How can precision agriculture techniques contribute to the breeding for low grain cadmium content in cereals?

Therése Bengtsson & Mats Söderström, SLU

NORDIC FIELD TRIAL NETWORK

SLU Grogrund funded project, 2022-2024

Aim: To identify genomic regions in **winter wheat** and **oat** associated with low grain-Cd content, **develop diagnostic markers and prediction models for selection of low-Cd lines** for implementation at Lantmännen

Partners:

Department of Plant Breeding, Soil and Environment,

SLU Fältforsk and Lantmännen

Collaboration:

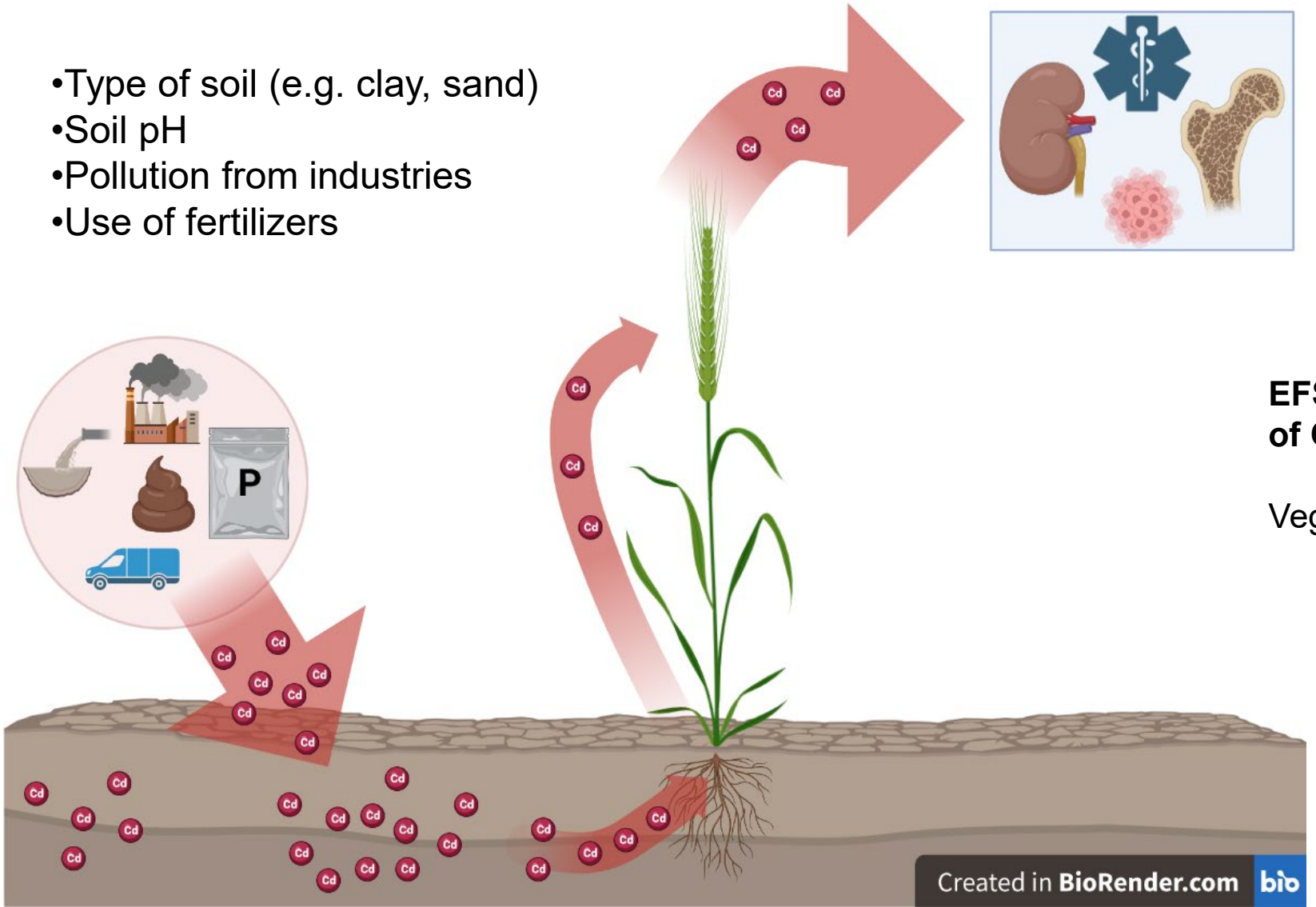
Lucia Guiterrez /Maria Inés Berro Rovella Uni.

Wisconsin-Madison

Increased accuracy and reduced time and cost!

Cadmium's journey to your body

- Type of soil (e.g. clay, sand)
- Soil pH
- Pollution from industries
- Use of fertilizers



Kidney damage,
bone damage and cancer

EFSA tolerable weekly intake→ 2.5 µg of Cd/kg body weight/week

Vegetarians and children can exceed!

Illustration: Rami Apuli

Cadmium in our crops

High levels!
Spinach, sunflower seeds, flaxseeds, algae, seaweed, and cocoa beans

Declining Cd levels

14%

Vegetables

22%

Root vegetables

40%

Cereals

In non-smokers→ dietary exposure is the highest

Declining Cd level

Rice and durum wheat > bread wheat > oat, barley and rye

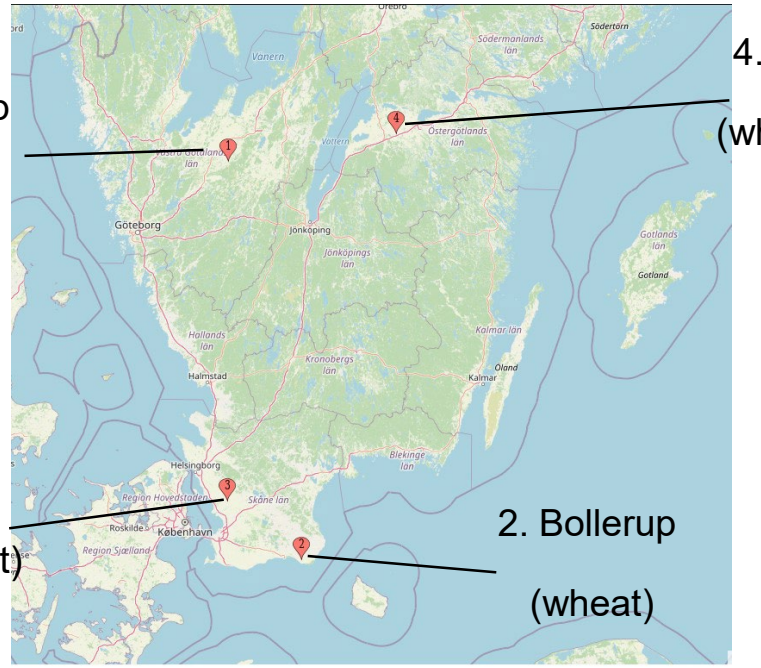
Project plan

Lantmännen's yield trials

3 years, 3 locations, 2 replications

1. Bjertorp

(oat)



4. Kölbäck

(wheat + oat)

3. Svalöv

(wheat + oat)

2. Bollerup

(wheat)

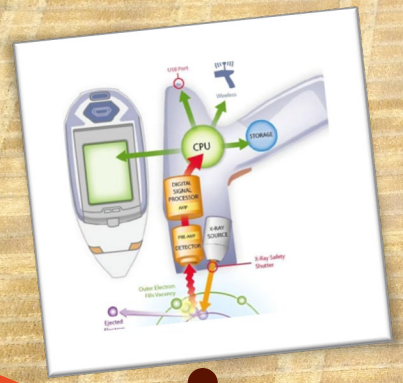
Breeding lines of wheat (n≈400) and oat (n=266)

- Grain Cd, ear emergence, height & yield

Soil estimates:
- Cd levels
- Clay content
- Organic matter content
- pH

Climate variables:
- Temperature
- Rainfall

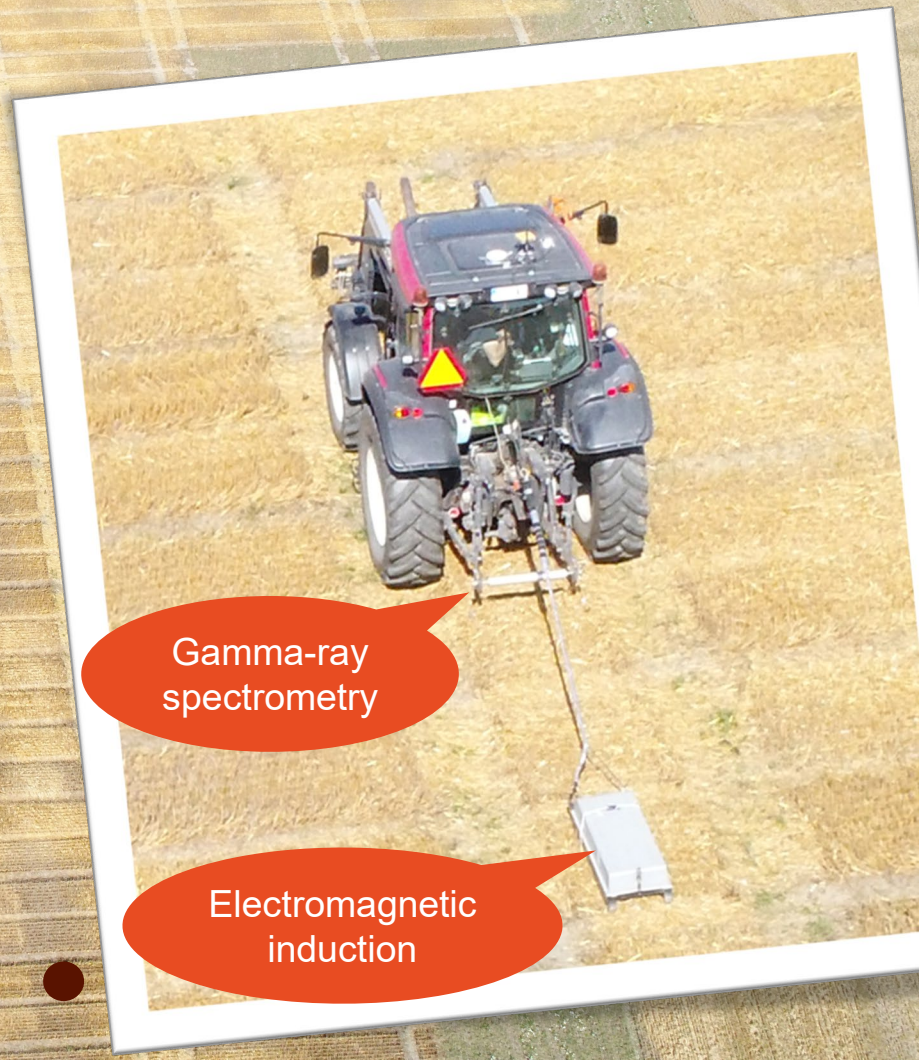
Predictions of soil Cd, pH, Clay content and SOM content in each parcel, two depths: 0-20 cm and 40-60 cm



Portable X-ray fluorescence on each sample

Budget limitation: soil samples from 25 locations per trial

Soil sampling + proximal sensor scanning of samples and fields + other covariates
→ Prediction modelling



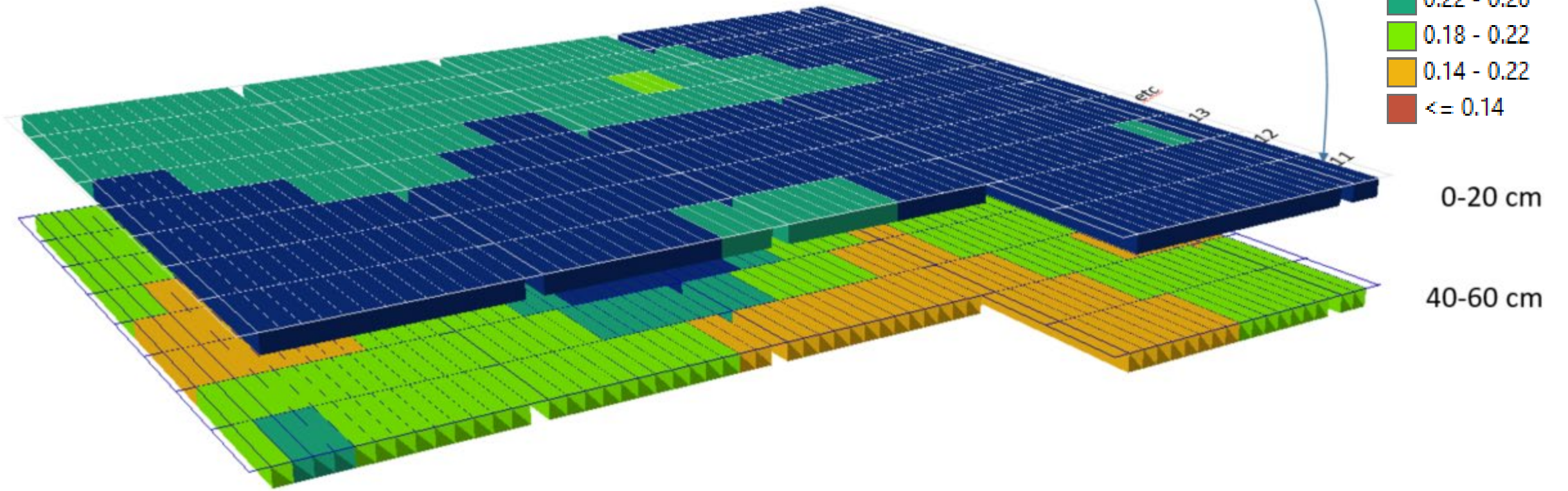
Gamma-ray spectrometry

Electromagnetic induction

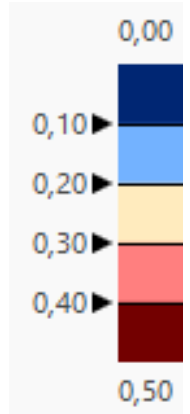
Predictions of soil Cd, pH, Clay content and SOM content in each parcel, two depths: 0-20 cm and 40-60 cm

Example

Plot_id	Cd_020	clay_020	SOM_020	pH_020	Cd_4060	clay_4060	SOM_4060	pH_4060	Type
10									Border
11	0.28	17	1.6	7.2	0.19	24	0.7	7.4	Plot
12	0.28	17	1.6	7.3	0.19	24	0.6	7.4	Plot
13	0.27	17	1.6	7.3	0.17	25	0.3	7.5	Plot
etc									Plot

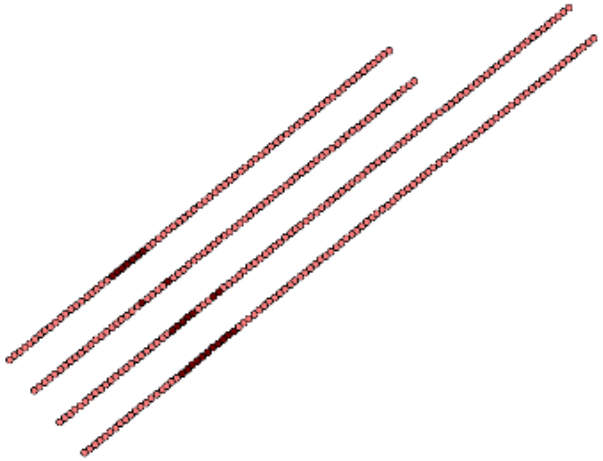


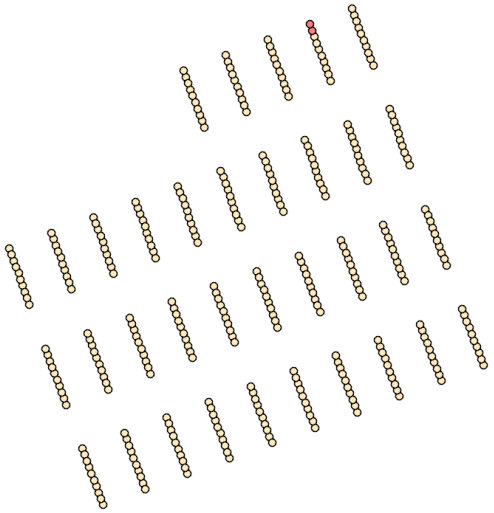
Predicted soil cadmium levels

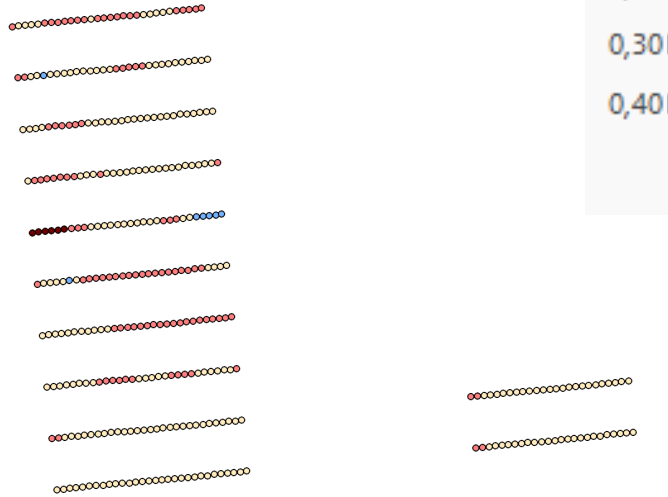


Topsoil

(0-20 cm)

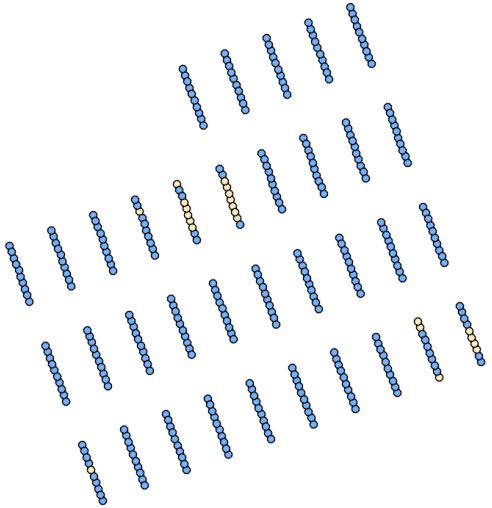






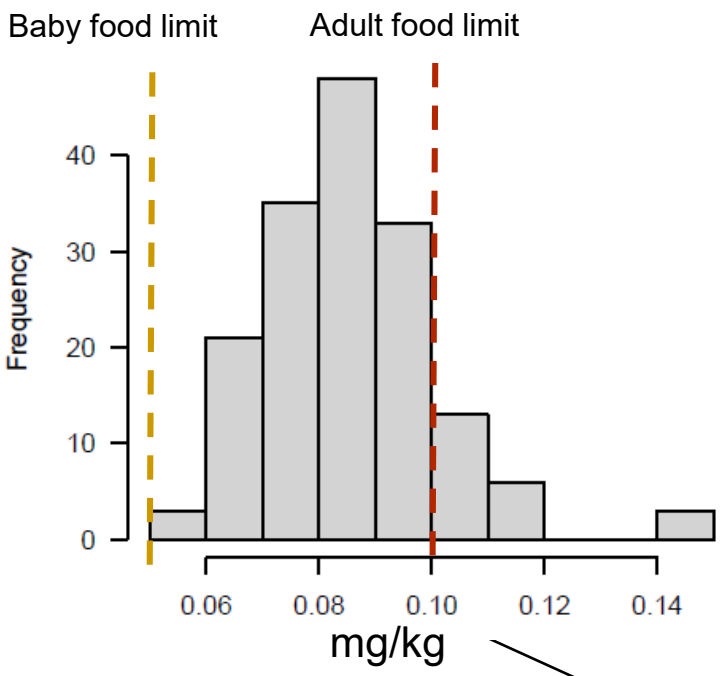
Subsoil

(20-40 cm)

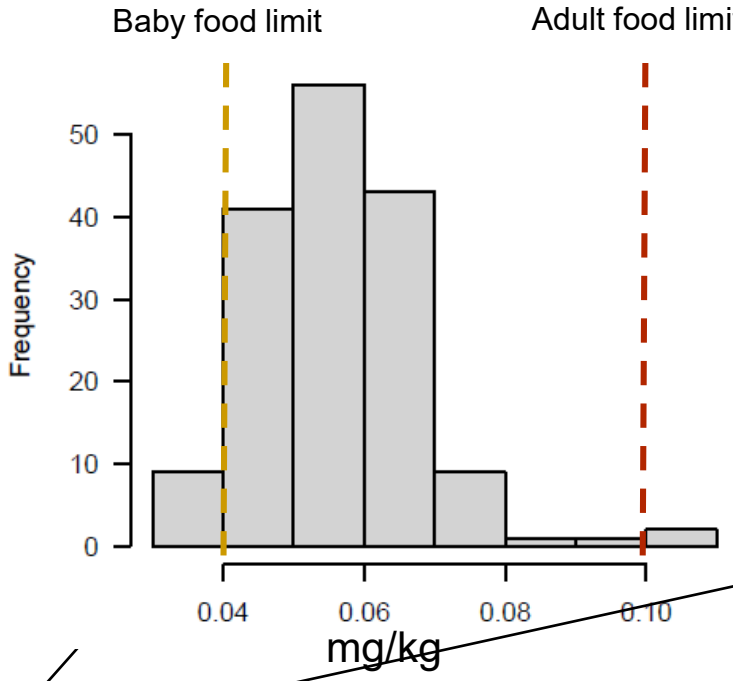


Bollerup **Svalöv** **Kölbäck**

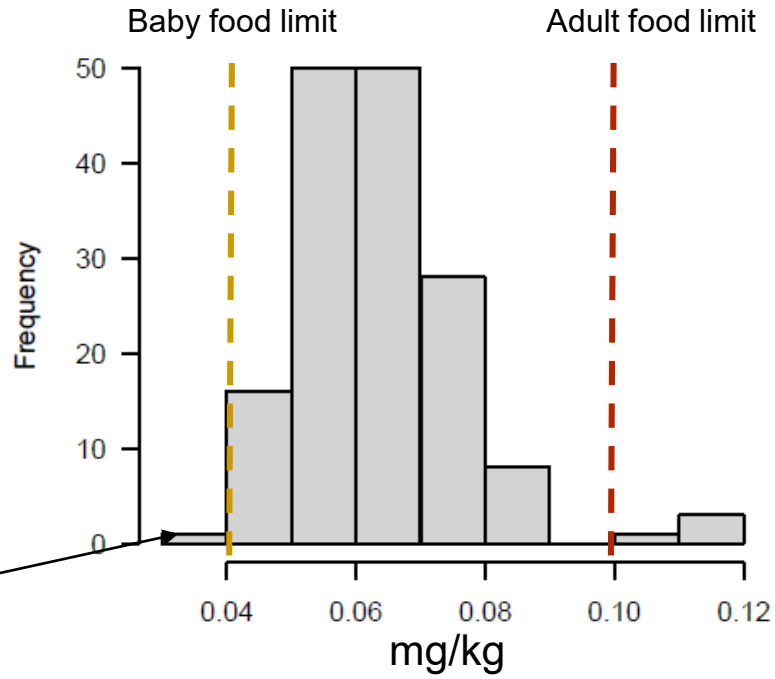
GCd_Bollerup_BLUEs_cov



GCd_Svalöv_BLUEs_cov



GCd_Kölbäck_rep1



Ex. Wheat, 2022 (n=163)

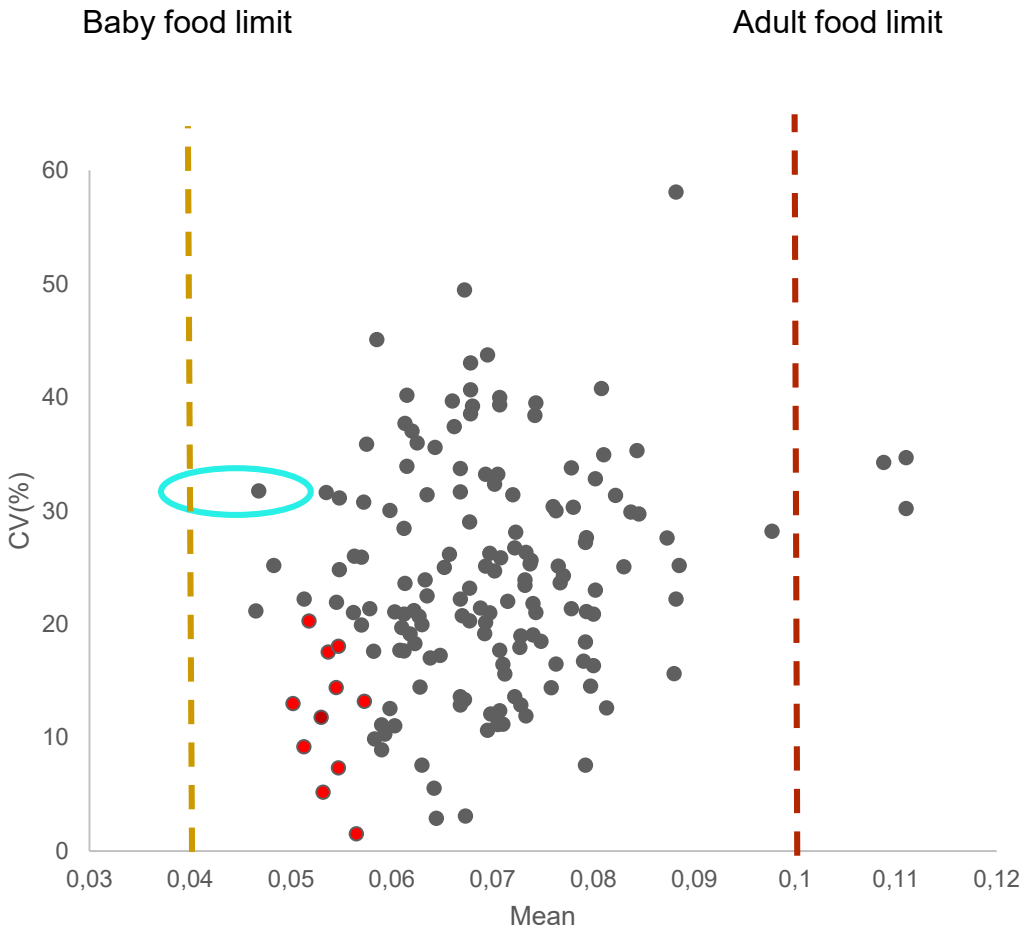
One line in common

Bollerup:Soil characteristics	Level Top/Subsoil
SCd	High/Medium
pH	High/High
SOM	High/Medium
Clay	Low/Low

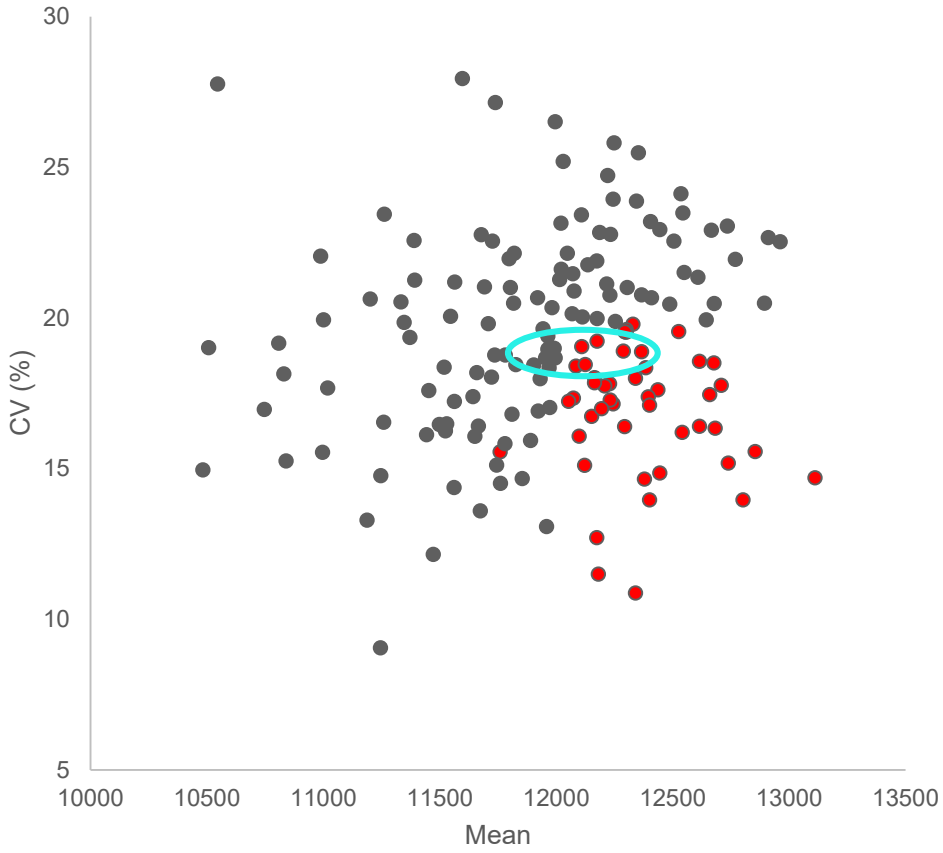
Svalöv: Soil characteristics	Level Top/Subsoil
SCd	Medium/Low
pH	High/Medium
SOM	High/Low
Clay	Medium/Medium

Kölbäck: Soil characteristics	Level Top/Subsoil
SCd	Medium/Low
pH	Low/Medium
SOM	Medium/Low
Clay	High/High

GCd (mg/kg)



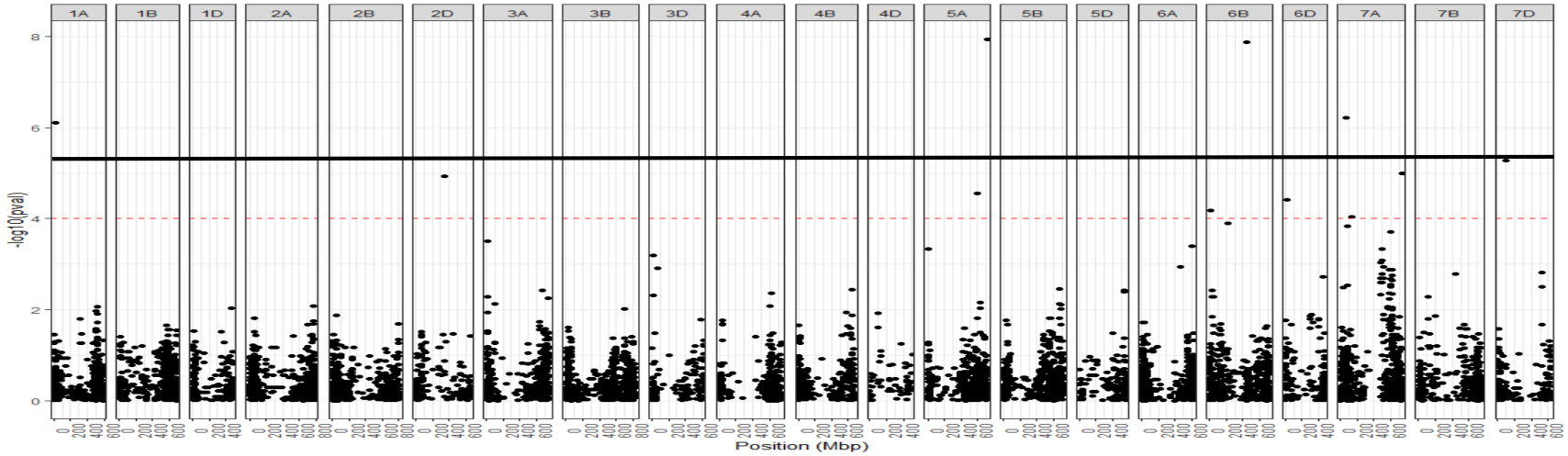
Yield (kg/ha)

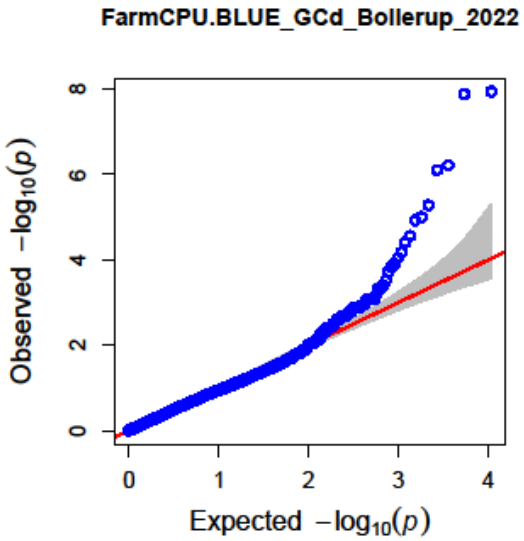


All three locations, 2022

GCd_Bollerup_2022

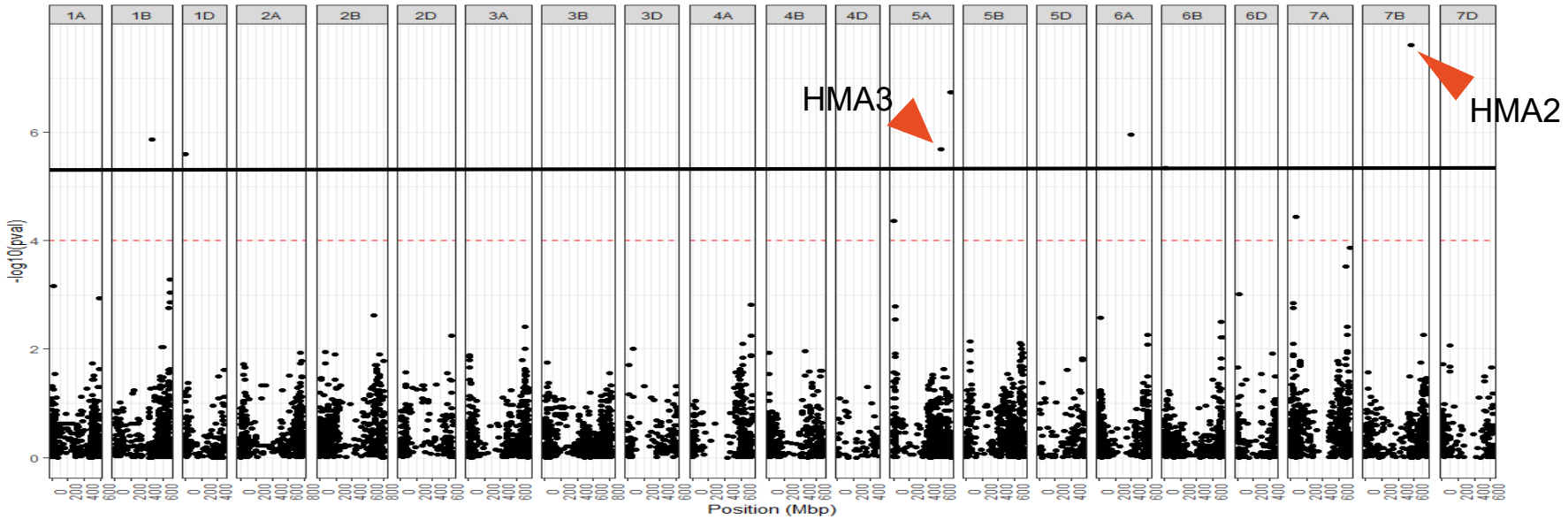
H^2= 0.92

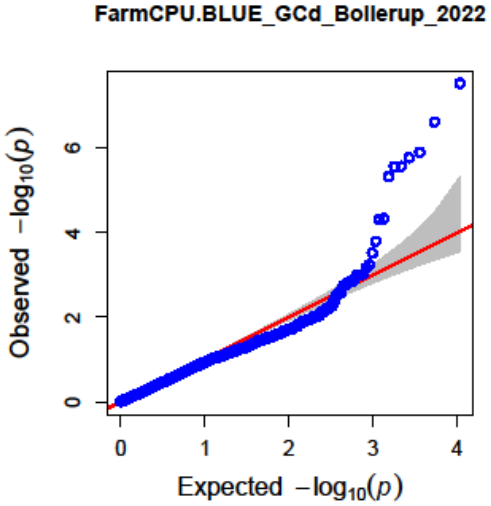




GCd_Bollerup_2022_cov (SCd, SOM and clay→top soil)

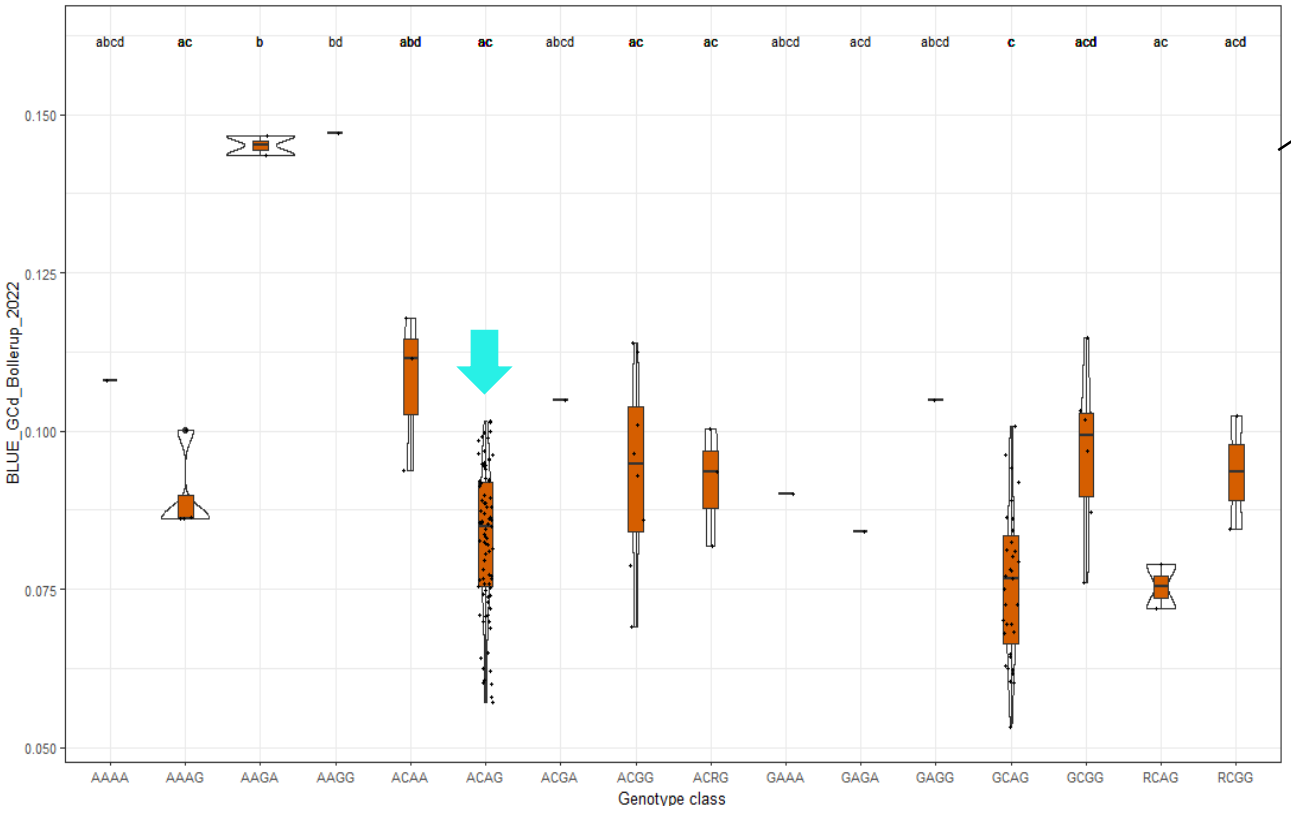
H^2= 0.93





Allele combinations using the model with covariates

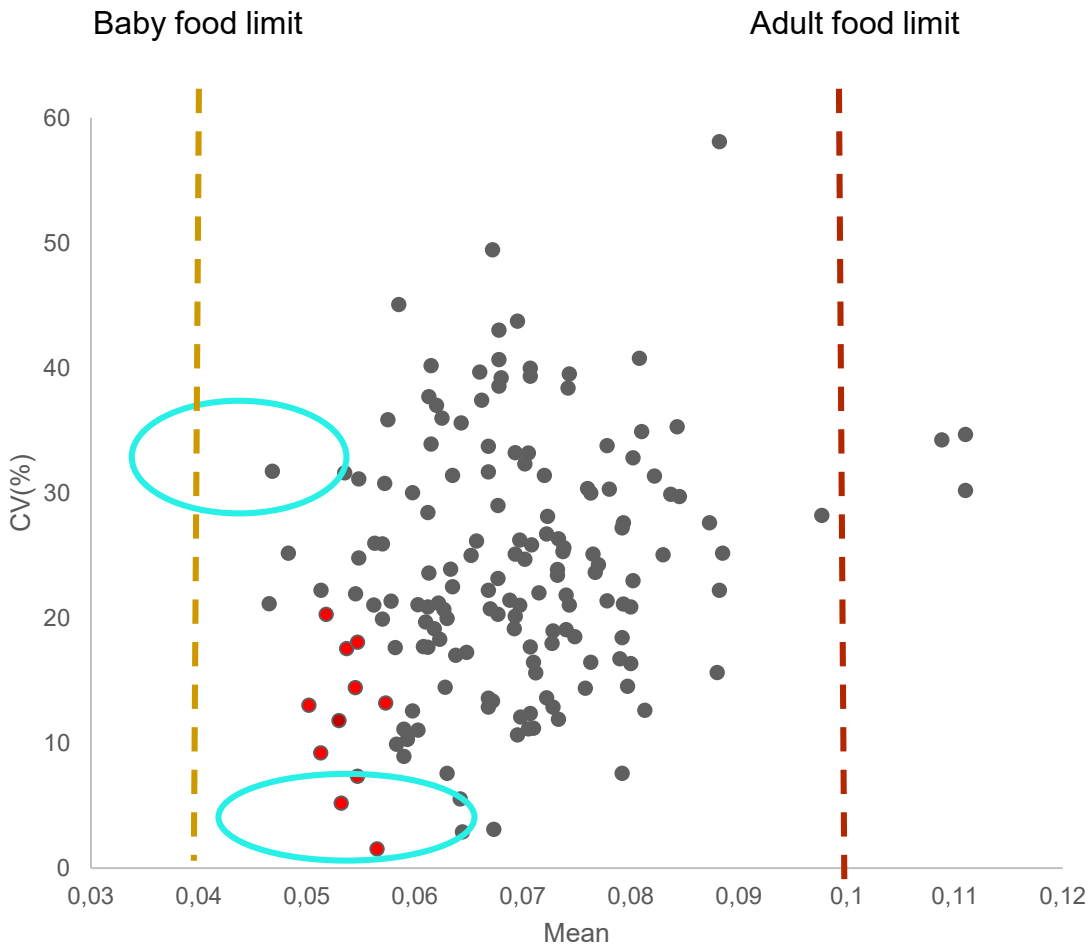
Top four markers



Chr	P.value	LOD	MAF
7B	2.440558e-08	7.612511	0.29012346
5A	1.845177e-07	6.733962	0.07407407
6A	1.118796e-06	5.951249	0.15740741
1B	1.378992e-06	5.860438	0.05555556
5A	2.086037e-06	5.680678	0.07716049
1D	2.499105e-06	5.602216	0.06172840

lines	Class	Phenotype
All	All	All
LM_210	ACAGCT	0.05993964
LM_211	ACAGCT	0.05703957
LM_212	ACAGCT	0.06031245
LM_212	ACAGCT	0.08800541

GCd (mg/kg)



All three locations, 2022

The way forward

- One more year of field trials
- Nutrient levels
- Develop genomic prediction models
- Identify covariates of highest importance
- Validate markers and implement tools at Lantmännen

SLU Grogrund

Dept. of Plant Breeding
Therése Bengtsson
Haftom Brhanie Mesfin
Marwan Alamrani
Anders Carlsson

SLU Fältforsk
Ortrud Jäck

Tina Henriksson
Johanna Holmblad
Alf Ceplitis
Pernilla Vallenback
Rikard Westbom

Dept. of Soil and Environment
Mats Söderström

Referensgrupp
Jens Weibull- Jordbruksverket
Annika Svanbäck- Jordbruksverket
Anette Andersson- Kemikalieinspektionen

Lucia Gutierrez
Maria Inés Berro Rovella