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Genetic analysis of stillbirth, birth weight and fertility traits in Landrace and Large White pigs

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Introduction – piglet survival



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Production systems:

- management ¹
- infection pressure ¹



Breeding:

- litter size ² ↑
- birth weights ³ ↓
- birth weight variation ⁴ ↑



Piglet
Survival

¹ Rothschild, 1998; ² Rutherford, 2013; ³ Roehe and Kalm, 2000; ⁴ Milligan et al., 2002

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Breeding:

- litter size ² ↑
- birth weights ³ ↓
- birth weight variation ⁴ ↑



Politics and society:



- animal welfare ⁵
- medical treatments ⁶
- health status ⁷

Farmers:



- economic viability ⁸
- public acceptance ⁹

¹ Rothschild, 1998; ² Rutherford, 2013; ³ Roehe and Kalm, 2000; ⁴ Milligan et al., 2002;

⁵ Rutherford, 2013; ⁶ BMEL, 2015; ⁷ FLI, 2015; ⁸ Kapell et al., 2008; ⁹ BLE, 2015

Current situation and challenges

- Increased litter size¹: plus 1 piglet every 3 years²
- Decreased individual birth weights³
- High variation of birth weights within litter⁴
 - Reduced piglet survival⁵
 - Reduced fattening performance⁶



fachinfo-schwein.de

¹ Tribout et al., 1998 and 2003, ² VanEngen et al. 2010, Hortmann Scholten 2012, ³ Roehe and Kalm, 2000, ⁴ Milligan et al., 2002, ⁵ Roehe et al., 2014, ⁶ Fix et al., 2010

Aim of the study

- Investigate the potential of selection to improve piglet survival

1. Estimate variance components for

- survival traits and individual birth weight of piglets
- reproductive traits of the sow

2. Genome-wide association study (GWAS)





Allaboutfeed.net

3. Genomic BLUP (GBLUP)

Materials and methods - data set

Data sets (2010-2016)

	Pedigree (N)	Piglet (N)	Reproduction (N_{sows}, N_{litters})	Herds (N)	Line
	46.059	42.774	2.364 5.487	2	Landrace
	63.390	60.012	2.287 5.373	2	Large White

Materials and methods – piglet survival

Individual birth weight
(BW, kg)

Stillbirth
(SB, binary: 0/1 – alive/born dead)

Suckling piglet losses
(SPL, binary: 0/1 – survived/
died before weaning)

univariate

Fixed effects:
parity, (herd-)year-season, sex

Fixed effects:
parity, (herd-)year-season, sex,
(BW)

1. Estimation
of variance
components

bivariate

Fixed effects:
parity, (herd-)year-season, sex

2. GWAS &
3. GBLUP

Statistical model – piglet survival

- Bivariate animal model

$$y = X\beta + Za + Zm + Zpe + e$$

- SB and SPL:

Threshold model &

Logit-Link function $\rightarrow \sigma_e^2 = 3.29$

Matrix	Effects estimated		Piglet data
	$X\beta$		x
A	Za	h^2	x
A	Zm	m^2	x
I	Zpe	pe^2	x
I	e		x

y = vector of observations

β = vector of fixed effects

m = vector of maternal genetic effects (physical or foster dam) a = vector of additive genetic effects

pe = vector of permanent environment effects

e = vector of random residuals

X = incidence matrix of fixed effects

Z = incidence matrix of random effects

The analyses were conducted with ASReml 4.0 (Gilmour, 1999) and WOMBAT (Meyer, 2007)

Results – birth weight & stillbirth

Variance components for stillbirth and birth weight in piglets

Landrace					Large White				
Trait	SB	BW	m ²	pe ²	Trait	SB	BW	m ²	pe ²
SB	0.05 (±0.01)	-0.49 (±0.11)	0.02 (±0.01)	0.09 (±0.01)	SB	0.05 (±0.02)	-0.40 (±0.15)	0.02 (±0.01)	0.06 (±0.01)
BW	-0.19	0.13 (±0.01)	0.16 (±0.02)	0.06 (±0.01)	BW	-0.21	0.14 (±0.01)	0.12 (±0.01)	0.08 (±0.02)

Heritabilities (h^2) on the diagonal, phenotypic correlations (r_p) below the diagonal and genotypic correlations (r_G) above the diagonal, maternal genetic effects (m^2) and permanent environment effects (pe^2)

SB=Stillbirth, BW=Birth weight

Results – birth weight & stillbirth

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BW	-0.19	0.13 (±0.01)	0.16 (±0.02)	0.06 (±0.01)	BW	-0.21	0.14 (±0.01)	0.12 (±0.01)	0.08 (±0.02)

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Results – birth weight & stillbirth

Variance components for stillbirth and birth weight in piglets

Landrace					Large White				
Trait	SB	BW	m^2	pe^2	Trait	SB	BW	m^2	pe^2
SB	0.05 (±0.01)	-0.49 (±0.11)	0.02 (±0.01)	0.09 (±0.01)	SB	0.05 (±0.02)	-0.40 (±0.15)	0.02 (±0.01)	0.06 (±0.01)
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SB=Stillbirth, BW=Birth weight

Results – birth weight & suckling piglet losses

Variance components for suckling piglet losses and birth weight in piglets

Landrace					Large White				
Trait	BW	SPL	m ²	pe ²	Trait	BW	SPL	m ²	pe ²
BW	0.13 (±0.01)	-0.67 (±0.09)	0.16 (±0.02)	0.06 (±0.01)	BW	0.14 (±0.01)	-0.40 (±0.09)	0.12 (±0.01)	0.08 (±0.02)
SPL	-0.30	0.02 (±0.01)	0.02 (±0.01)	0.07 (±0.01)	SPL	-0.31	0.03 (±0.01)	0.04 (±0.01)	0.07 (±0.01)

Heritabilities (h^2) on the diagonal, phenotypic correlations (r_p) below the diagonal and genotypic correlations (r_G) above the diagonal, maternal genetic effects (m^2) and permanent environment effects (pe^2)

SPL=Suckling piglet losses, BW=Birth weight

Results – birth weight & suckling piglet losses

Variance components for suckling piglet losses and birth weight in piglets

Landrace					Large White				
Trait	BW	SPL	m ²	pe ²	Trait	BW	SPL	m ²	pe ²
BW	0.13 (±0.01)	-0.67 (±0.09)	0.16 (±0.02)	0.06 (±0.01)	BW	0.14 (±0.01)	-0.40 (±0.09)	0.12 (±0.01)	0.08 (±0.02)
SPL	-0.30	0.02 (±0.01)	0.02 (±0.01)	0.07 (±0.01)	SPL	-0.31	0.03 (±0.01)	0.04 (±0.01)	0.07 (±0.01)

Heritabilities (h^2) on the diagonal, phenotypic correlations (r_p) below the diagonal and genotypic correlations (r_G) above the diagonal, maternal genetic effects (m^2) and permanent environment effects (pe^2)

SPL=Suckling piglet losses, BW=Birth weight

Results – birth weight & suckling piglet losses

Variance components for suckling piglet losses and birth weight in piglets

Landrace					Large White				
Trait	BW	SPL	m ²	pe ²	Trait	BW	SPL	m ²	pe ²
BW	0.13 (±0.01)	-0.67 (±0.09)	0.16 (±0.02)	0.06 (±0.01)	BW	0.14 (±0.01)	-0.40 (±0.09)	0.12 (±0.01)	0.08 (±0.02)
SPL	-0.30	0.02 (±0.01)	0.02 (±0.01)	0.07 (±0.01)	SPL	-0.31	0.03 (±0.01)	0.04 (±0.01)	0.07 (±0.01)

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SPL=Suckling piglet losses, BW=Birth weight

Results – birth weight & suckling piglet losses

Variance components for suckling piglet losses and birth weight in piglets

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Trait	BW	SPL	m^2	pe^2	Trait	BW	SPL	m^2	pe^2
BW	0.13 (±0.01)	-0.67 (±0.09)	0.16 (±0.02)	0.06 (±0.01)	BW	0.14 (±0.01)	-0.40 (±0.09)	0.12 (±0.01)	0.08 (±0.02)
SPL	-0.30	0.02 (±0.01)	0.02 (±0.01)	0.07 (±0.01)	SPL	-0.31	0.03 (±0.01)	0.04 (±0.01)	0.07 (±0.01)

Heritabilities (h^2) on the diagonal, phenotypic correlations (r_p) below the diagonal and genotypic correlations (r_g) above the diagonal, maternal genetic effects (m^2) and permanent environment effects (pe^2)

SPL=Suckling piglet losses, BW=Birth weight

Materials and methods – sow reproduction

Number of piglets born alive (NBA)

Number of piglets born dead (NBD)

Number of suckling piglet losses (SPL)

Variance of birth weight within litter (VarLW)

Mean birth weight within litter (MeanLW)

univariate

series of bivariate analyses

1. Estimation
of variance
components

Fixed effects:

parity, herd-year-season

Covariable:

nested effect of time-between-litters and weaning-conception-interval

2. GWAS &
3. GBLUP

Statistical model – sow reproduction

- Animal model

$$y = X\beta + Za + Zpe + e$$

Matrix	Effects estimated	Reproduction traits (sow)
	$X\beta$	x
A	Za h^2	x
I	Zpe pe^2	x
I	e	x

y = vector of observations

β = vector of fixed effects

a = vector of additive genetic effects

pe = vector of permanent environment effects

e = vector of random residuals

X = incidence matrix of fixed effects

Z = incidence matrix of random effects

The analyses were conducted with ASReml 4.0 (Gilmour, 1999)

Results - reproduction

Variance components for the reproductive traits of the sow - Landrace

Trait	NBA	NBD	SPL	VarLW	MeanLW
NBA	0.10(±0.02)				
NBD		0.07(±0.02)			
SPL			0.07(±0.02)		
VarLW				0.12(±0.02)	
MeanLW					0.41(±0.03)

Heritabilities (h^2) on the diagonal

NBA=Number of piglets born alive, NBD=Number of piglets born dead, SPL=Suckling piglet losses, VarLW=Variance of birth weight within litter, MeanLW=Mean birth weight within litter

Results - reproduction

Variance components for the reproductive traits of the sow - Landrace

Trait	NBA	NBD	SPL	VarLW	MeanLW
NBA	0.10(±0.02)	0.39(±0.15)	0.52(±0.12)	0.38(±0.12)	-0.54(±0.07)
NBD	-0.11	0.07(±0.02)	0.24(±0.16)	0.27(±0.13)	-0.20(±0.11)
SPL	0.32	0.07	0.07(±0.02)	0.07(±0.15)	-0.67(±0.08)
VarLW	0.16	0.08	0.16	0.12(±0.02)	0.13(±0.09)
MeanLW	-0.45	-0.19	-0.38	-0.11	0.41(±0.03)

Heritabilities (h^2) on the diagonal, phenotypic correlations (r_p) below the diagonal and genotypic correlations (r_g) above the diagonal.

NBA=Number of piglets born alive, NBD=Number of piglets born dead, SPL=Suckling piglet losses, VarLW=Variance of birth weight within litter, MeanLW=Mean birth weight within litter

Results - reproduction

Variance components for the reproductive traits of the sow - Landrace

Trait	NBA	NBD	SPL	VarLW	MeanLW
NBA	0.10(±0.02)	0.39(±0.15)	0.52(±0.12)	0.38(±0.12)	-0.54(±0.07)
NBD	-0.11	0.07(±0.02)	0.24(±0.16)	0.27(±0.13)	-0.20(±0.11)
SPL	0.32	0.07	0.07(±0.02)	0.07(±0.15)	-0.67(±0.08)
VarLW	0.16	0.08	0.16	0.12(±0.02)	0.13(±0.09)
MeanLW	-0.45	-0.19	-0.38	-0.11	0.41(±0.03)

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NBA=Number of piglets born alive, NBD=Number of piglets born dead, SPL=Suckling piglet losses, VarLW=Variance of birth weight within litter, MeanLW=Mean birth weight within litter

Results - reproduction

Variance components for the reproductive traits of the sow - Landrace

Trait	NBA	NBD	SPL	VarLW	MeanLW
NBA	0.10(±0.02)	0.39(±0.15)	0.52(±0.12)	0.38(±0.12)	-0.54(±0.07)
NBD	-0.11	0.07(±0.02)	0.24(±0.16)	0.27(±0.13)	-0.20(±0.11)
SPL	0.32	0.07	0.07(±0.02)	0.07(±0.15)	-0.67(±0.08)
VarLW	0.16	0.08	0.16	0.12(±0.02)	0.13(±0.09)
MeanLW	-0.45	-0.19	-0.38	-0.11	0.41(±0.03)

Heritabilities (h^2) on the diagonal, phenotypic correlations (r_p) below the diagonal and genotypic correlations (r_g) above the diagonal.

NBA=Number of piglets born alive, NBD=Number of piglets born dead, SPL=Suckling piglet losses, VarLW=Variance of birth weight within litter, MeanLW=Mean birth weight within litter

Results - reproduction

Variance components for the reproductive traits of the sow – Large White

Trait	NBA	NBD	SPL	VarLW	MeanLW
NBA	0.12(±0.02)				
NBD		0.06(±0.01)			
SPL			0.05(±0.01)		
VarLW				0.07(±0.02)	
MeanLW					0.39(±0.03)

Heritabilities (h^2) on the diagonal

NBA=Number of piglets born alive, NBD=Number of piglets born dead, SPL=Suckling piglet losses, VarLW=Variance of birth weight within litter, MeanLW=Mean birth weight within litter

Results - reproduction

Variance components for the reproductive traits of the sow – Large White

Trait	NBA	NBD	SPL	VarLW	MeanLW
NBA	0.12(±0.02)	0.34(±0.17)	0.25(±0.18)	0.37(±0.15)	-0.18(±0.10)
NBD	-0.10	0.06(±0.01)	0.67(±0.18)	0.10(±0.19)	-0.24(±0.12)
SPL	0.23	0.08	0.05(±0.01)	-0.16(±0.22)	-0.52(±0.11)
VarLW	0.23	0.09	0.20	0.07(±0.02)	0.41(±0.13)
MeanLW	-0.42	-0.21	-0.33	-0.21	0.39(±0.03)

Heritabilities (h^2) on the diagonal, phenotypic correlations (r_p) below the diagonal and genotypic correlations (r_g) above the diagonal.

NBA=Number of piglets born alive, NBD=Number of piglets born dead, SPL=Suckling piglet losses, VarLW=Variance of birth weight within litter, MeanLW=Mean birth weight within litter

Summary and conclusion

Piglet survival:

- Lower birth weights increase the piglets probability to be stillborn or to die before weaning
- Ongoing :
 - Modelling SB/SPL as binary traits in a multivariate context needs further inspection

Sow reproduction:

- Higher mean birth weights decrease NBA, NBD and SPL
- Increased variation is associated with a higher amount of NBA and NBD
- In larger litters the amount of NBD and SPL is increased

Ongoing steps

- More sophisticated phenotyping of health and blood parameters
 - Characterize the health status of sows and piglets
- Generating genomic data:
 - GWAS
 - GBLUP

Thank you for your attention!

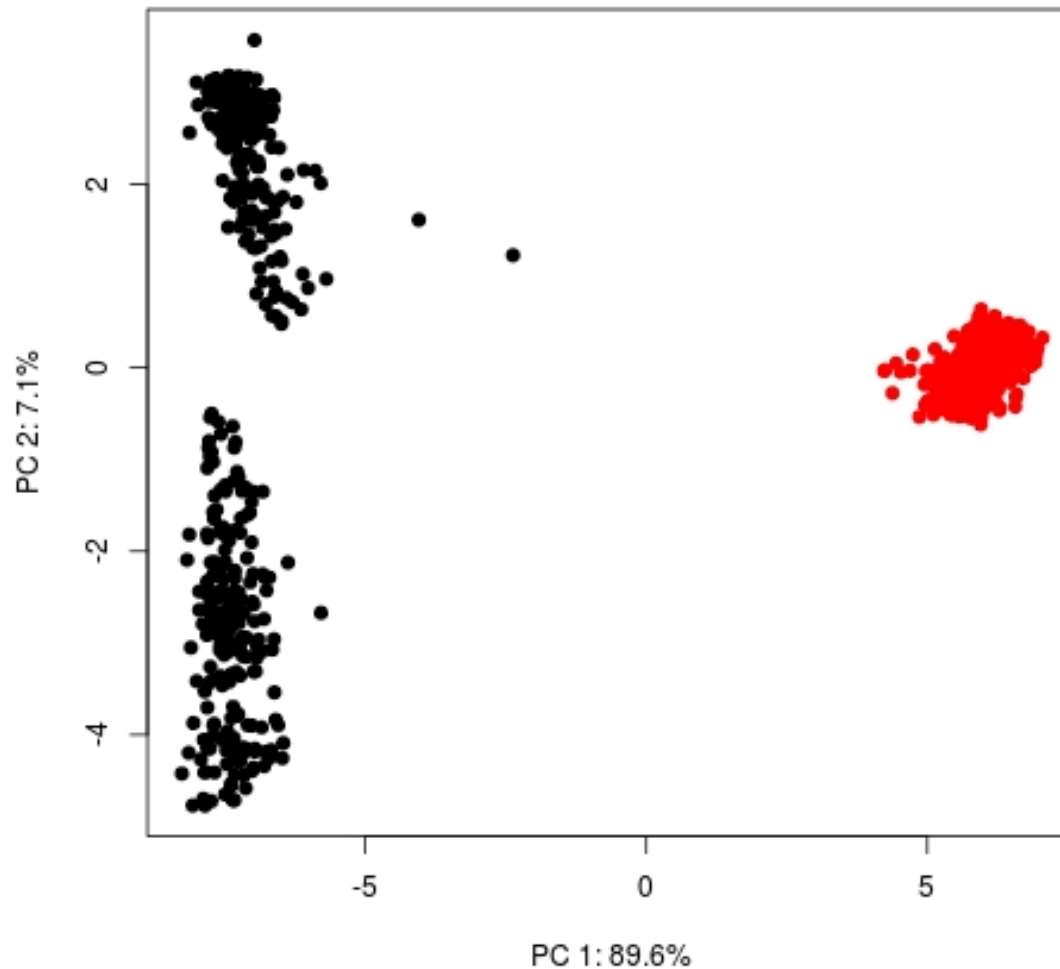
This study was performed within the 'pigFit' project.
The project is supported by funds of German Government's Special Purpose Fund held at Landwirtschaftliche Rentenbank (FKZ28-RZ-3-72.038).



Appendix

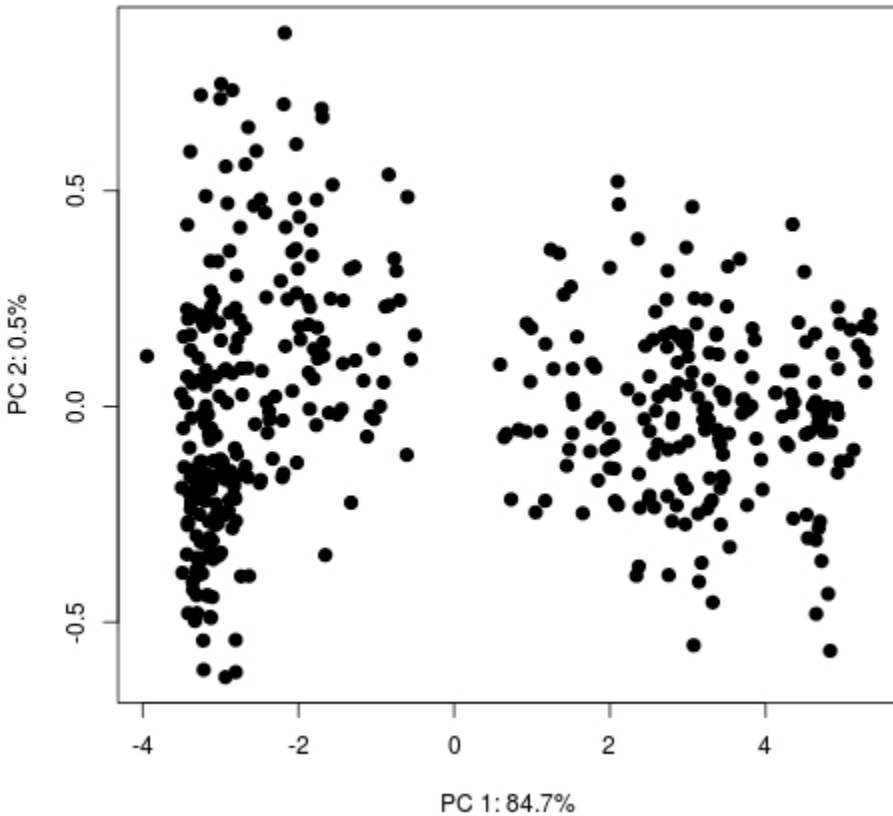
GWAS and GBLUP

Structure of the data set – both breeds

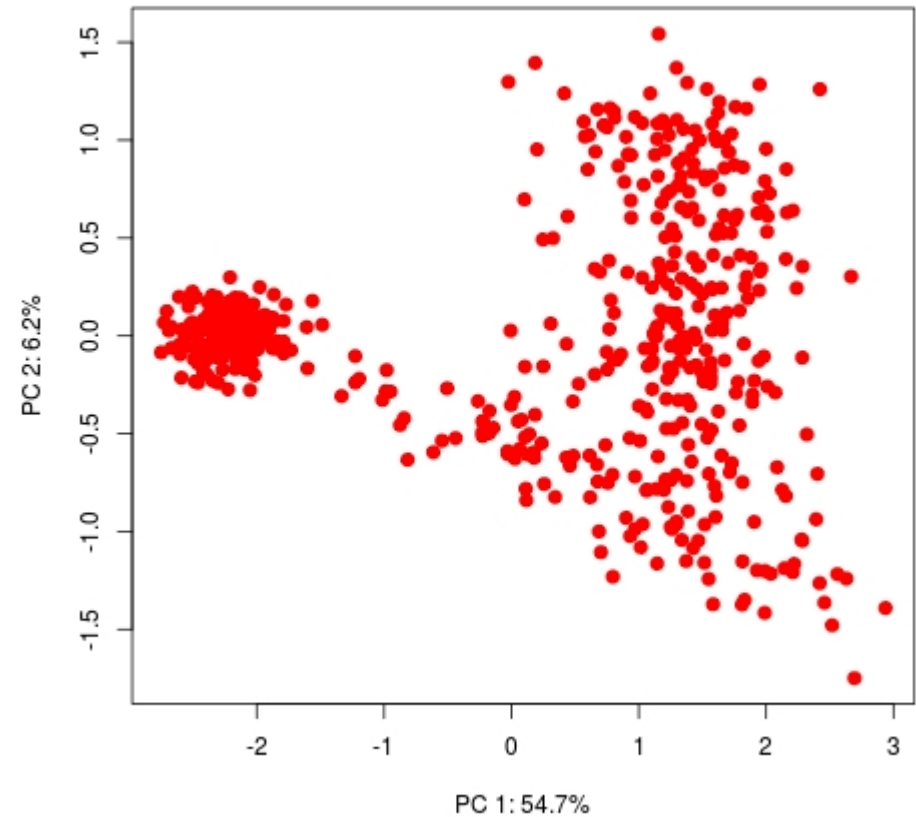


Structure within the populations

- Landrace (N=454)



- Large White (N=553)



Available genotypes

		2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Landrace	Boars	47	58	44	26	22	24	28	38	27	20
	Sows	-	-	-	-	-	-	-	-	-	120
Large White	Boars	34	61	48	25	31	30	36	35	46	16
	Sows	-	-	-	-	-	-	-	-	-	191

Available phenotypes and EBVs for genotyped animals

		BW	EBVs BW	EBVs SB	EBVs NBA
Landrace	Boars	136	242	242	213
	Sows	117	120	120	116
	Total	253	348	348	329
Large White	Boars	216	249	249	295
	Sows	182	106	106	162
	Total	398	355	355	457

BW = Birth weight, EBVs = Estimated breeding values, SB = Stillbirth,
NBA = Number born alive

Genome-wide association study (GWAS)

- Association study

- **Score test** (GenABEL; Schaid et al. 2002, Aulchenko et al. 2007)

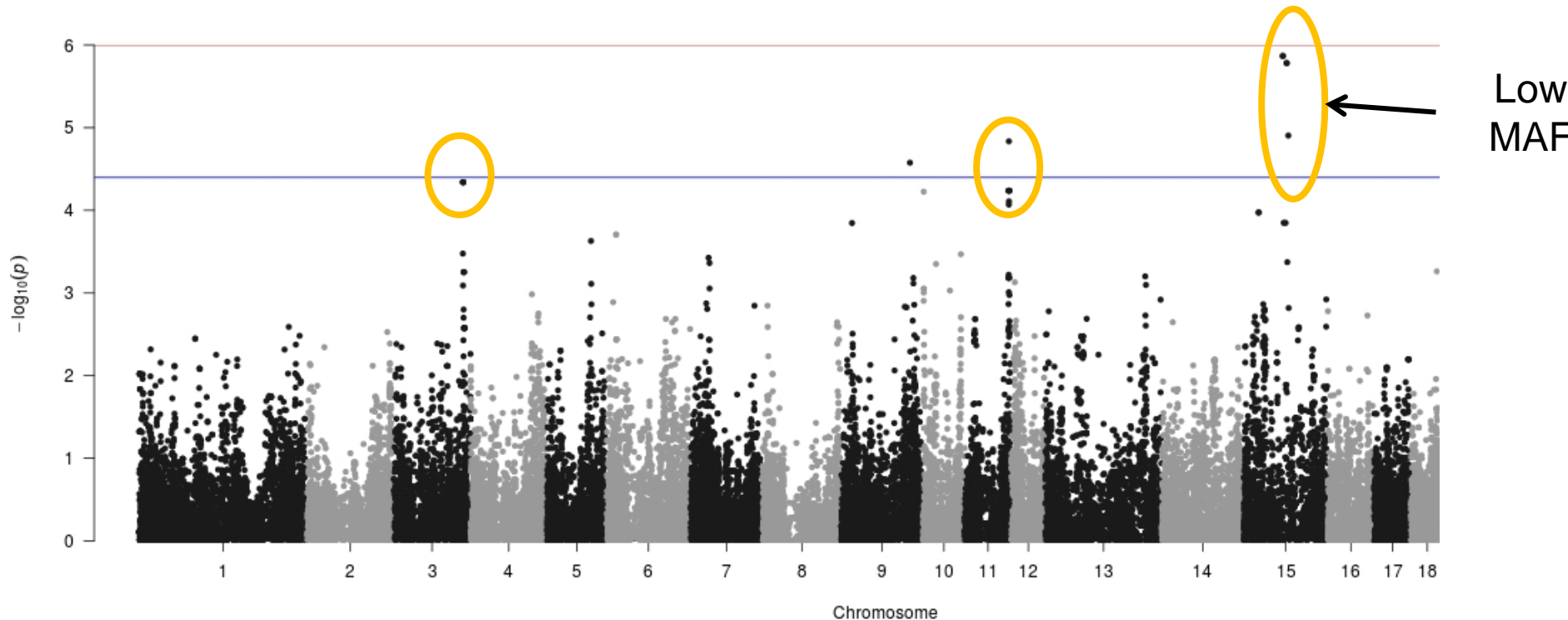
$$y_i = \mu + kg_i + e_i$$

- y_i : conventional EBVs
- k : marker genotype effect
- g : vector of genotypes

- Genome and chromosome-wide significance level:

- q-Value

GWAS for EBV SB - Landrace



- 22 chromosome-wide significant SNPs
- ~ 4 QTL regions
- Proportion of explained phenotypic variance: 6.5 – 10%
- Potential candidate genes within these regions

Genomic selection (GS)

- Genomic BV estimation: ridge regression BLUP
 - R package: rrBLUP (Endelman et al. 2011)
 - $EBV = Zu + e$
 - $u \sim N(0, G \sigma_a^2)$, G: genomic relationship matrix (vanRaden 2008)
- Accuracy of the forward prediction
 1. r_{MP} : Correlation between observed and estimated breeding values
 2. $r_{PEV} = \sqrt{1 - (PEV/\sigma_g^2)}$ (Henderson 1975)

Validation samples

- Scenario 1:
 - C -> All boars between 2002 and 2010
 - V -> Boars of 2011 and Sows of 2011

- Scenario 2:
 - C -> All boars between 2002 and 2010 + Sows of 2011
 - V -> Boars of 2011

		2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Landrace	Boars	47	58	44	26	22	24	28	38	27	20
	Sows	-	-	-	-	-	-	-	-	-	120
Large White	Boars	34	61	48	25	31	30	36	35	46	16
	Sows	-	-	-	-	-	-	-	-	-	191

C = Calibration sample; V = Validation sample

Literature cited

HORTMANN-SCHOLTEN, A. (2012): Markt für Ferkel. In: Hoy, S.: Schweinezucht und Ferkelerzeugung, Verlag Eugen Ulmer, Stuttgart.

ROEHE, R.; KALM, E. (2000): Estimation of genetic and environmental risk factors associated with pre-weaning mortality in piglets using generalized linear mixed models. *Animal Science* 70, S. 227-240.

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