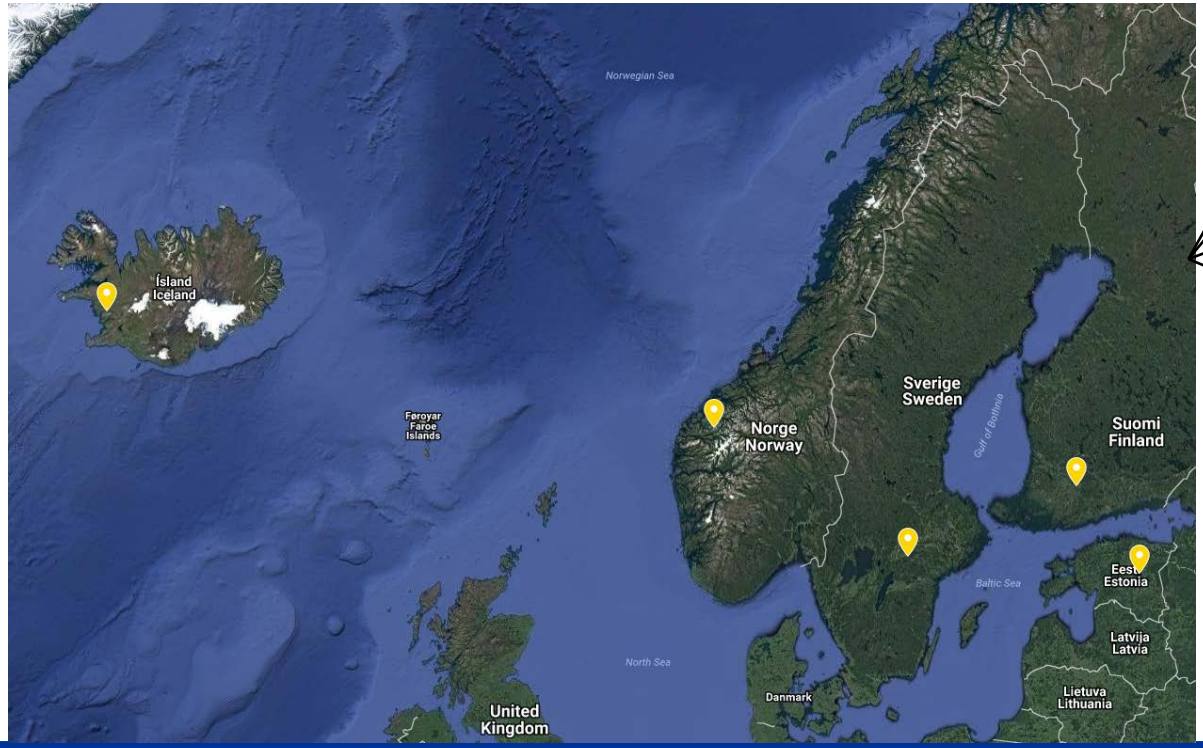
Origin of the 22 selected varieties

ID Variety	Ploidy	Origin
Norlea	2n	Canada
Premium	2n	Denmark
Raidi	2n	Estonia
Raite	4n	Estonia
Riikka	2n	Finland
Ivana	2n	Germany
Pionero	2n,4n	Germany
Arvicola	4n	Germany
Spidola	4n	Latvia
Fagerlin	2n	Norway
Falk	2n	Norway
Einar	4n	Norway
Trygve	4n	Norway
Fjaler	4n	Norway
SW Irene	2n	Sweden
SW Birger	4n	Sweden
SW Leia	4n	Sweden
SW Svea	2n	Sweden
SW Gunne	2n	Sweden
Arvella	2n	Switzerland
Salamandra	4n	Switzerland
Cavia	2n	Switzerland

Test of the 22 selected varieties

Five Nordic locations

Test site	Longitude	Latitude	Elevation (m)	N fert 2013 (kg/ha)	P fert 2013 (kg/ha)	K fert 2013 (kg/ha)	N fert 2014 (kg/ha)	P fert 2014 (kg/ha)	K fert 2014 (kg/ha)	Soil type	Herbicide treatment
Estonia	26°24'E	58°45'N	68	270	33	129	190	24	90	Calcaric Luvisol	Mustang
Norway	11°12'E	60°45'N	187	212	35	177	212	35	177	Haplic Phaeozem	
Finland	43°0'E	58°20'N	95	240	13	65	240	13	65	Clay	ArianeS
Iceland	21°45'V	64°9'N	35	150	65	122	150	150	150	Gleyic Andosol	
Sweden	17°43'E	63°8'N	27	130	11	36	190	11	36	Silt Loam	



total yield
first cut yield
spring cover
fall cover

Test of the 22 selected varieties

	Estonia		Norway		Finland		Iceland		Sweden	
sowing	15-05-2012		21-06-2012		30-08-2012		07-06-2012		06-07-2012	
autumn cutting after sowing	23-10-2012		12-09-2012				15-08-2012			
harvest height	7 cm		5 cm		8 cm		5 cm		5 cm	
Year 1 (2013)	Date	No of days	Date	No of days	Date	No of days	Date	No of days	Date	No of days
1st cut	03-06-2013	154	20-06-2013	171	15-06-2013	166	04-07-2013	185	24-06-2013	175
2nd cut	02-07-2013	183	19-07-2013	200	09-07-2013	190	12-08-2013	224	23-07-2013	204
3rd cut	09-08-2013	221	11-09-2013	254	12-09-2013	255			27-08-2013	239
4th cut	11-10-2013	284								
Year 2 (2014)	Date	No of days	Date	No of days	Date	No of days	Date	No of days	Date	No of days
1st cut	10-06-2014	161	06-06-2014	157	11-06-2014	162	20-06-2014	171	15-06-2014	166
2nd cut	18-07-2014	199	17-07-2014	198	17-07-2014	198	14-08-2014	226	23-07-2014	204
3rd cut	01-09-2014	244	15-09-2014	258	16-09-2014	259			27-08-2014	239
4th cut	17-10-2014	290								
Year 3 (2015)										
1st cut	04-06-2015	155	19-06-2015	170	17-06-2015	168	30-06-2015	181	18-06-2015	169
2nd cut	06-07-2015	187	24-07-2015	206	03-08-2015	216	25-08-2015	137	24-07-2015	205
3rd cut	04-09-2015	248	07-09-2015	250	11-09-2015	254			25-08-2015	237
4th cut										

Test of the 22 selected varieties

1,513,481 SNPs

MAF > 1
0.1 < genotype frequency < 0.9
5 < locus coverage < 100

276,146 SNPs

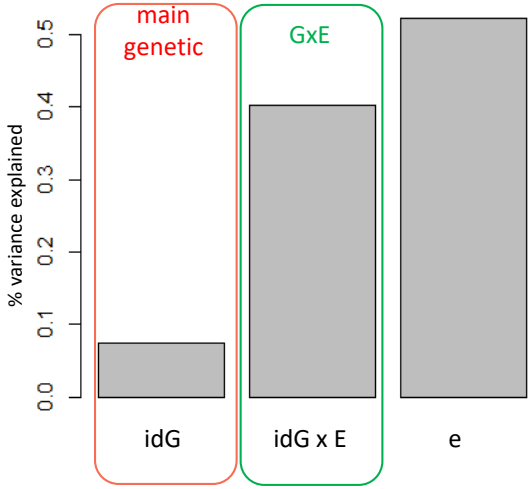
2.494% missing values

Genetic feature	Number of SNPs
3utr	5,664
5utr	6,040
exons	61,741
introns	19,201
cds	51,959
genes	79,313
genes + 500bp	90,026
genes + 1kb	109,991
genes + 2kb	109,991
cold DE genes *Falster*	11,970
cold DE genes *Veyo*	6,634
cold & drought DE genes *Falster*	14,147
cold & drought DE genes *Veyo*	26,936
vernalization flowering DE scaffolds	72,775
snow mold DE scaffolds	89,341
drought DE scaffolds	77,086

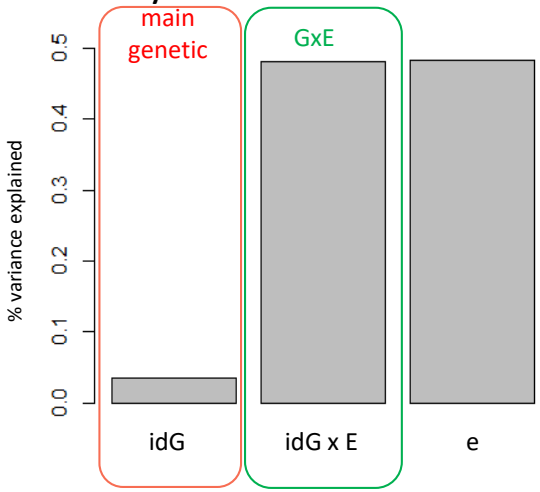
Test of the 22 selected varieties

$$y = location\_year\_block + structure + ploidy + idG + (idG \times E) + e$$

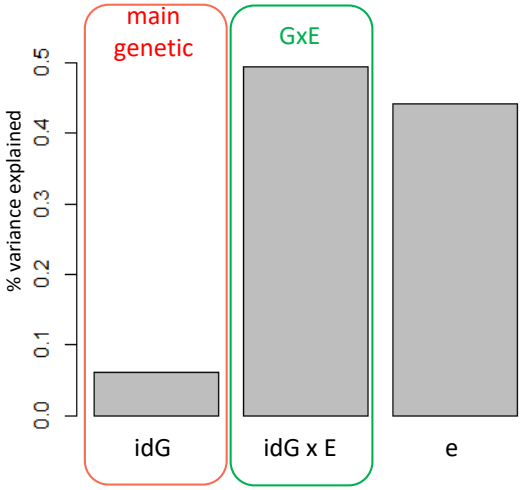
Total yield



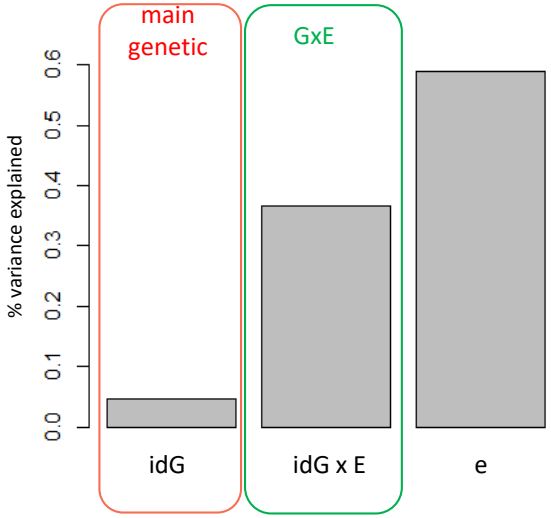
First cut yield



Spring cover



Fall cover



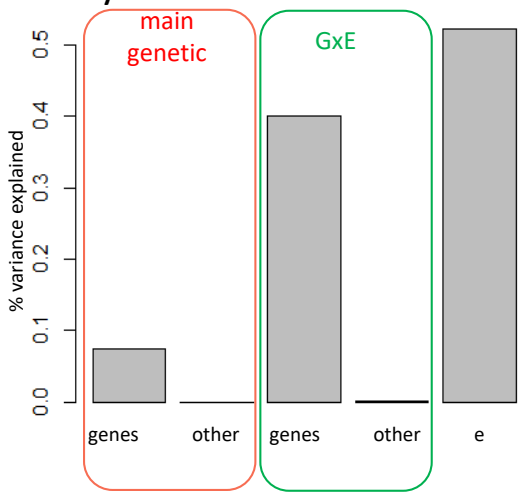
Test of the 22 selected varieties

$$idG = \underbrace{idGf}_{\text{genetic feature}} + \underbrace{idGnf}_{\text{non-feature}}$$

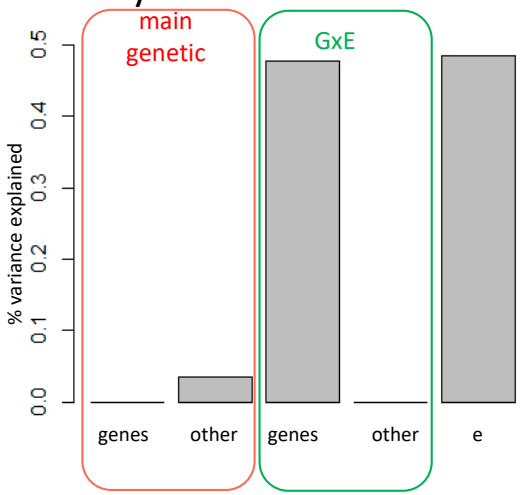
$$y = location\_year\_block + structure + ploidy + \underbrace{idGf + idGnf}_{idG} + \underbrace{(idGf \times E) + (idGnf \times E)}_{idG \times E} + e$$

Genetic feature: genic regions *(Byrne et al., 2015)*

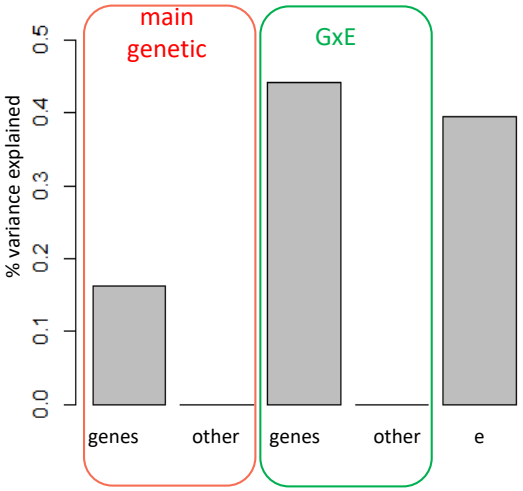
Total yield



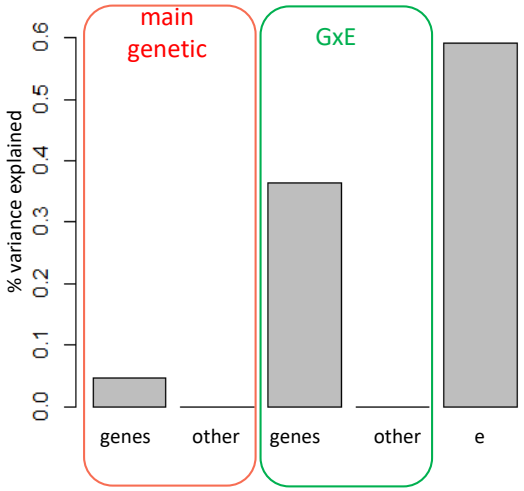
First cut yield



Spring cover

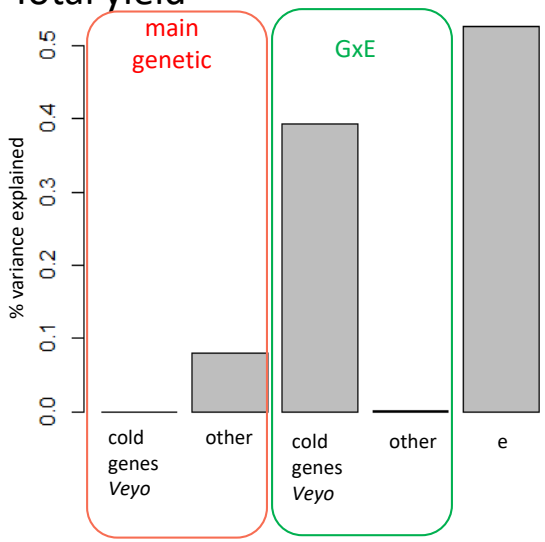


Fall cover

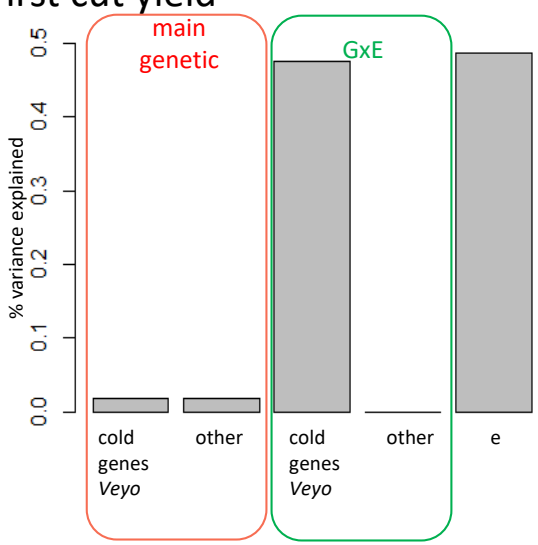


Genetic feature: cold genes *(Abeynayake et al., 2015)*

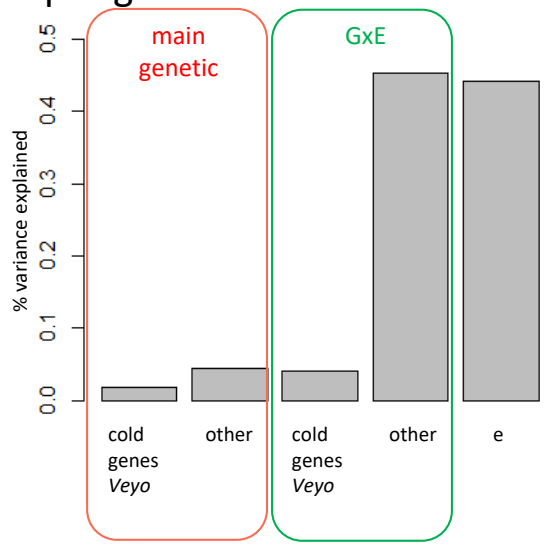
Total yield



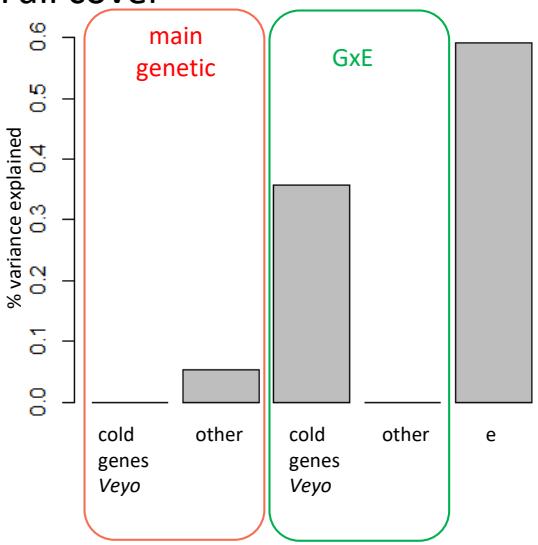
First cut yield



Spring cover

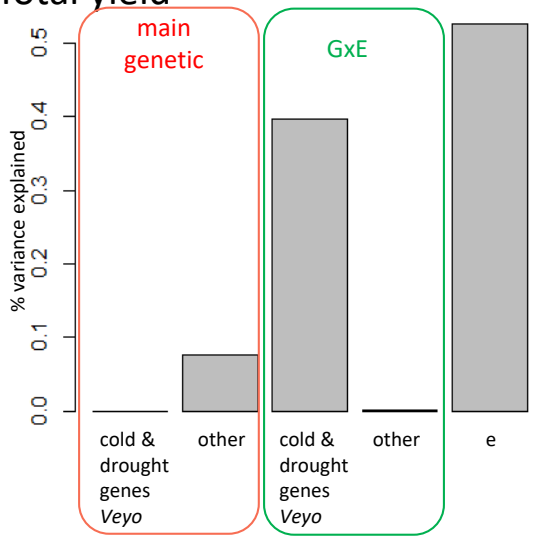


Fall cover

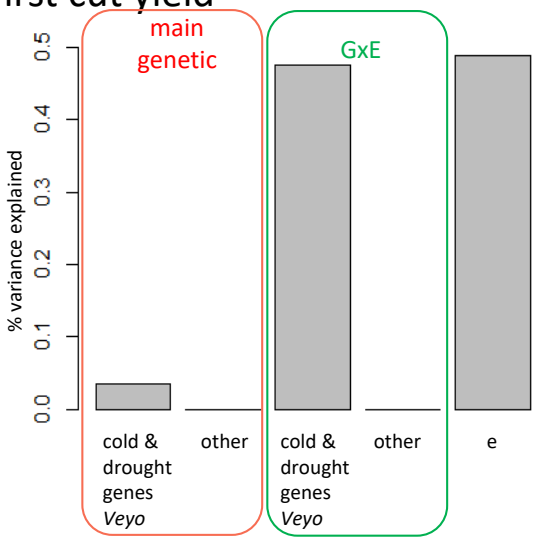


Genetic feature: cold and drought genes *(Abeynayake et al., 2015; Leyva et al., 2017)*

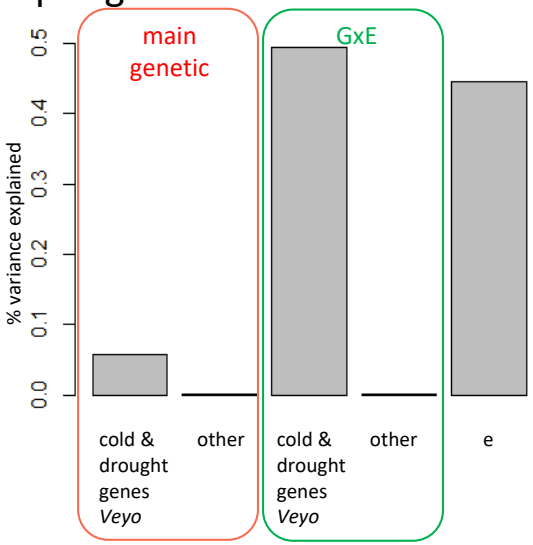
Total yield



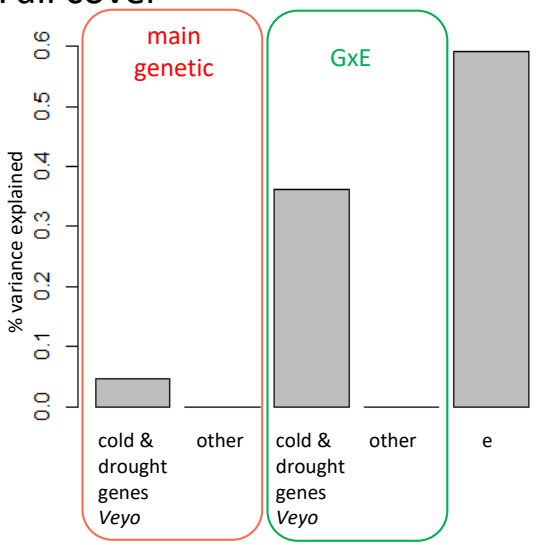
First cut yield



Spring cover

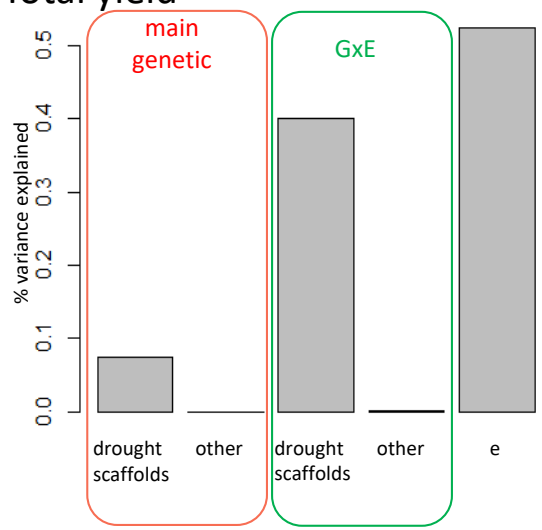


Fall cover

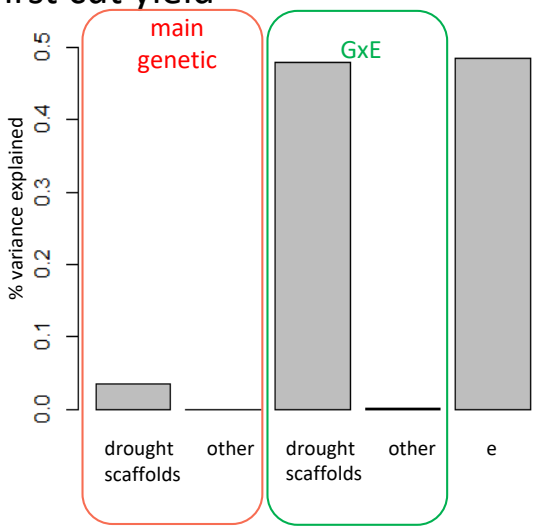


Genetic feature: drought scaffolds *(Leyva et al., 2017; Byrne et al., 2015)*

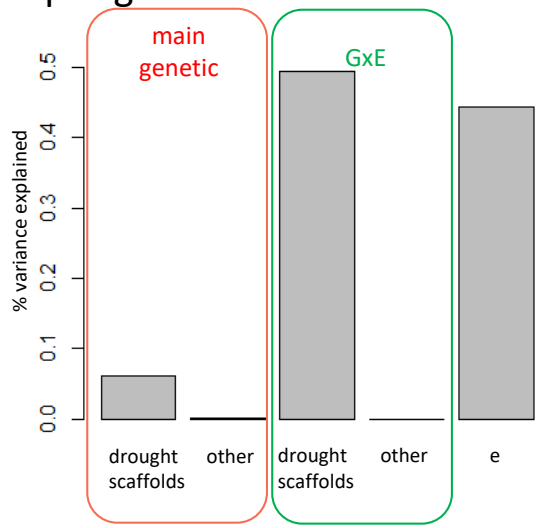
Total yield



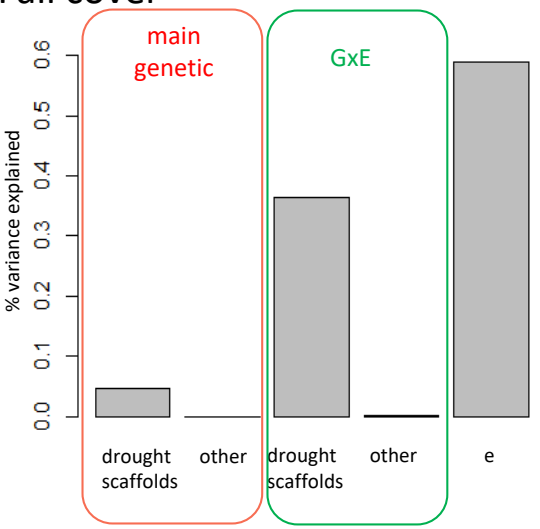
First cut yield



Spring cover

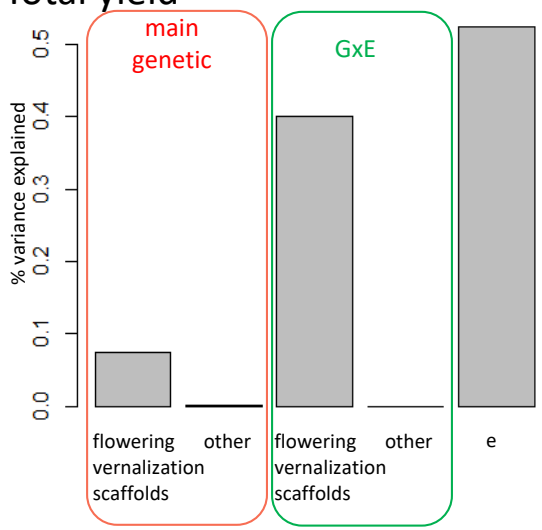


Fall cover

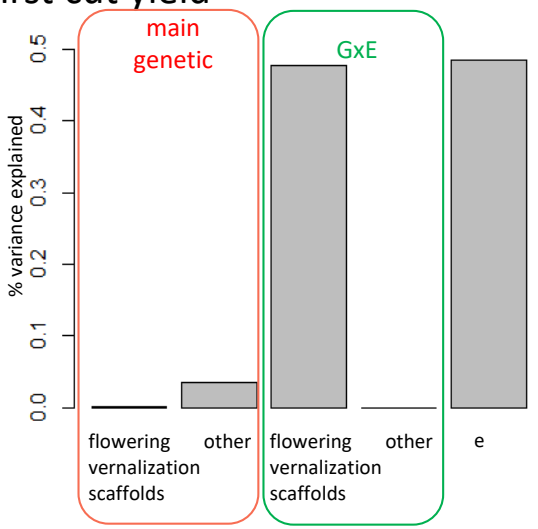


Genetic feature: vernalization and induction of flowering scaffolds *(Paina et al., 2014; Byrne et al., 2015)*

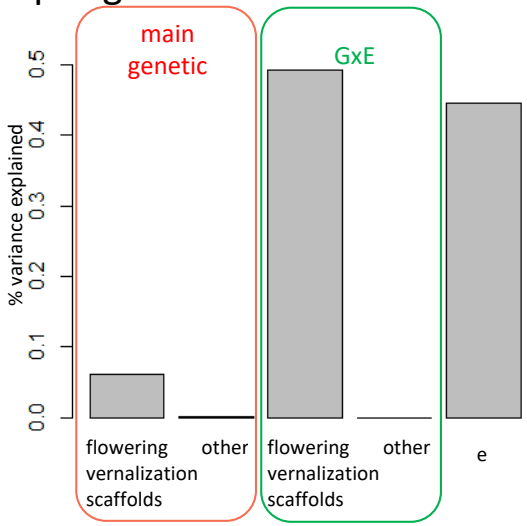
Total yield



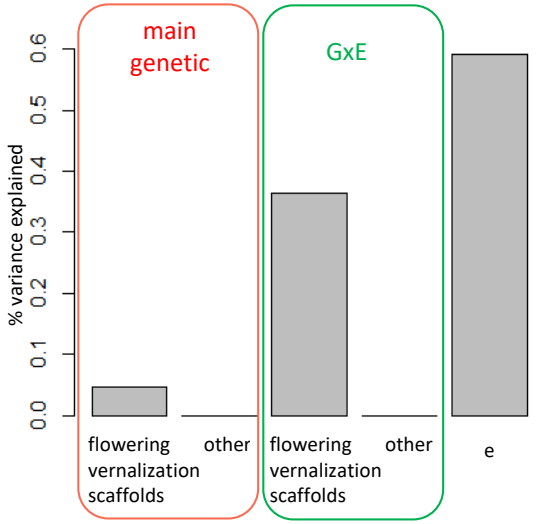
First cut yield



Spring cover

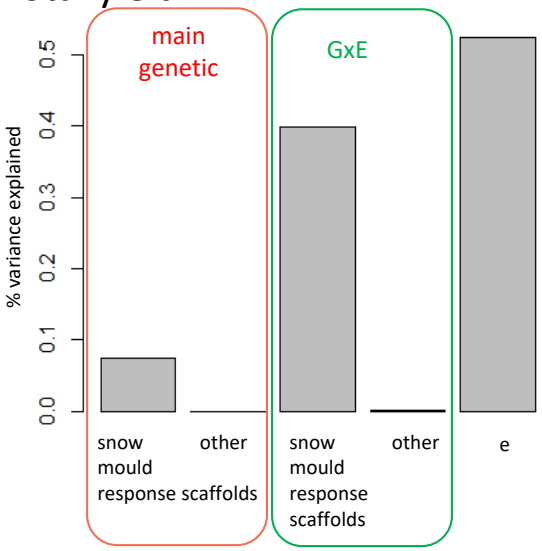


Fall cover

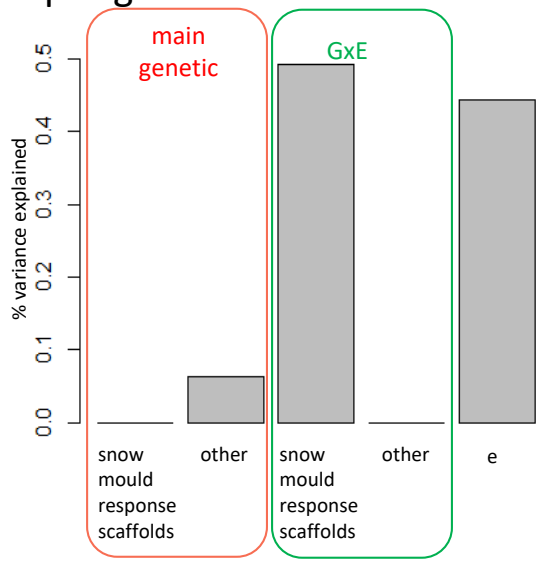


Genetic feature: snow mould response scaffolds *(Kovi et al., 2016; Byrne et al., 2015)*

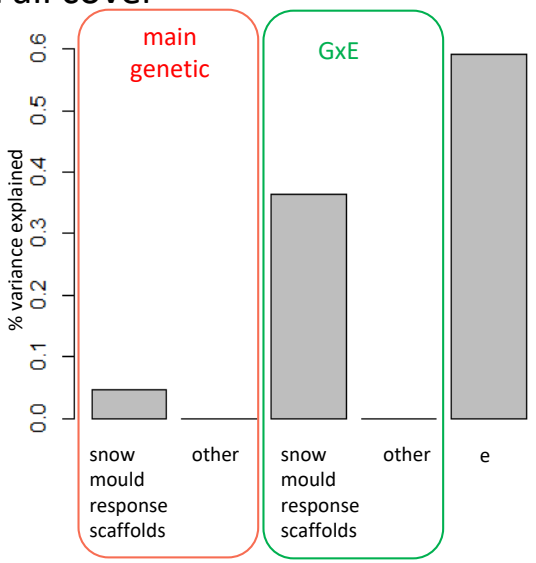
Total yield



Spring cover



Fall cover



Acknowledgements

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Thank you