What is the impact of Blackleg on Canola yield in Australia?

M. BABIAR, L. BARRETT, S.J SPRAGUE
www.csiro.au

What is the estimated impact of Blackleg on Canola and economy ? A few statistics…

Blackleg worldwide:

- global loss estimated “over US$ 900M”[1]

Blackleg (*Leptosphaeria maculans*) in Australia:

- loss estimation from <10% to 40% [2]
- “up to 90% yield loss” [3]

What is the estimated impact of Blackleg on Canola and economy ?
A few statistics…

Specific quantitative assessments, or qualitative relationship, but no quantitative relationship :

➔ Is it possible to quantify this disease-yield relationship ?

What is the estimated impact of Blackleg on the Canola plant ?
A bit of biology…

According to previous studies:

- strong link between stem canker symptom and yield loss

- extreme cases : lodging causing complete yield loss

- disease development :
disease spread ~ rainfall
canker severity ~ temperature

Assessing disease development: percentage of stem section cankered

S.J Sprague

Material and methods : data collection

Yield and disease data from:

Summarizing environmental variables
- 16 locations
- 4 states
- 4 years (2013-2016)

Parameters sampled:

Genetics & cultivation practices variables
- 22 varieties
- 6 genetic resistance rating levels (R ; R-MR ; MR ; MR-MS ; MS ; MS-S)
- 13 fungicide treatments (including “Nil” control treatment)

Material and methods : data collection

SARDI:
Andrew Ware
Jenny Davidson

MGP:
Steve Marcroft
Biz Sheedy
Alistair Smith
Buffy Harrison

DAFWA:
Ravjit Khangura
Andrea Hills
Ciara Beard

NSW DPI:
Kurt Lindbeck
Audrey Leo

CSIRO:
Susie Sprague

UM:
Alex Idnurm
Barbara Howlett
Angela Van de Wouw

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

S.J Sprague

Material and methods : presentation of the data set

Disease data:

- Environmental variables
- Genetics & cultivation practices variables
- Disease severity (CSII)

Total : 33 356 measurements taken

Yield data:

- Environmental variables
- Genetics & cultivation practices variables
- Yield

Total : 1352 observations

Material and methods : presentation of the data set

Disease data:

- Environmental variables
- Genetics & cultivation practices variables
- Disease severity (CSII)

Total : 33 356 measurements taken

+ Rainfall data from Bureau of Meteorology [4]

Yield data:

- Environmental variables
- Genetics & cultivation practices variables
- Yield

Total : 1352 observations

General data frame, per observation :

- Mean disease severity
- Yield

- Location
- Variety
- Genetic resistance rating
- Treatment
- Repetition
- Year
- Rainfall data

Total : 1352 observations

Material and methods : presentation of the data set

Disease data:

- Environmental variables
- Genetics & cultivation practices variables
- Disease severity (CSII)

Total : 33 356 measurements taken

+ Rainfall data from Bureau of Meteorology [4]

Yield data:

- Environmental variables
- Genetics & cultivation practices variables
- Yield

Total : 1352 observations

Mean disease severity = Σ (CSII)/n

General data frame, per observation :

- Mean disease severity
- Yield
- Location
- Variety
- Genetic resistance rating
- Treatment
- Repetition
- Year
- Rainfall data

Total : 1352 observations

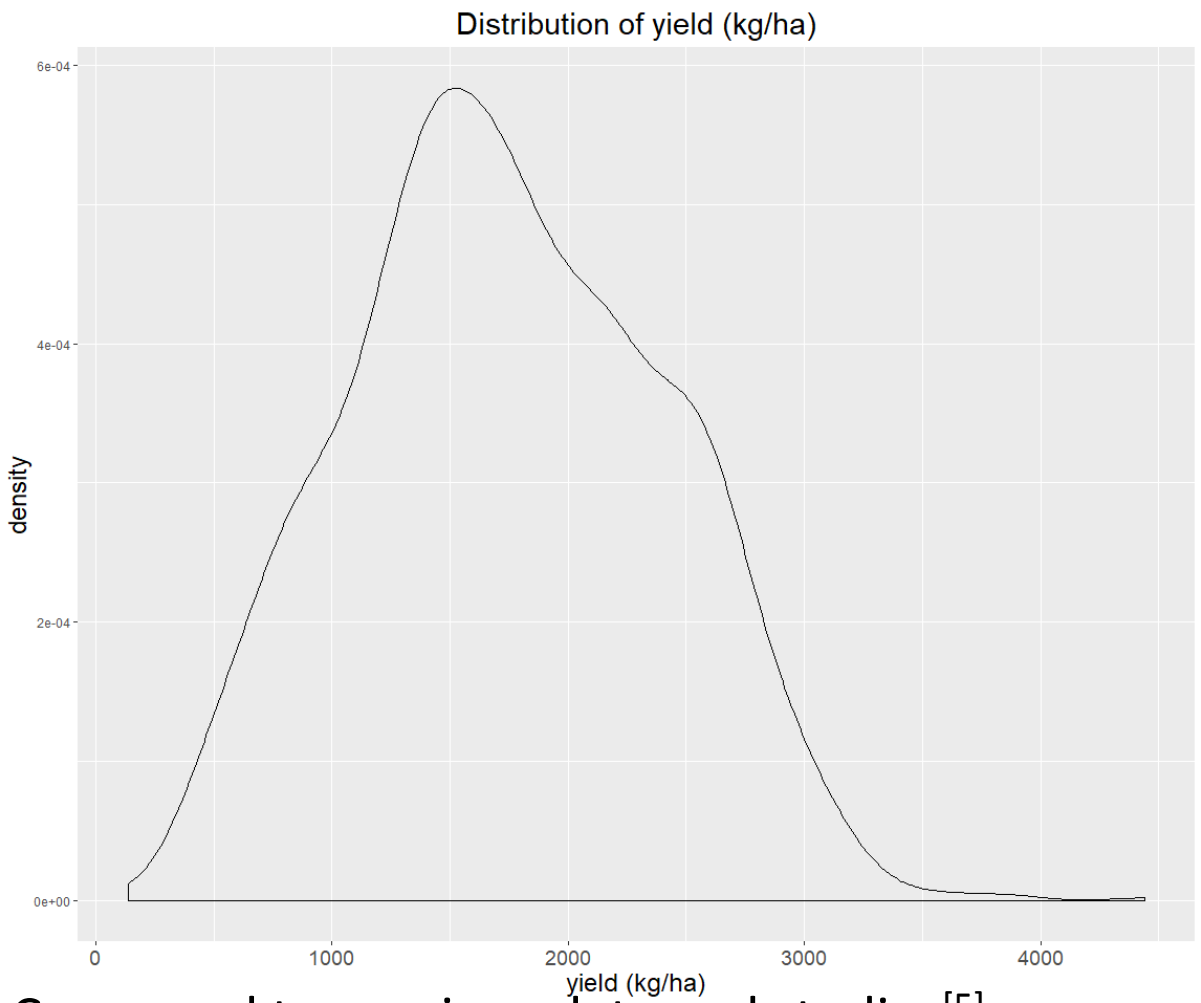
Questions raised :

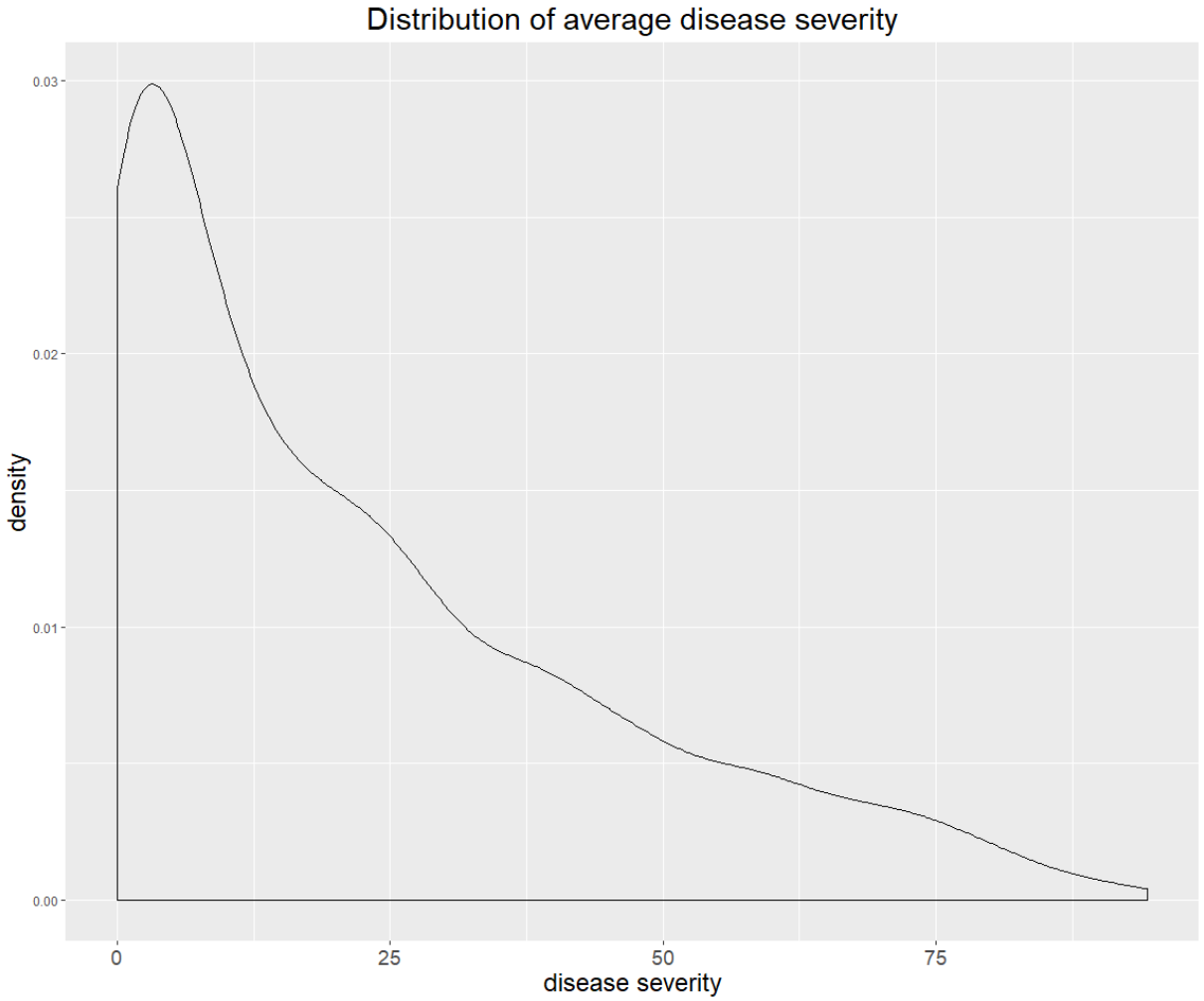
I) What are the parameters influencing disease severity ?

II) How do those parameters influence the yield-disease relationship ?

III) What is the yield response to disease presence ?

Results: disease severity and yield across Australia





Compared to previous data and studies[5] :

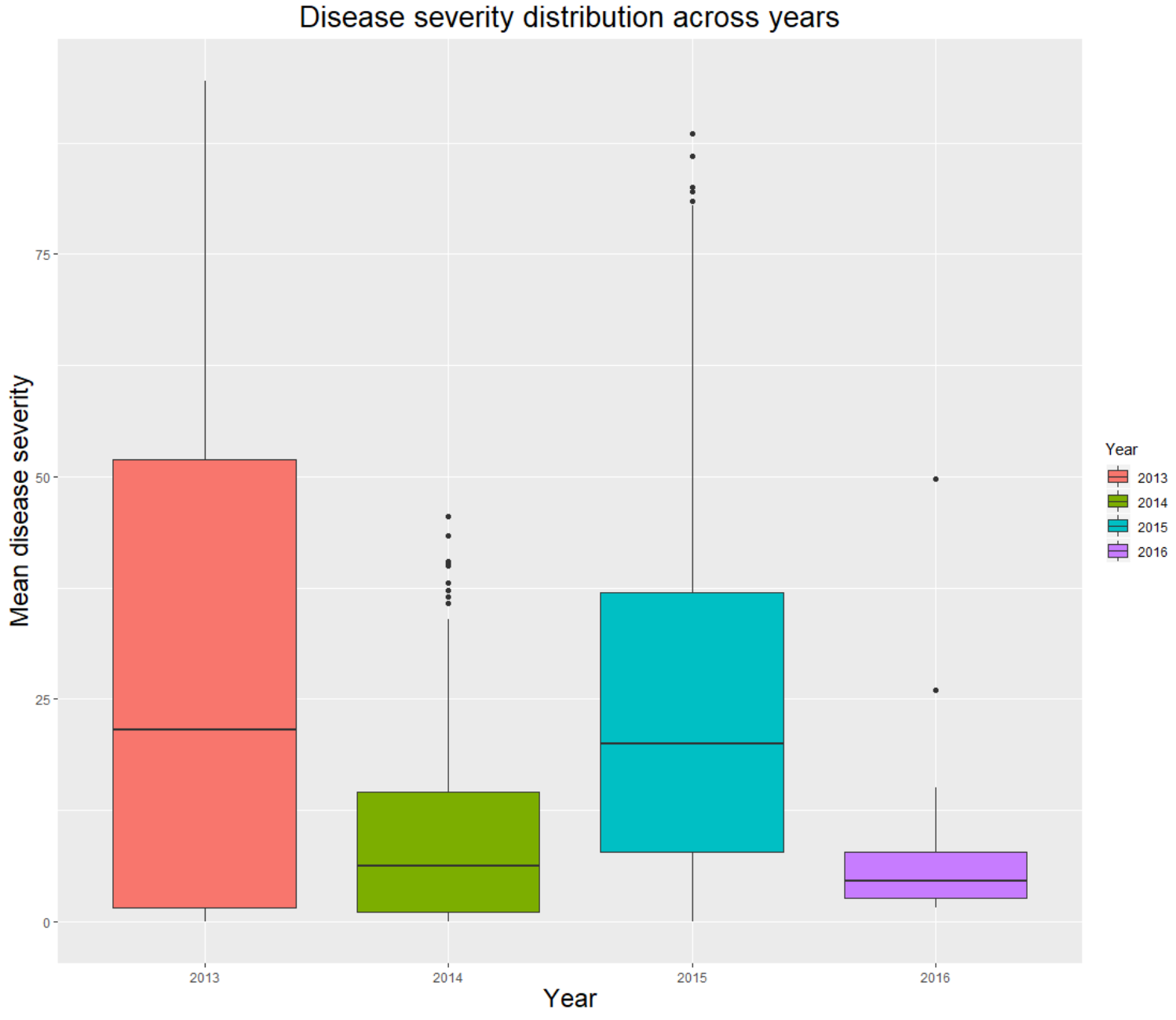
- Consistent yield mean between 1,5 and 2 t/ha
- Coherent yield range sampling across Australia

As a result of data collection :

- A large sampling of disease severity

I) What are the parameters influencing disease severity ?

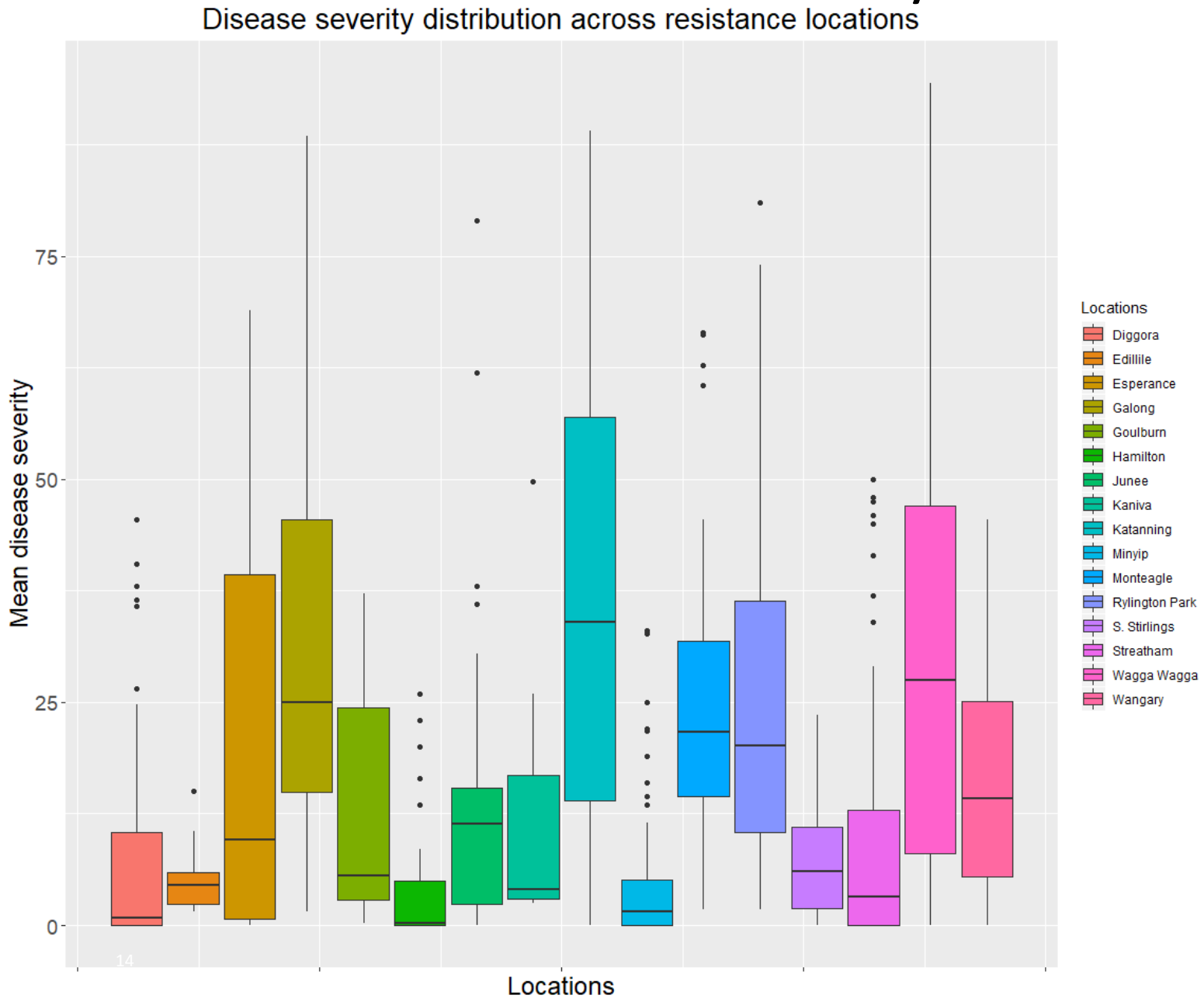
Disease severity varies amongst years



Means comparison test on disease severity :

(2014 ~ 2016) < (2013~2015)

Disease severity varies amongst location

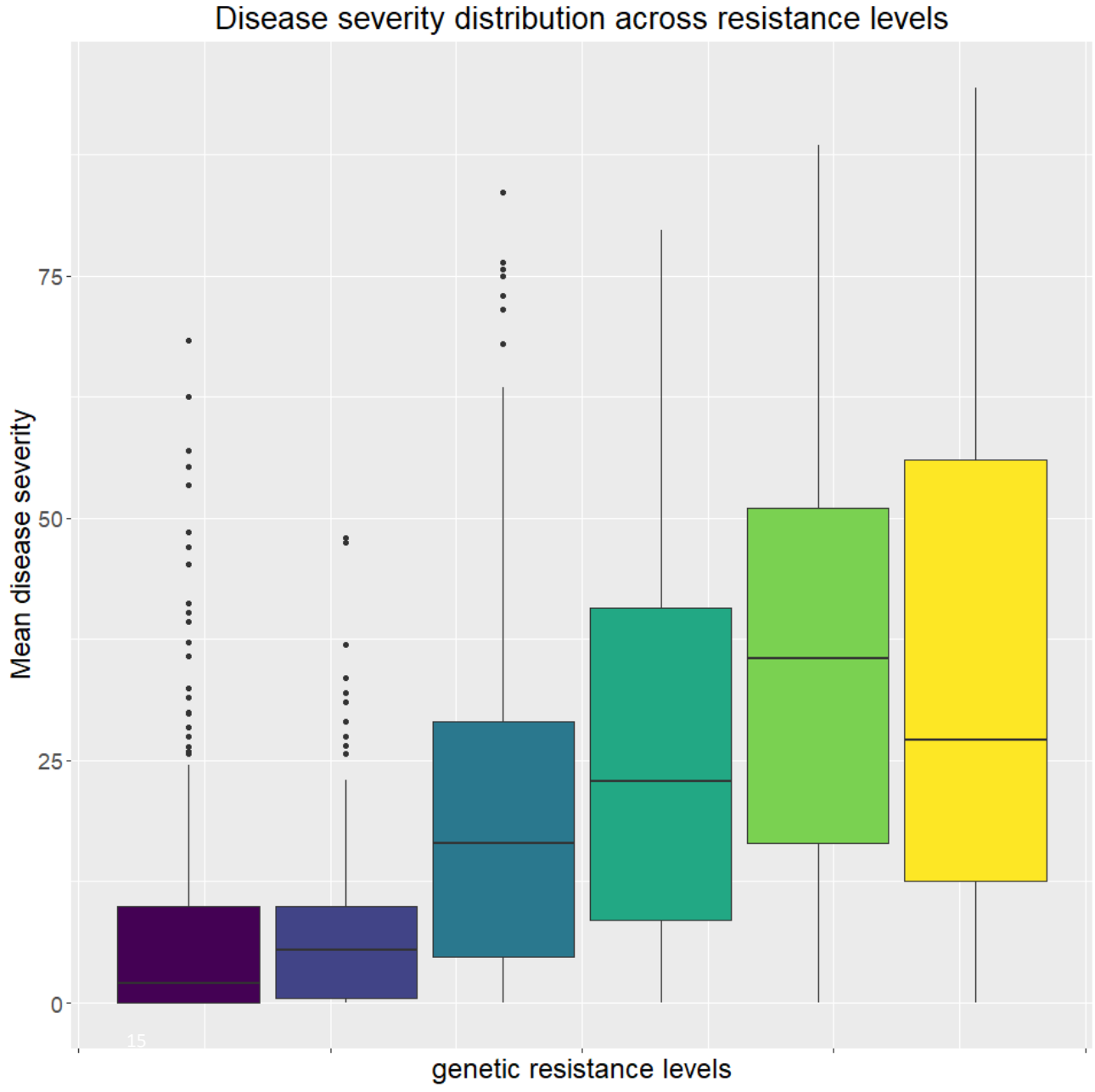


Means comparison test on disease severity :

~ 4 groups with significantly different disease levels

No obvious link between distance and significant difference

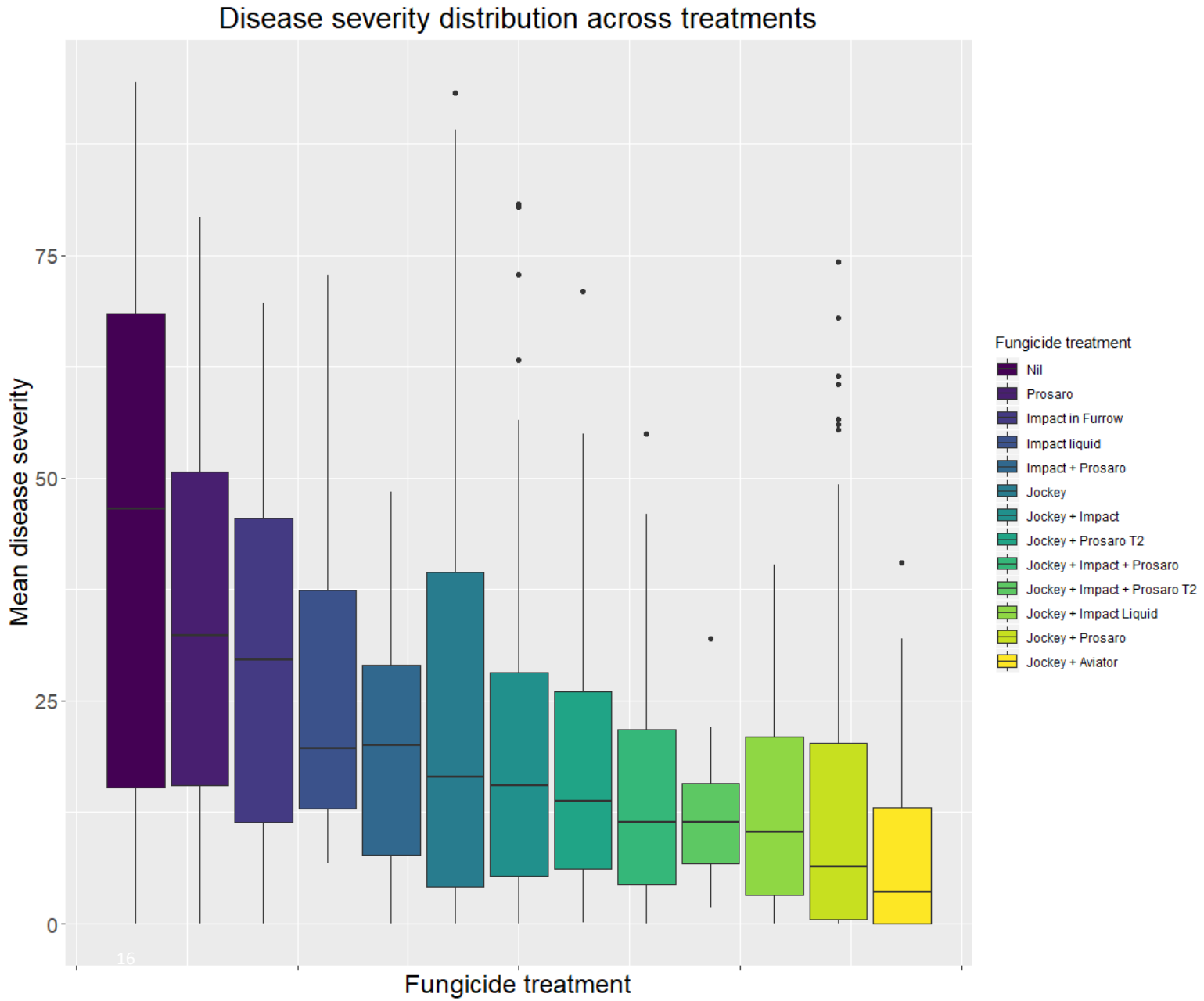
Disease severity varies amongst resistance levels



Means comparison test on genetic resistance:

(R~R-MR) < MR < MR-MS < (MS~MS-S)

Disease severity varies amongst fungicide treatments



Fungicide treatments allow a large disease severity distribution

Disease severity distribution: importance of genetics, environmental factors, and cultivation practices

In a nutshell:

- Many parameters influencing disease level
- Complex interaction between those parameters
- Incomplete, unbalanced data set

II) How do those parameters influence the yield-disease relationship ?

“Kitchen sink”/Fully-factorial analysis and sources of yield variability

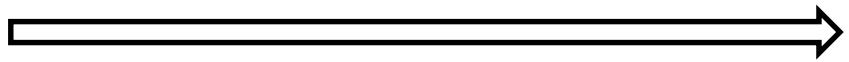
```
Linear mixed model fit by REML ['lmerMod']
Formula: Yield..kg.Ha. ~ Rep.severity.means + Year + Long.term.Apr.Jun +      Long.term.total + (1 | Location) + (1 | Variety)
   Data: yield.disease.rainfall.cat.df

REML criterion at convergence: 19638.1

Scaled residuals:
    Min      1Q  Median      3Q     Max
-4.1824 -0.5968 -0.0234  0.5509  5.0465

Random effects:
 Groups   Name        Variance Std.Dev.
 Variety  (Intercept) 107348   327.6
 Location (Intercept) 532633   729.8
 Residual             109738   331.3
Number of obs: 1352, groups:  Variety, 22; Location, 16

Fixed effects:
                   Estimate Std. Error t value
(Intercept)         310.0537   239.1471   1.296
Rep.severity.means   -3.6837     0.6534  -5.638
Year2014            -19.6025    75.6778  -0.259
Year2015           -236.7615    46.3136  -5.112
Year2016           -530.1212   558.7573  -0.949
Long.term.Apr.Jun   -10.3906     0.8647 -12.016
Long.term.total       9.8900     0.4789  20.650

Correlation of Fixed Effects:
            (Intr) Rp.sv. Yr2014 Yr2015 Yr2016 L..A.J
Rp.svrty.mn -0.042
Year2014    -0.003  0.138
Year2015    -0.140 -0.114  0.142
Year2016    -0.265  0.008  0.027  0.048
Lng.trm.A.J  0.005 -0.085 -0.850 -0.010 -0.006
Lng.trm.ttl -0.338  0.033  0.582  0.103 -0.035 -0.720
```

“Kitchen sink”/Fully-factorial analysis and sources of yield variability

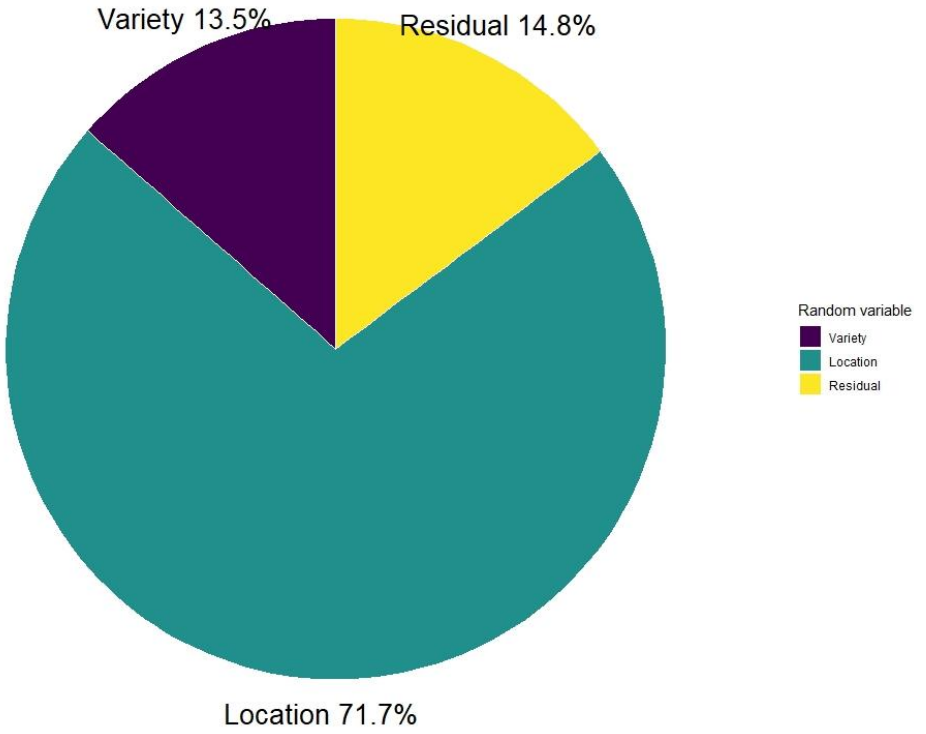
```
Linear mixed model fit by REML ['lmerMod']
Formula: Yield..kg.Ha. ~ Rep.severity.means + Year + Long.term.Apr.Jun +      Long.term.total + (1 | Location) + (1 | Variety)
   Data: yield.disease.rainfall.cat.df

REML criterion at convergence: 19638.1

Scaled residuals:
    Min      1Q  Median      3Q     Max
-4.1824 -0.5968 -0.0234  0.5509  5.0465

Random effects:
 Groups   Name        Variance Std.Dev.
 Variety  (Intercept) 107348   327.6
 Location (Intercept) 532633   729.8
 Residual             109738   331.3
Number of obs: 1352, groups:  Variety, 22; Location, 16

Fixed effects:
                   Estimate Std. Error t value
(Intercept)         310.0537   239.1471   1.296
Rep.severity.means   -3.6837     0.6534  -5.638
Year2014            -19.6025    75.6778  -0.259
Year2015           -236.7615    46.3136  -5.112
Year2016           -530.1212   558.7573  -0.949
Long.term.Apr.Jun   -10.3906     0.8647 -12.016
Long.term.total       9.8900     0.4789  20.650

Correlation of Fixed Effects:
            (Intr) Rp.sv. Yr2014 Yr2015 Yr2016 L..A.J
Rp.svrty.mn -0.042
Year2014    -0.003  0.138
Year2015    -0.140 -0.114  0.142
Year2016    -0.265  0.008  0.027  0.048
Lng.trm.A.J  0.005 -0.085 -0.850 -0.010 -0.006
Lng.trm.ttl -0.338  0.033  0.582  0.103 -0.035 -0.720
```

“Kitchen sink”/Fully-factorial analysis and sources of yield variability

```
Linear mixed model fit by REML ['lmerMod']
Formula: Yield..kg.Ha. ~ Rep.severity.means + Year + Long.term.Apr.Jun +      Long.term.total + (1 | Location) + (1 | Variety)
   Data: yield.disease.rainfall.cat.df

REML criterion at convergence: 19638.1

Scaled residuals:
    Min      1Q  Median      3Q     Max
-4.1824 -0.5968 -0.0234  0.5509  5.0465

Random effects:
 Groups   Name        Variance Std.Dev.
 Variety  (Intercept) 107348   327.6
 Location (Intercept) 532633   729.8
 Residual             109738   331.3
Number of obs: 1352, groups:  Variety, 22; Location, 16

Fixed effects:
                   Estimate Std. Error t value
(Intercept)         310.0537   239.1471   1.296
Rep.severity.means   -3.6837     0.6534  -5.638
Year2014            -19.6025    75.6778  -0.259
Year2015           -236.7615    46.3136  -5.112
Year2016           -530.1212   558.7573  -0.949
Long.term.Apr.Jun   -10.3906     0.8647 -12.016
Long.term.total       9.8900     0.4789  20.650

Correlation of Fixed Effects:
            (Intr) Rp.sv. Yr2014 Yr2015 Yr2016 L..A.J
Rp.svrty.mn -0.042
Year2014    -0.003  0.138
Year2015    -0.140 -0.114  0.142
Year2016    -0.265  0.008  0.027  0.048
Lng.trm.A.J  0.005 -0.085 -0.850 -0.010 -0.006
Lng.trm.ttl -0.338  0.033  0.582  0.103 -0.035 -0.720
```

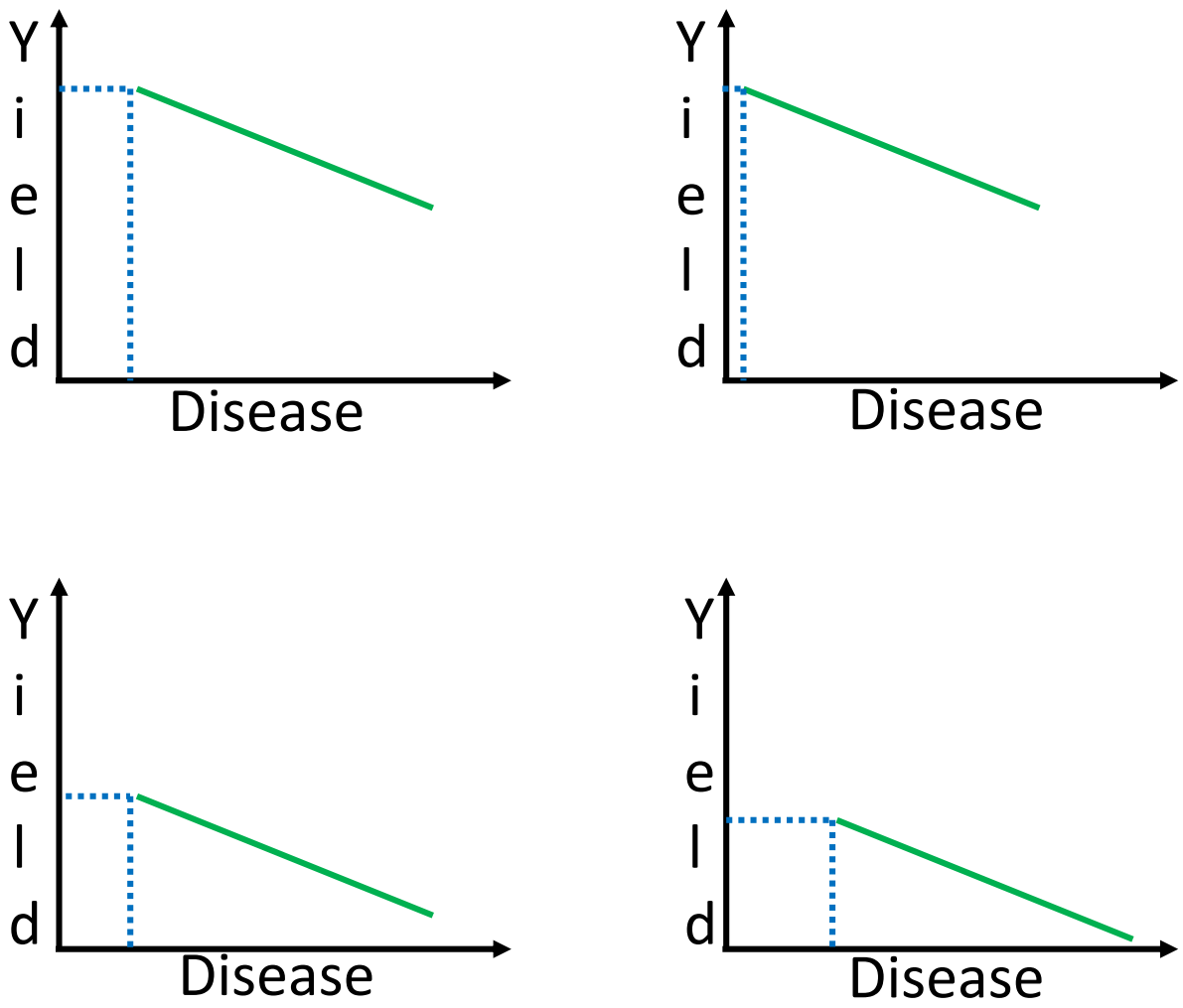


Impact of control parameters
on yield-disease relationship variability



Mixed linear model : assessing yield-disease relationship

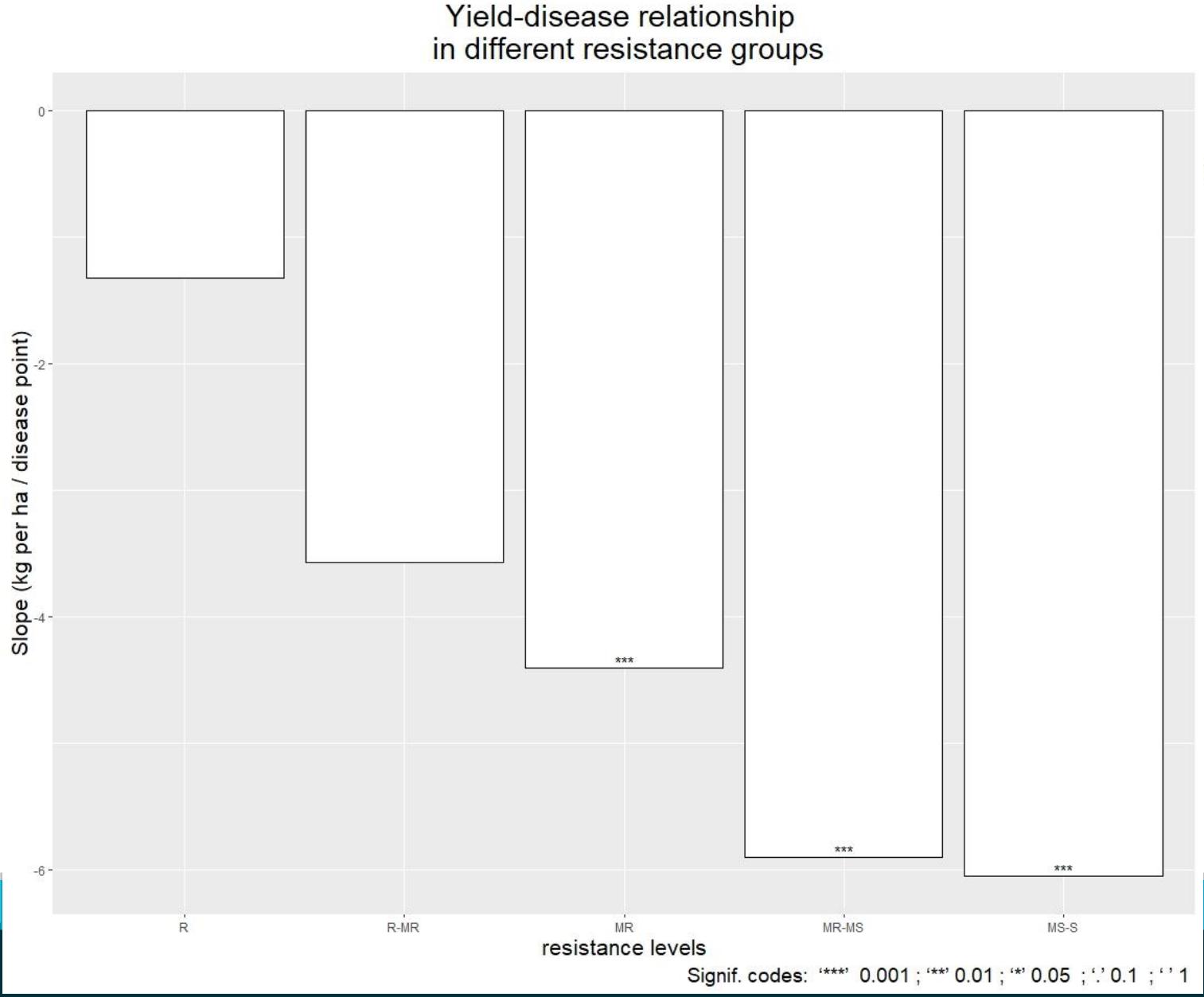
Controlling for a parameter



Relationship assessed by the slope :

yield loss according to disease severity

Sources of yield variability : the impact of genetics and environment



For each genetic resistance category :

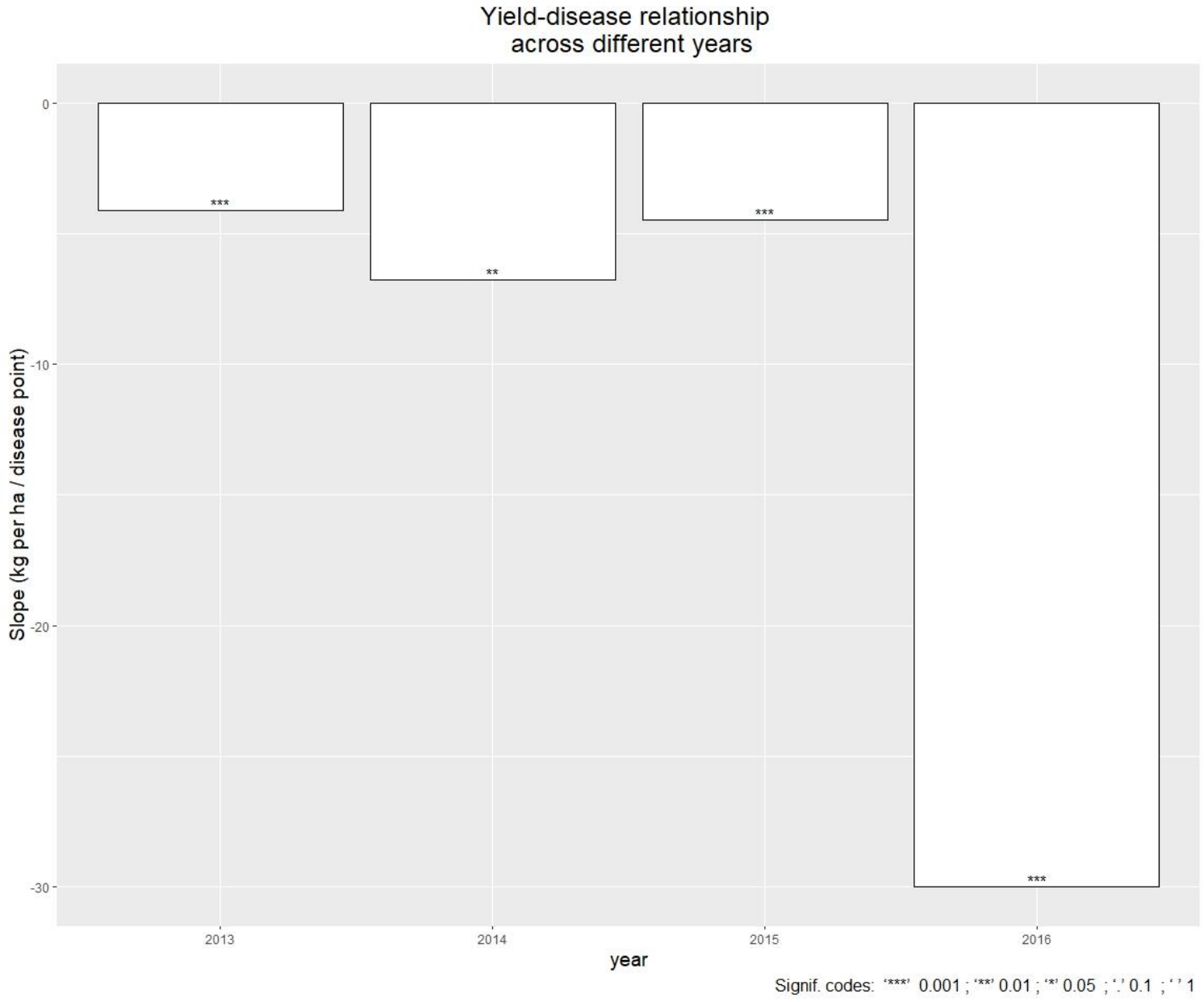
```
Formula: Yield..kg.Ha. ~ Rep.severity.means + Year + Long.term.Apr.Jun
+ Long.term.total + (1 | Location) + (1 | Variety)
```

Sources of yield variability : the impact of genetics and environment

For each genetic resistance category :

```
Formula: Yield..kg.Ha. ~ Rep.severity.means + Year + Long.term.Apr.Jun
+ Long.term.total + (1 | Location) + (1 | Variety)
```

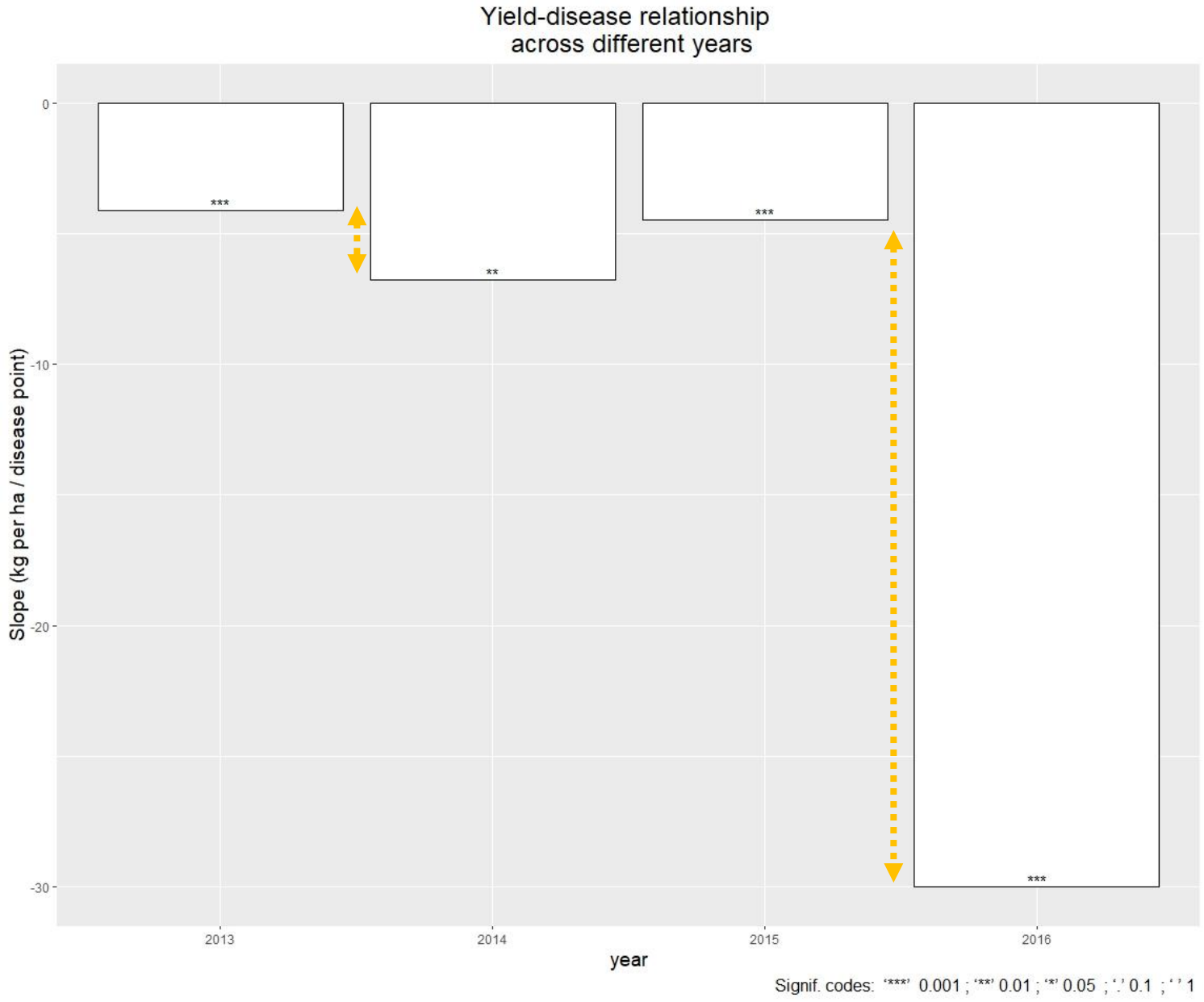
Sources of yield variability : the impact of genetics and environment



For each "Year" category :

Formula: Yield..kg.Ha. ~ Rep.severity.means + Long.term.Apr.Jun + Long.term.total + (1 | Location) + (1 | Variety)

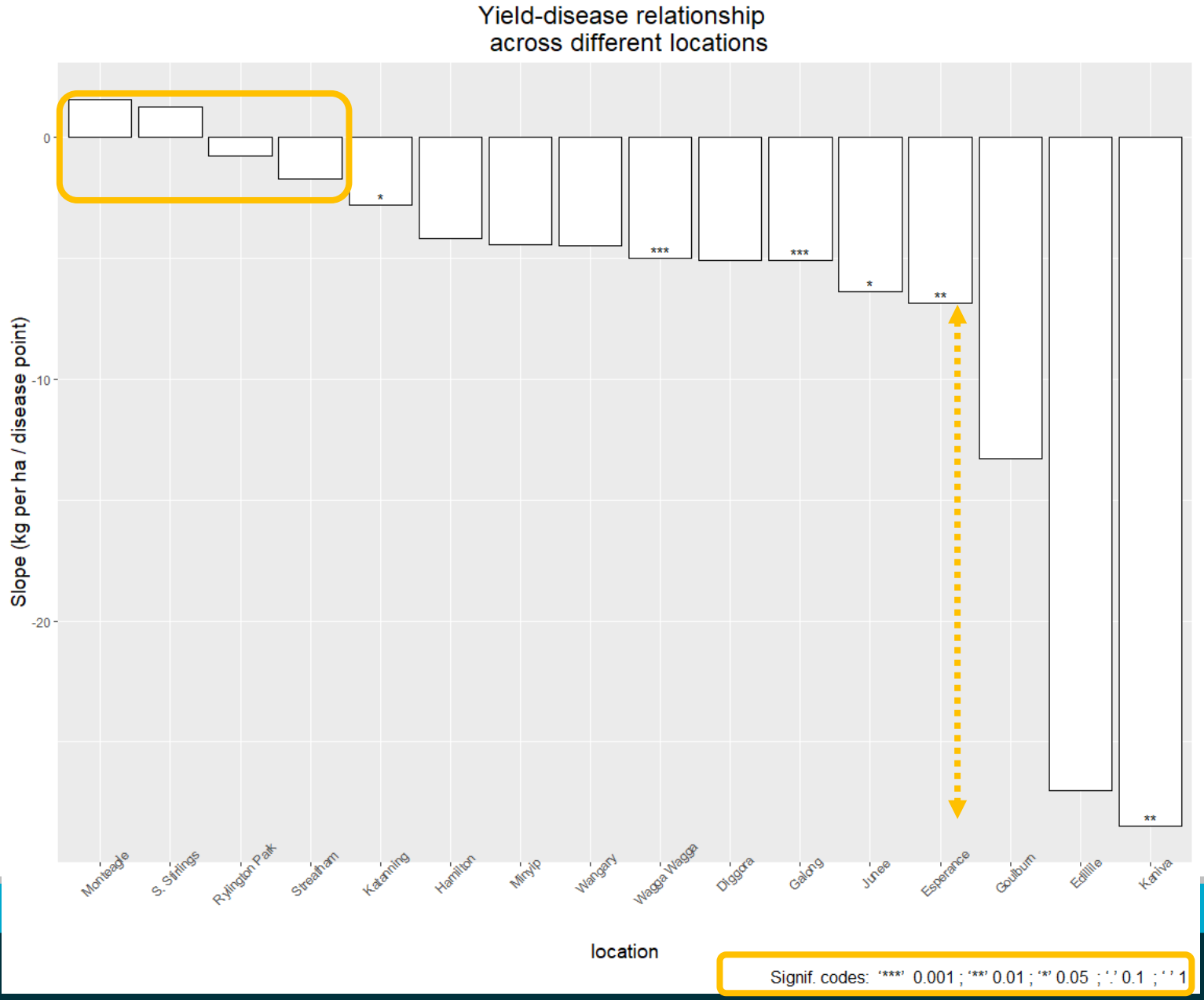
Sources of yield variability : the impact of genetics and environment



For each "Year" category :

```
Formula: Yield..kg.Ha. ~ Rep.severity.means + Long.term.Apr.Jun +
    Long.term.total + (1 | Location) + (1 | Variety)
```

Sources of yield variability : the impact of genetics and environment



For each "Location" category :

```
Formula: Yield..kg.Ha. ~ Rep.severity.means + Year + (1 | Location)
```

III) What is the yield response to disease presence ?

Yield-disease relationship : a distribution across significant observation

For each Year*Location*Variety observation :

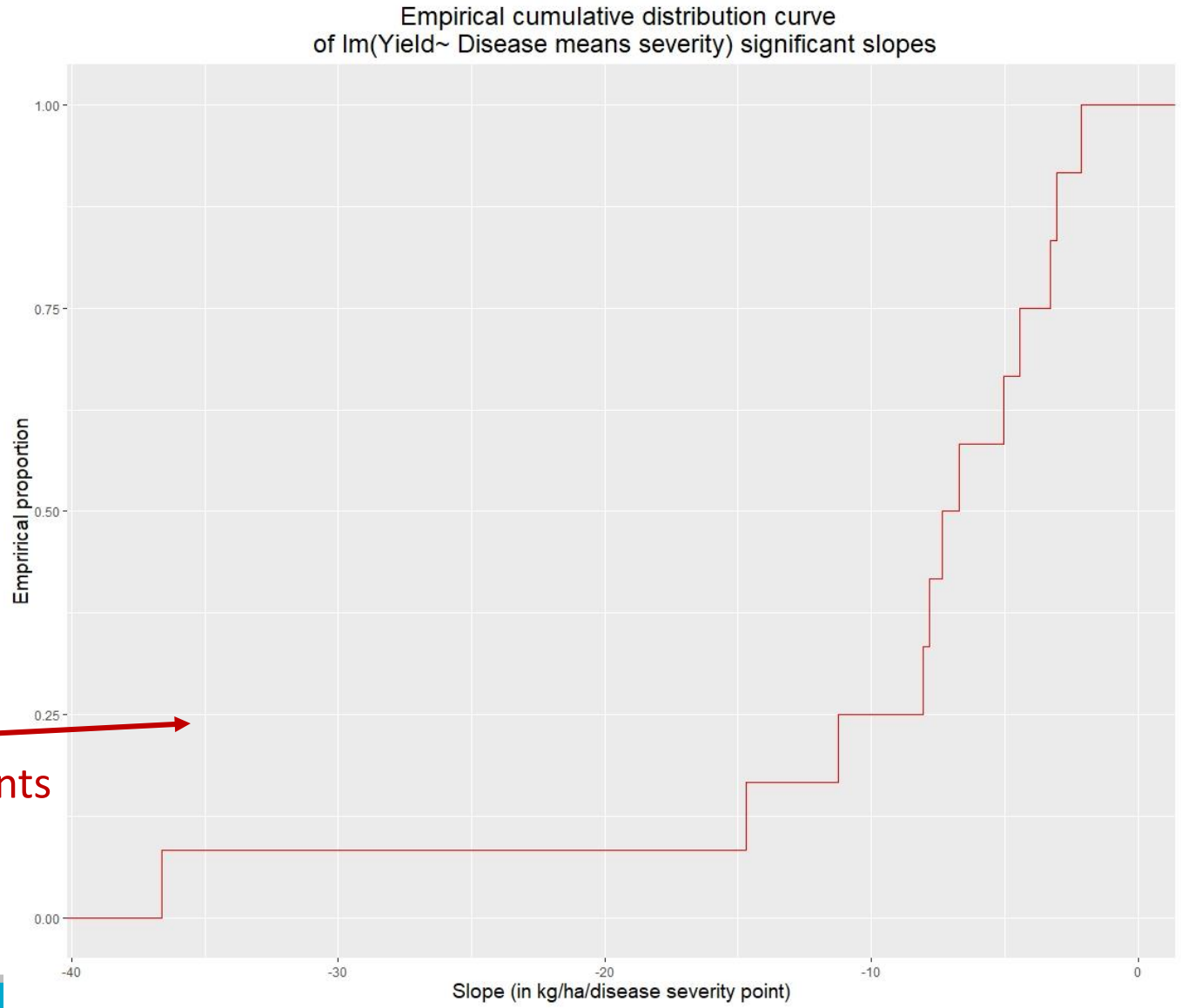
lm(Yield..kg.Ha.~Rep.severity.means)

Simple linear equation of the form :

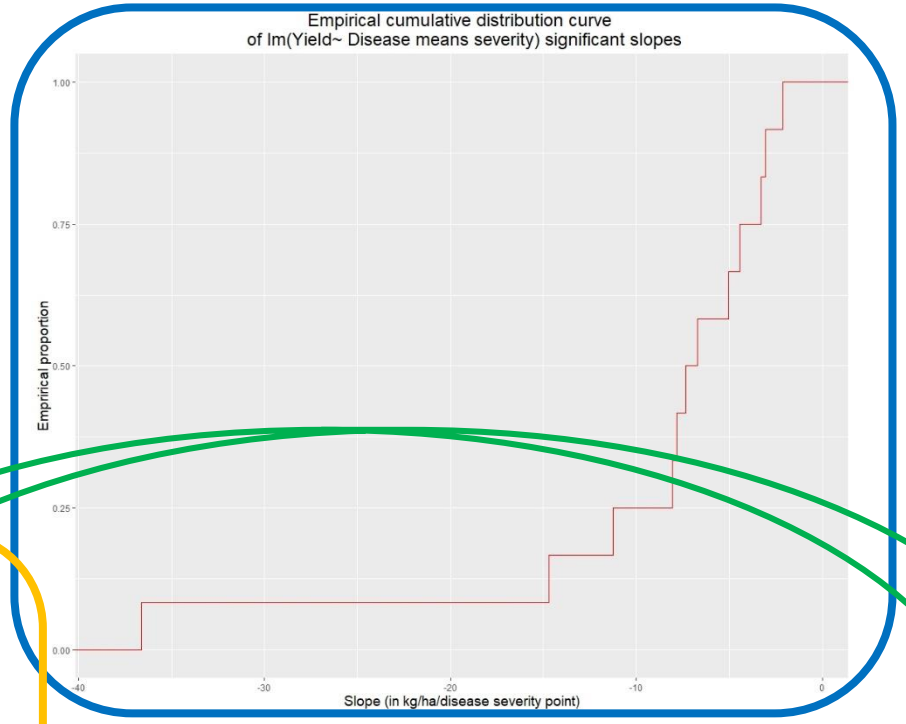
$Y = a + bX$

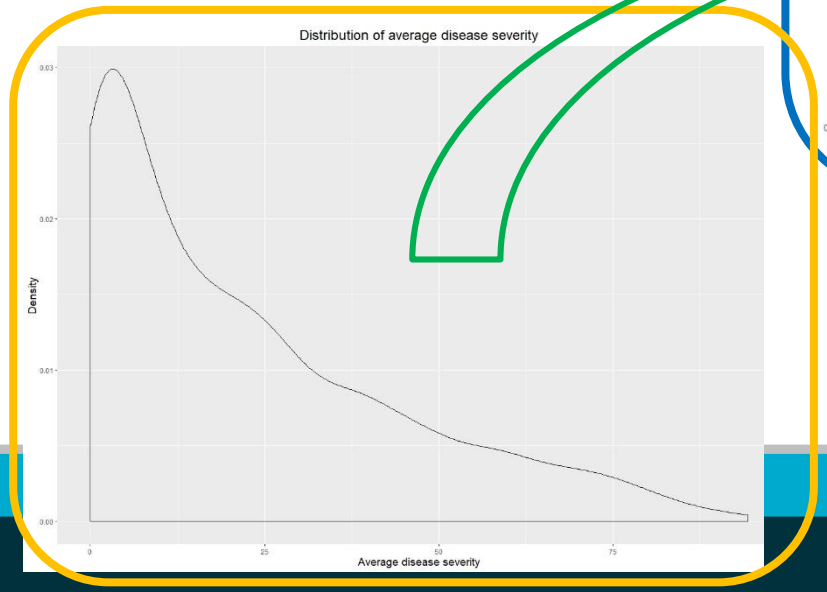
Distribution of all significant “b” coefficients

With :
Y representing the yield, and
X the mean severity score



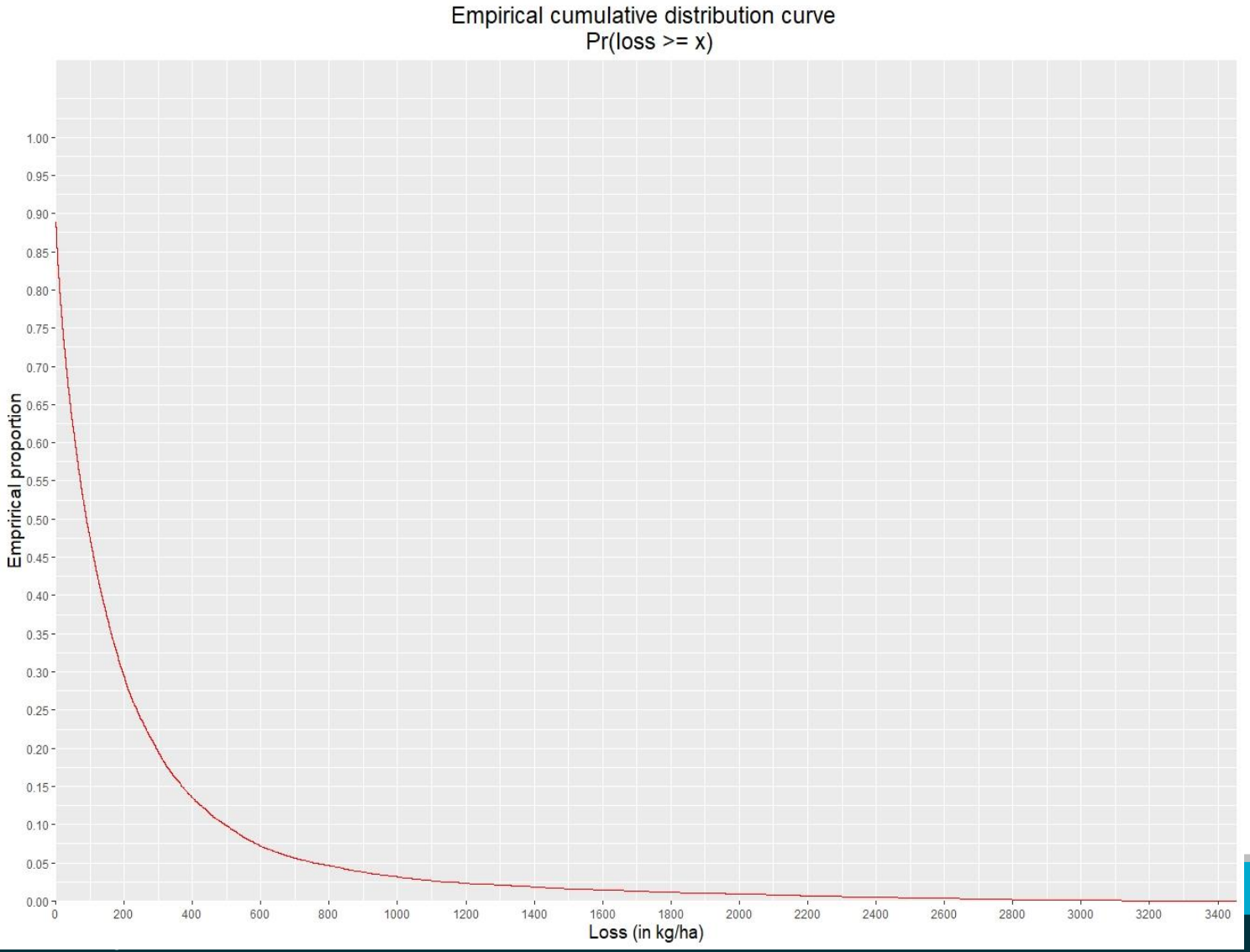
Yield-disease relationship : an estimation of the loss



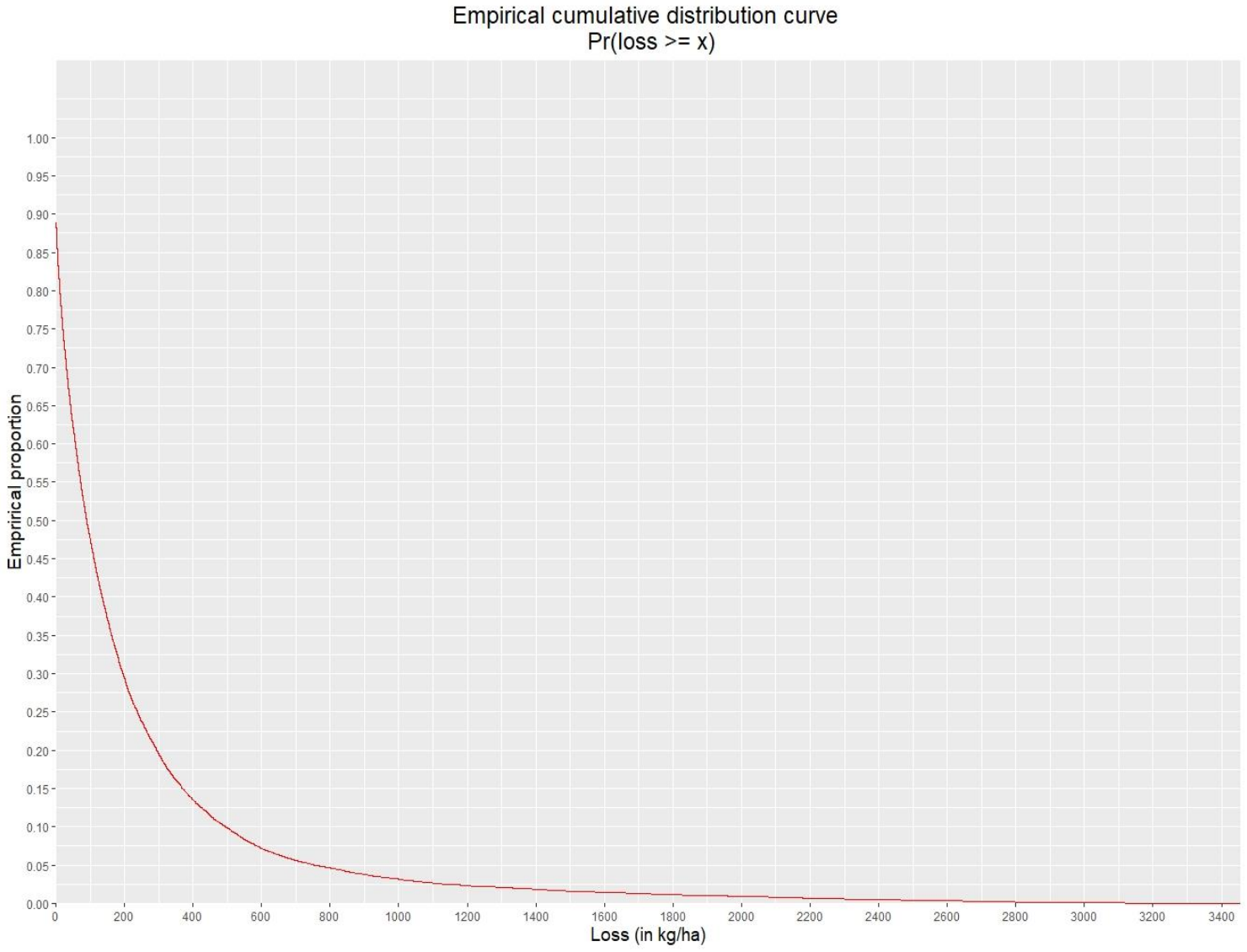


Potential loss $_{i,j}$ (kg/ha) =
Repetition Disease Severity means $_{i}$ (%^{age}) * Potential relationship slope $_{j}$ (kg/ha/ %^{age} point)

Yield-disease relationship :
a distribution of estimated loss across samples



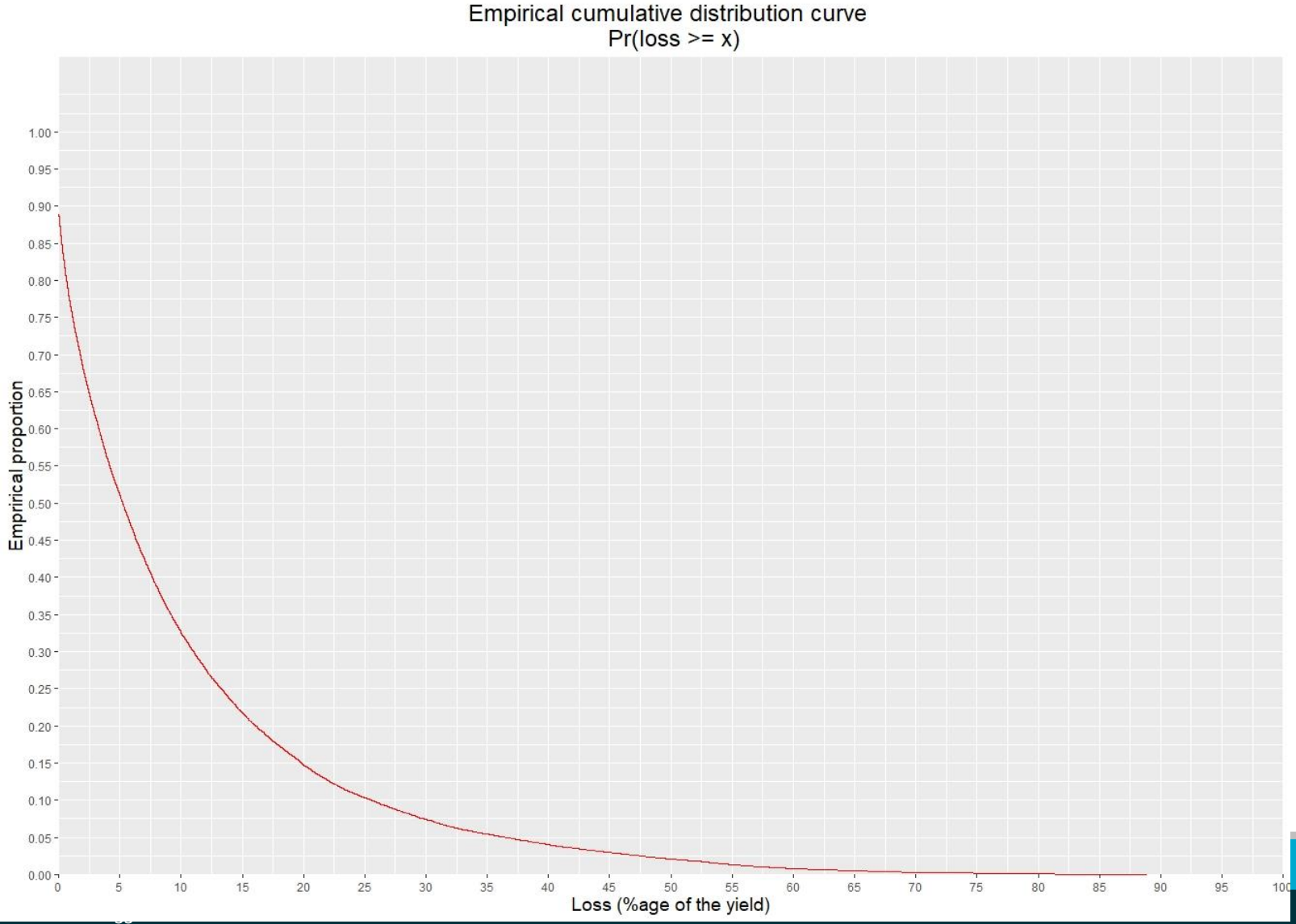
Yield-disease relationship :
a distribution of estimated loss across samples



Potential loss $_{i,j}$ (kg/ha) =
Repetition Disease Severity means $_{i}$ (%^{age}) *
Potential relationship slope $_{j}$ (kg/ha/ %^{age} point)

Potential loss $_{i,j}$ (percentage of potential yield) =
Potential loss $_{i,j}$ (kg/ha) /
(Yield $_{i}$ (kg/ha) + Potential loss $_{i,j}$ (kg/ha))

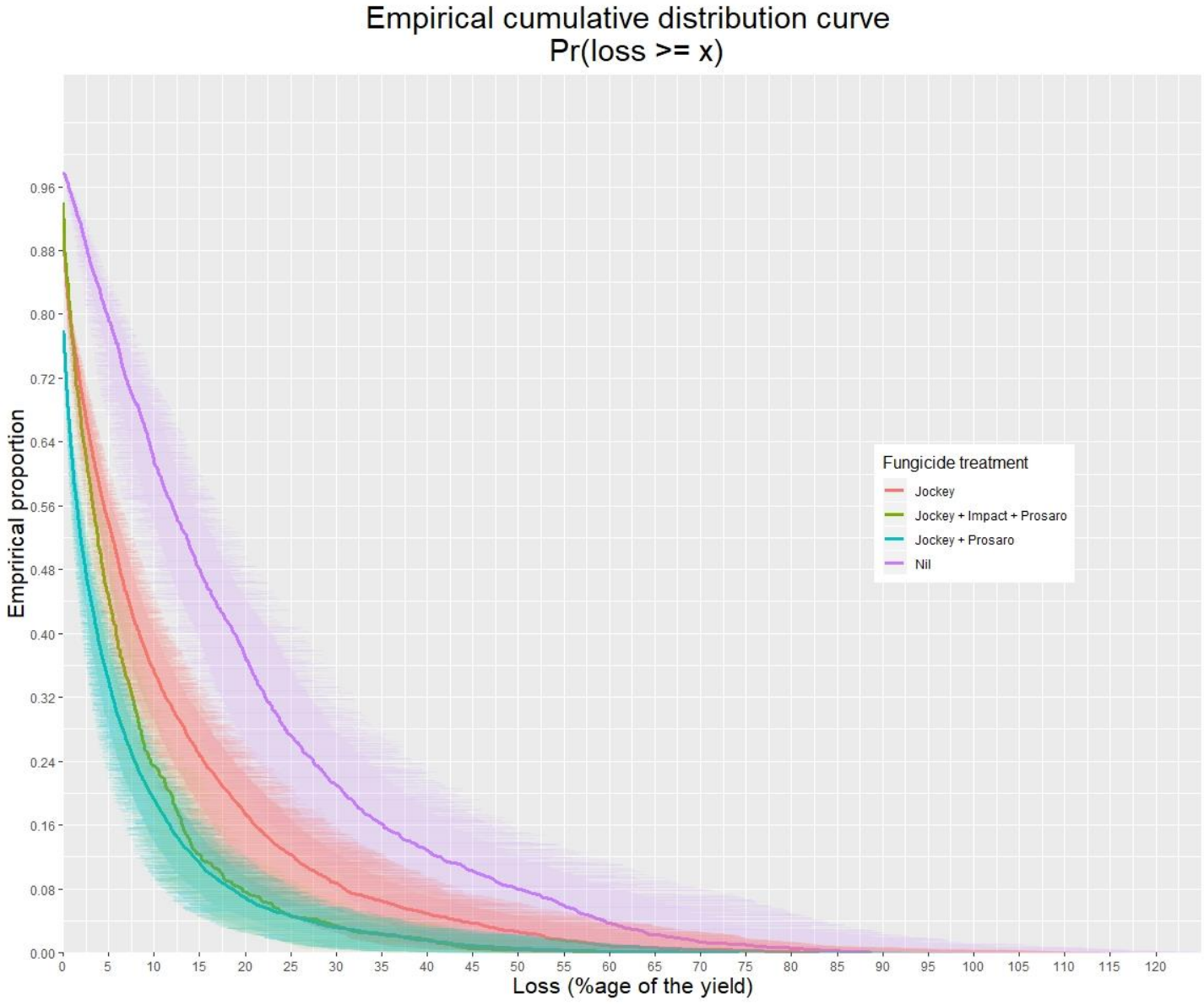
Yield-disease relationship : a distribution of estimated loss across samples



Under the assumption of significant yield-disease relationship conditions :

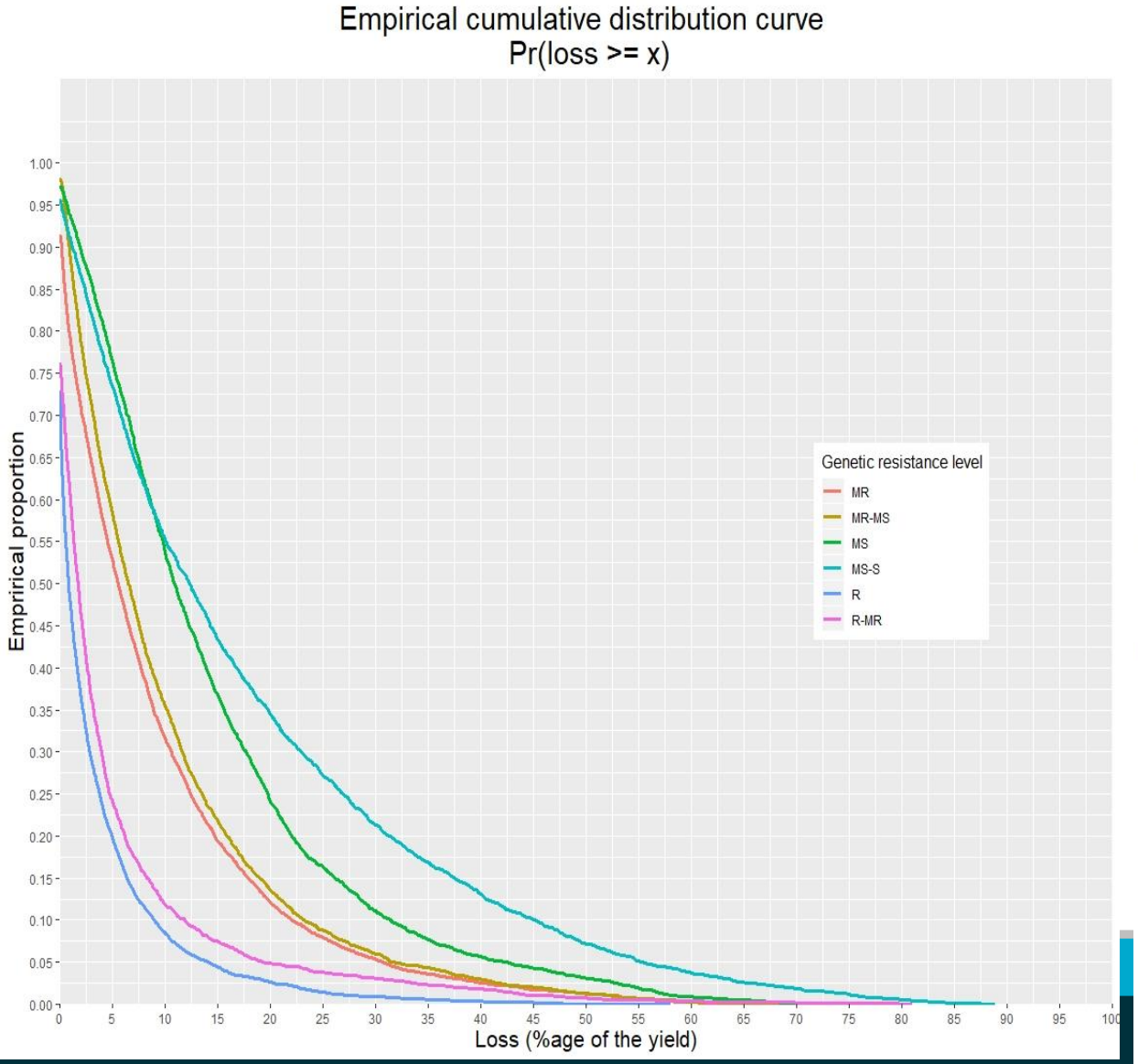
Empirical cumulative distribution curve of loss close to a linear function of log(percentage loss)

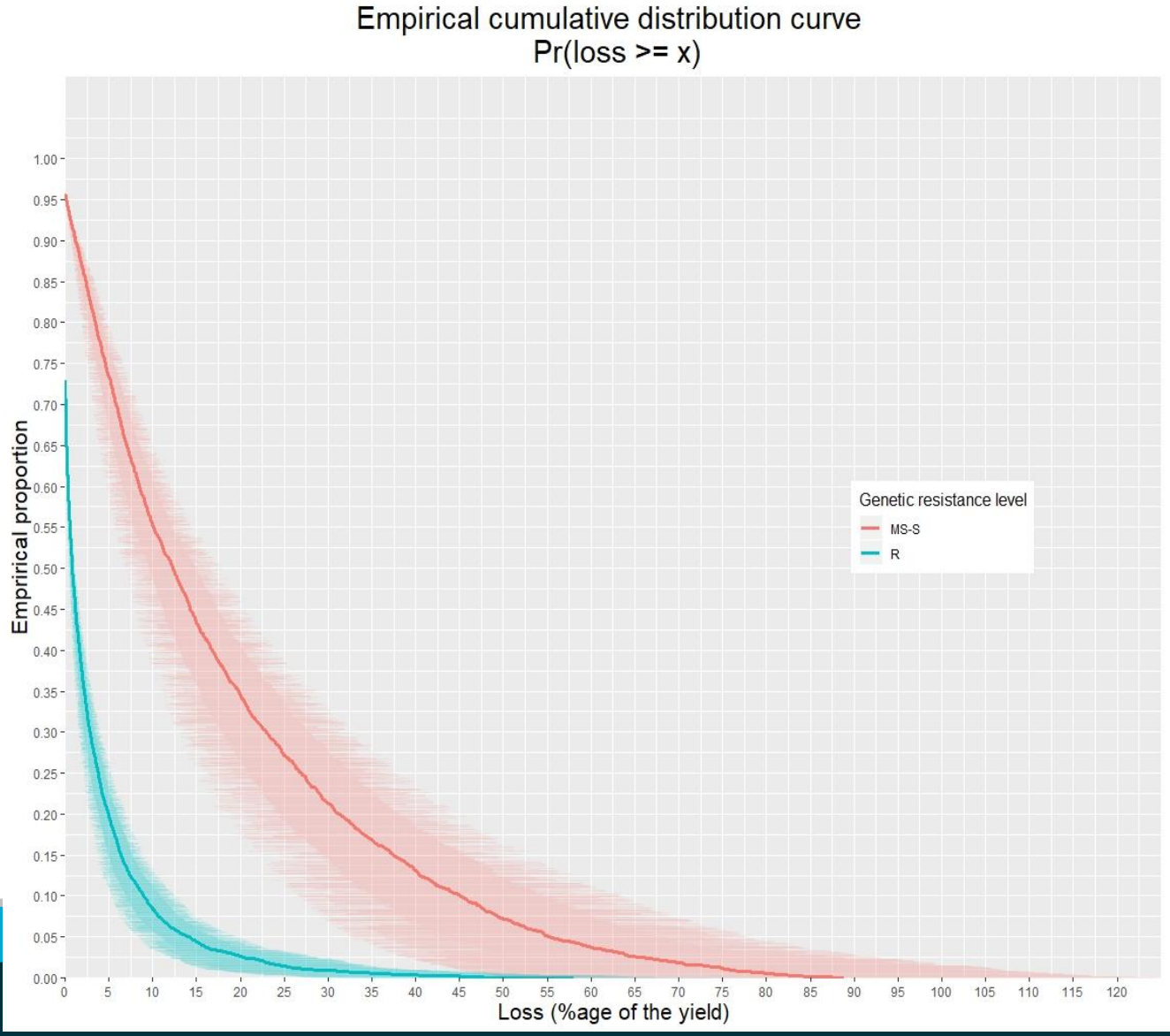
Yield-disease relationship :
a distribution of estimated loss weighted by fungicide treatment type



Difference between all three fungicide treatments distribution curves is never greater than the associated standard error.

Yield-disease relationship :
a distribution of estimated loss weighted by genetic resistance





Conclusion :
Effect of Blackleg on Canola

- Disease progression, severity, and yield-disease relationship all depend on environmental factors and genetics.

- Using this data, we could get economic parameters to fit into disease management models.

Acknowledgements :

to the multi-organisation team who collected this data, acknowledging their thorough work,

to Tim Capon and Ann Seitzinger, for their kind support and advice,

to Luke Barrett and Susie Sprague, for supervising this project,

to Sorada Tapsuwan, for her tips on statistics,

and all CSIRO Black Mountain A & F team for their warm welcoming.

Bibliography

[1] Fitt BDL, Hu BC, Li ZQ *et al.* , 2008. *Strategies to prevent spread of* Leptosphaeria maculans *(phoma stem canker) onto oilseed rape crops in China; costs and benefits*. *Plant Pathology* **57**, 652–64.

[2] R. Khangura, A. Hills, C. Beard, Updated 15th August 2019, *Managing blackleg in canola,* Department of Primary Industries and Regional development website, available at : <https://www.agric.wa.gov.au/canola/managing-blackleg-canola?page=0%2C0>

[3] Sprague SJ, Balesdent MH, Brun H, Hayden HL, Marcroft SJ, Pinochet X, Rouxel T, Howlett BJ (2006) Major gene resistance in Brassica napus (oilseed rape) is overcome by changes in virulence of populations of Leptosphaeria maculans in France and Australia. European Journal of Plant Pathology 114, 33–40. doi:10.1007/s10658-005-3683-5

[4] Commonwealth of Australia 2020, Bureau of Meteorology, Climate Data Online, available at : <http://www.bom.gov.au/climate/data/>

[5] D.E. Seberry, D.W. McCaffery, T.M. Kingham (2017) *Quality of Australian Canola,* Volume 23, ISSN 1322-9397

Other references :

Australian Bureau of Agricultural and Resource Economics and Sciences, *Australian crop report* No. 187 , September 2018

Sprague et al., 2007, *Pathways of infection of* Brassica napus *roots by* Leptosphaeria maculans, available at: < https://nph.onlinelibrary.wiley.com/doi/full/10.1111/j.1469-8137.2007.02156.x >

Bibliography

Means comparison test for treatments

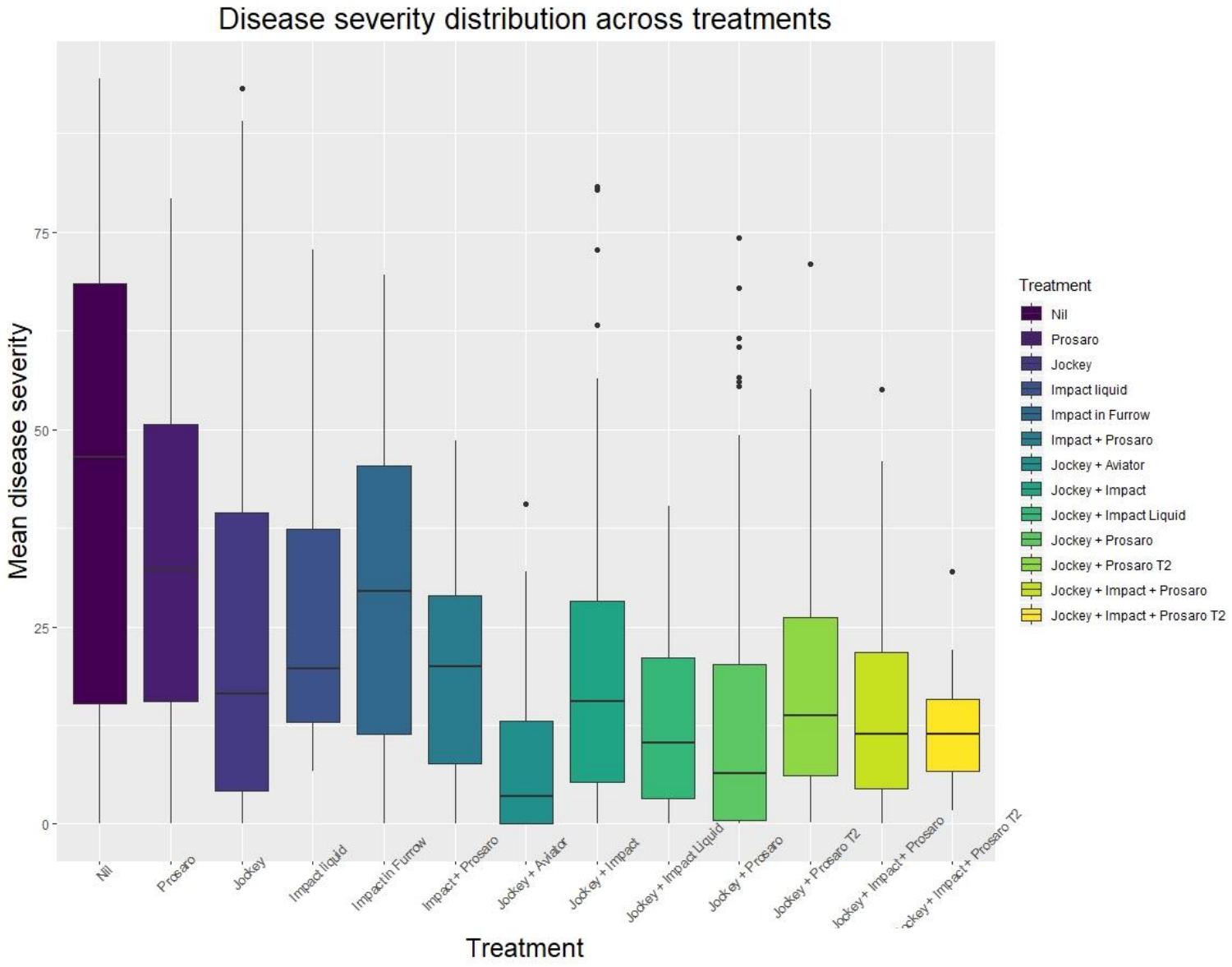
Pairwise comparisons using Wilcoxon rank sum test

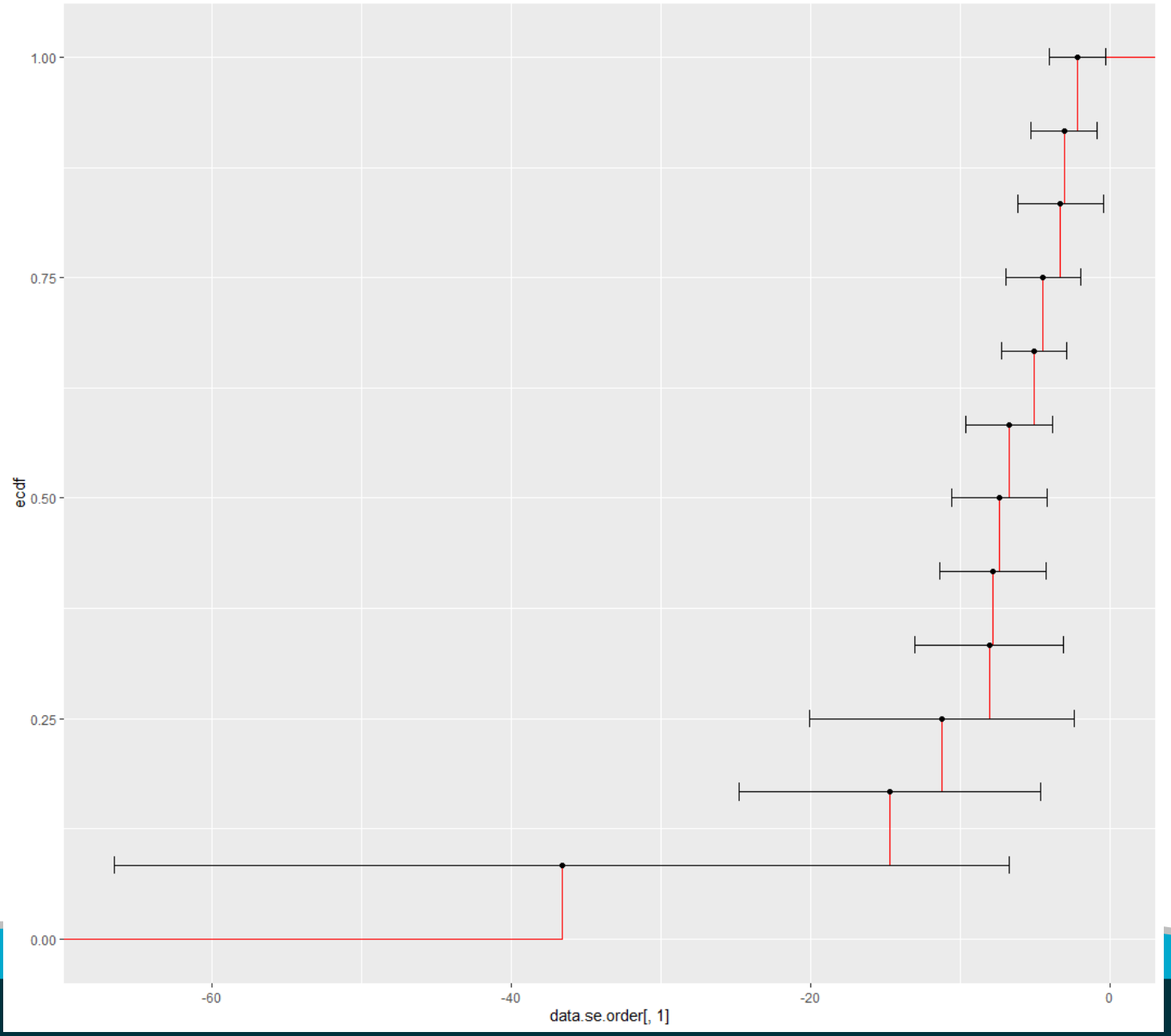
data: yield.disease.rainfall.cat.df$Rep.severity.means and yield.disease.rainfall.cat.df$Treatment

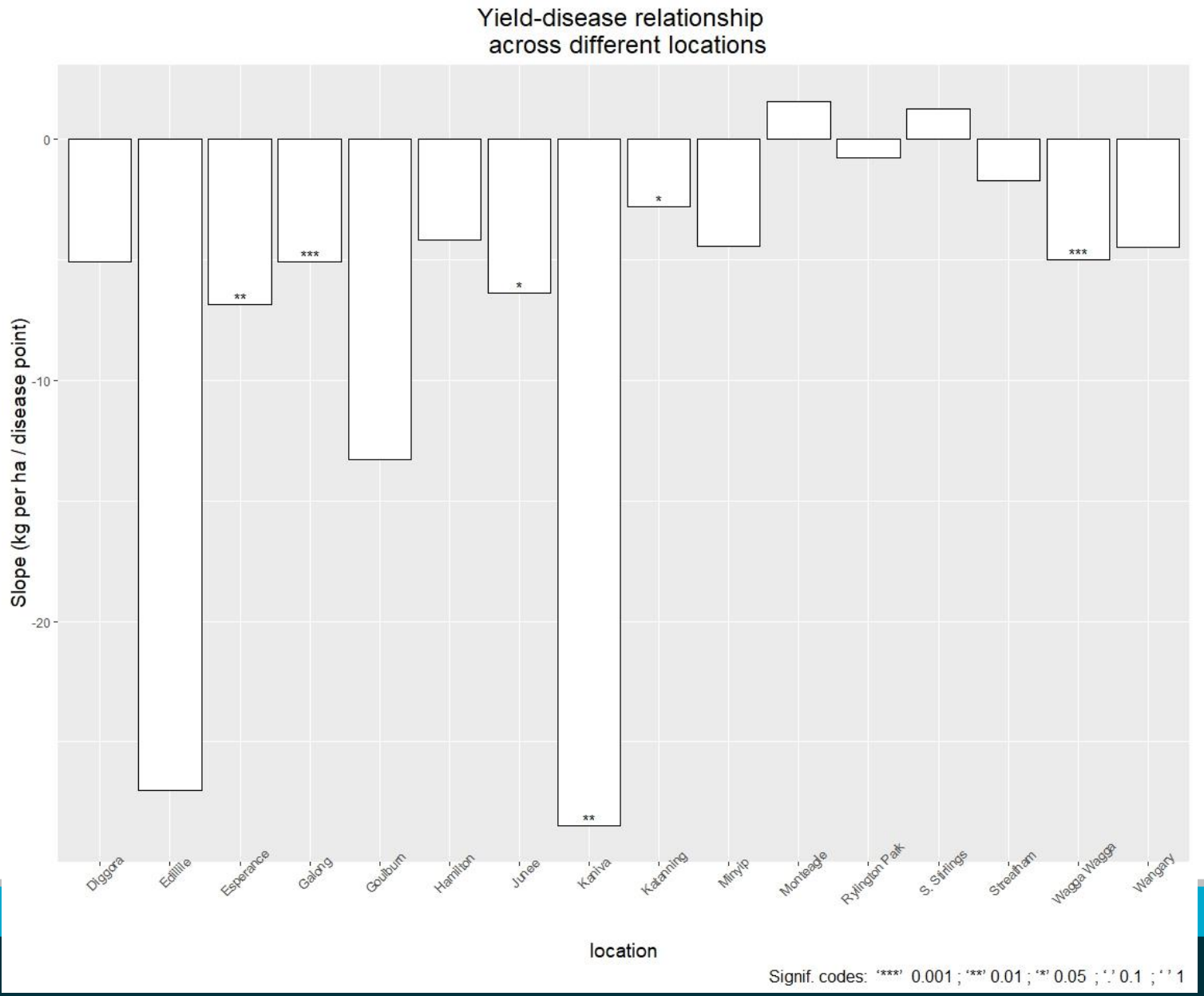
	Impact + Prosaro	Impact in Furrow	Impact liquid	Jockey	Jockey + Aviator	Jockey + Impact	Jockey + Impact + Prosaro
Impact in Furrow	0.02115	-	-	-	-	-	-
Impact liquid	0.49290	0.67929	-	-	-	-	-
Jockey	0.91594	0.01542	0.40769	-	-	-	-
Jockey + Aviator	3.2e-05	8.3e-10	0.00062	7.0e-07	-	-	-
Jockey + Impact	0.65300	0.00284	0.24780	0.61632	6.8e-06	-	-
Jockey + Impact + Prosaro	0.03744	8.6e-06	0.03163	0.03163	0.00176	0.10781	-
Jockey + Impact + Prosaro T2	0.13775	0.01660	0.06425	0.34086	0.05563	0.33780	0.89032
Jockey + Impact Liquid	0.08460	0.00145	0.04210	0.13463	0.03744	0.17285	0.70782
Jockey + Prosaro	0.00074	2.4e-12	0.00480	2.6e-10	0.06425	2.4e-05	0.05563
Jockey + Prosaro T2	0.43894	0.00959	0.16386	0.48880	0.00068	0.71807	0.39783
Nil	2.6e-05	0.00068	0.11612	2.6e-10	8.6e-14	1.7e-08	2.6e-10
Prosaro	0.00137	0.26138	0.34812	0.00021	2.3e-11	3.2e-05	6.7e-08

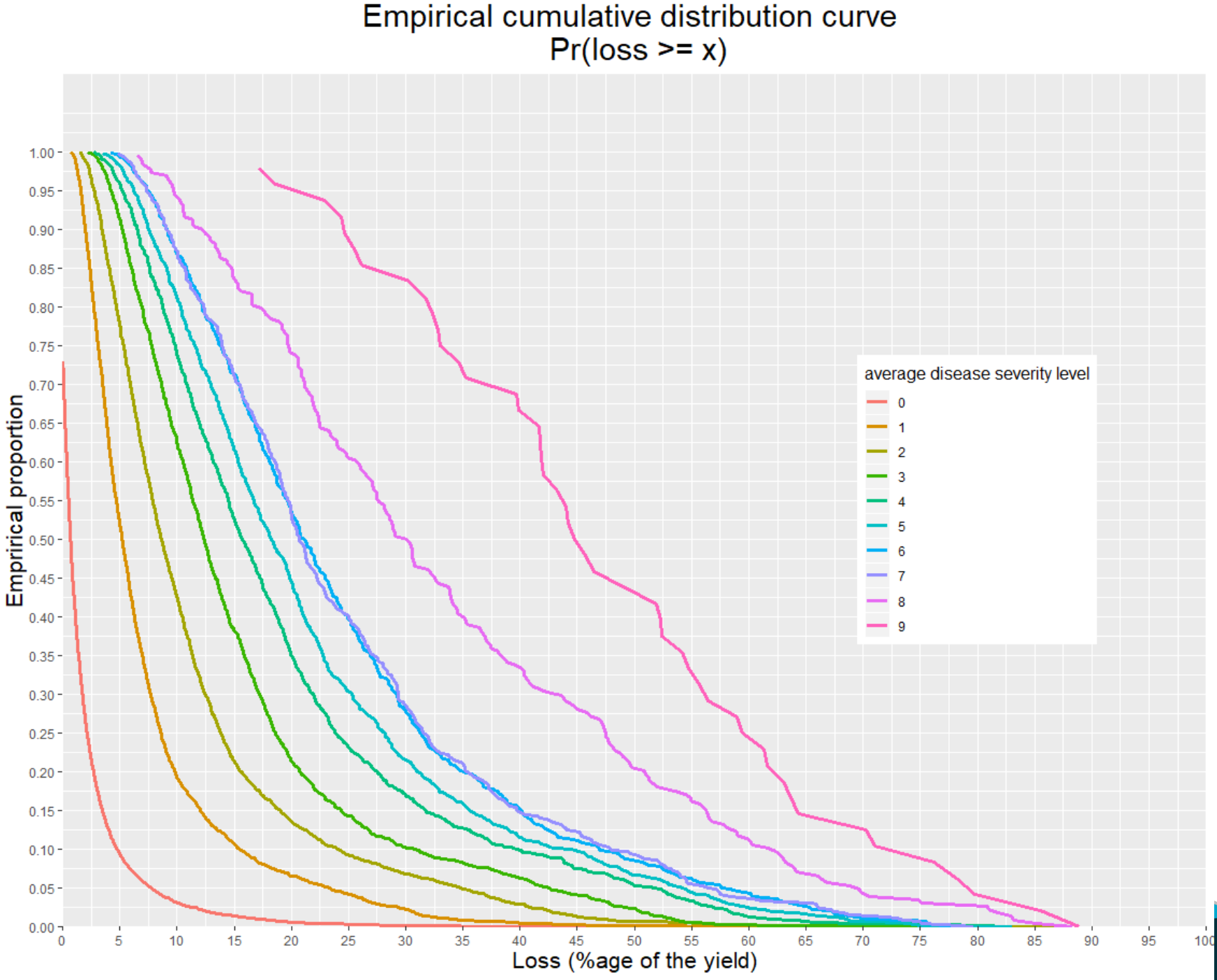
	Jockey + Impact + Prosaro T2	Jockey + Impact Liquid	Jockey + Prosaro	Jockey + Prosaro T2	Nil
Impact in Furrow	-	-	-	-	-
Impact liquid	-	-	-	-	-
Jockey	-	-	-	-	-
Jockey + Aviator	-	-	-	-	-
Jockey + Impact	-	-	-	-	-
Jockey + Impact + Prosaro	-	-	-	-	-
Jockey + Impact + Prosaro T2	-	-	-	-	-
Jockey + Impact Liquid	0.75131	-	-	-	-
Jockey + Prosaro	0.36398	0.37417	-	-	-
Jockey + Prosaro T2	0.54246	0.40879	0.02616	-	-
Nil	0.00145	2.4e-05	< 2e-16	2.2e-05	-
Prosaro	0.00306	0.00024	5.9e-16	0.00068	0.01893

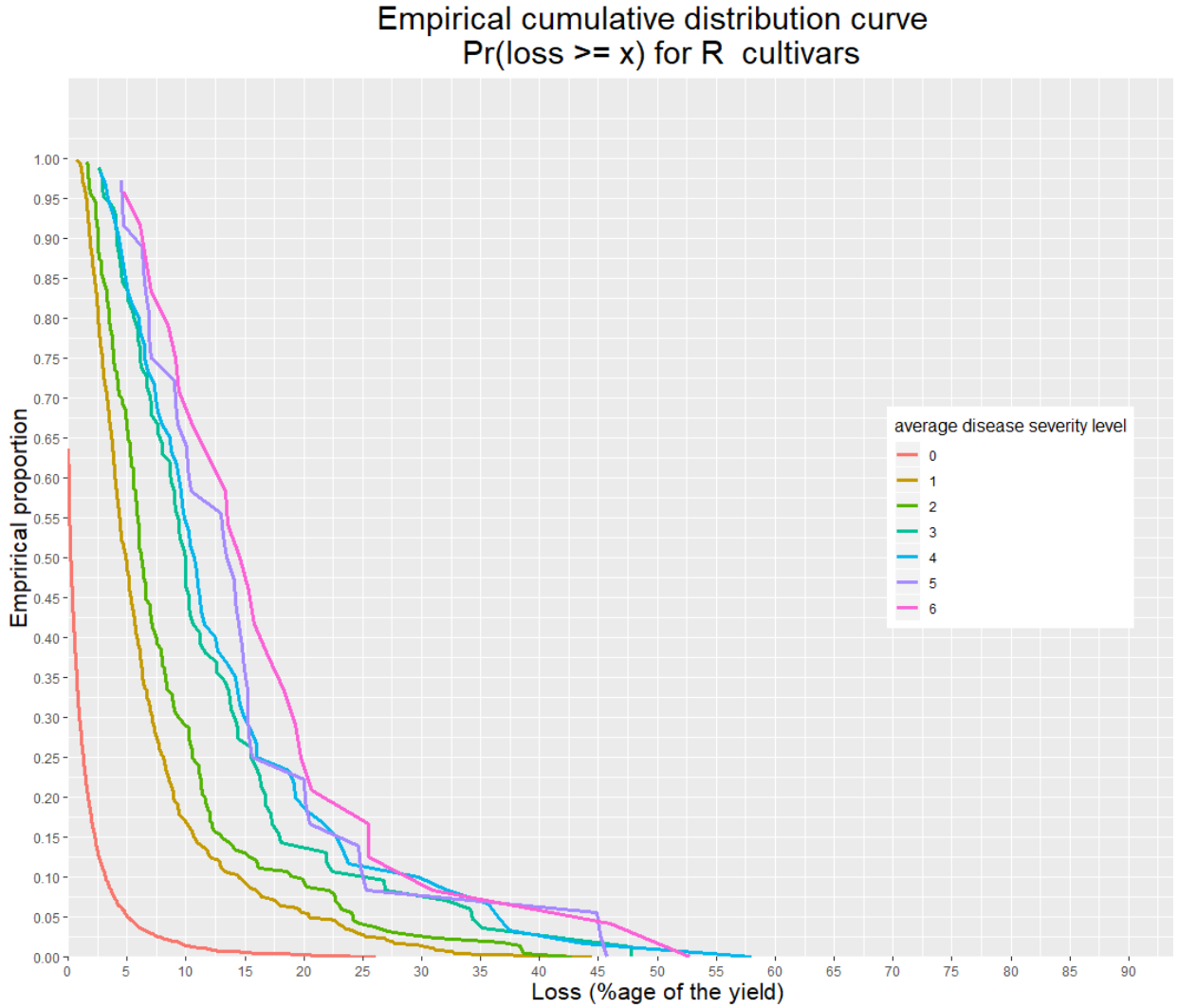
P value adjustment method: BH

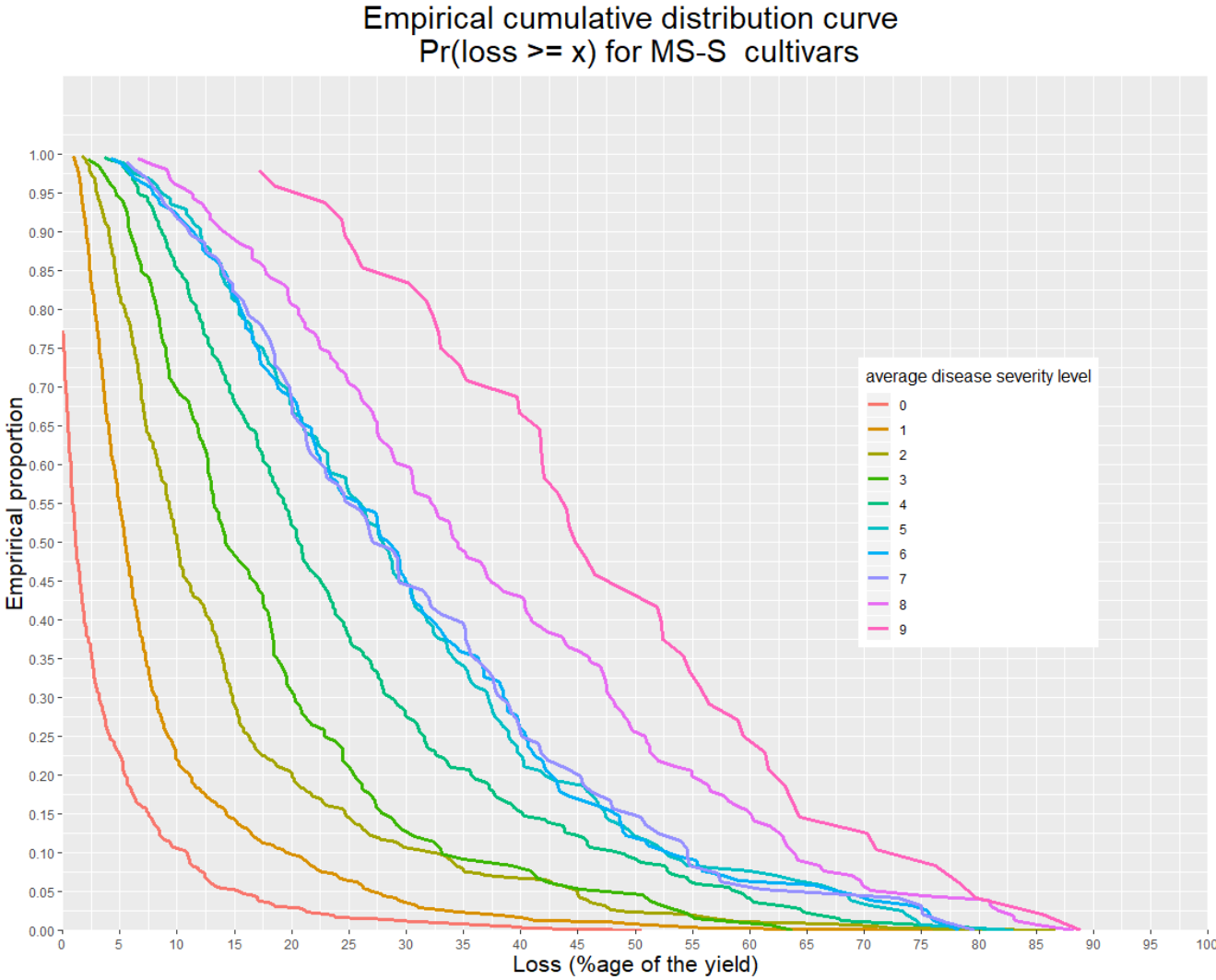

Disease severity distribution across treatments
Mean disease severity
75
50
25
0
Nil
Prosaro
Jockey
Impact liquid
Impact in Furrow
Impact + Prosaro
Jockey + Aviator
Jockey + Impact
Jockey + Impact Liquid
Jockey + Prosaro
Jockey + Prosaro T2
Jockey + Impact + Prosaro
Jockey + Impact + Prosaro T2
Treatment
Treatment
Nil
Prosaro
Jockey
Impact liquid
Impact in Furrow
Impact + Prosaro
Jockey + Aviator
Jockey + Impact
Jockey + Impact Liquid
Jockey + Prosaro
Jockey + Prosaro T2
Jockey + Impact + Prosaro
Jockey + Impact + Prosaro T2

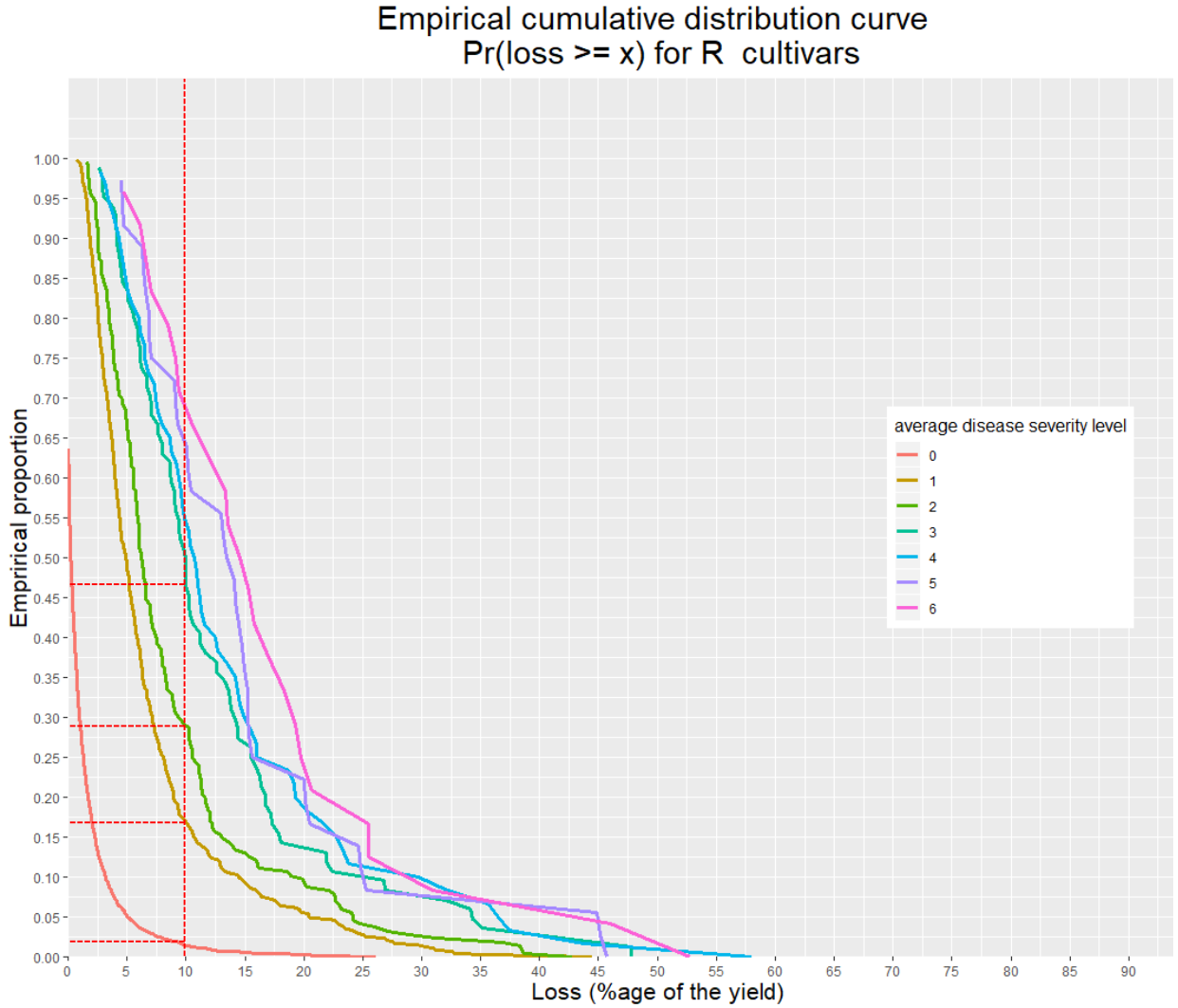

1.00
0.75
0.50
0.25
0.00
ecdf
-60
-40
-20
0
data.se.order[, 1]

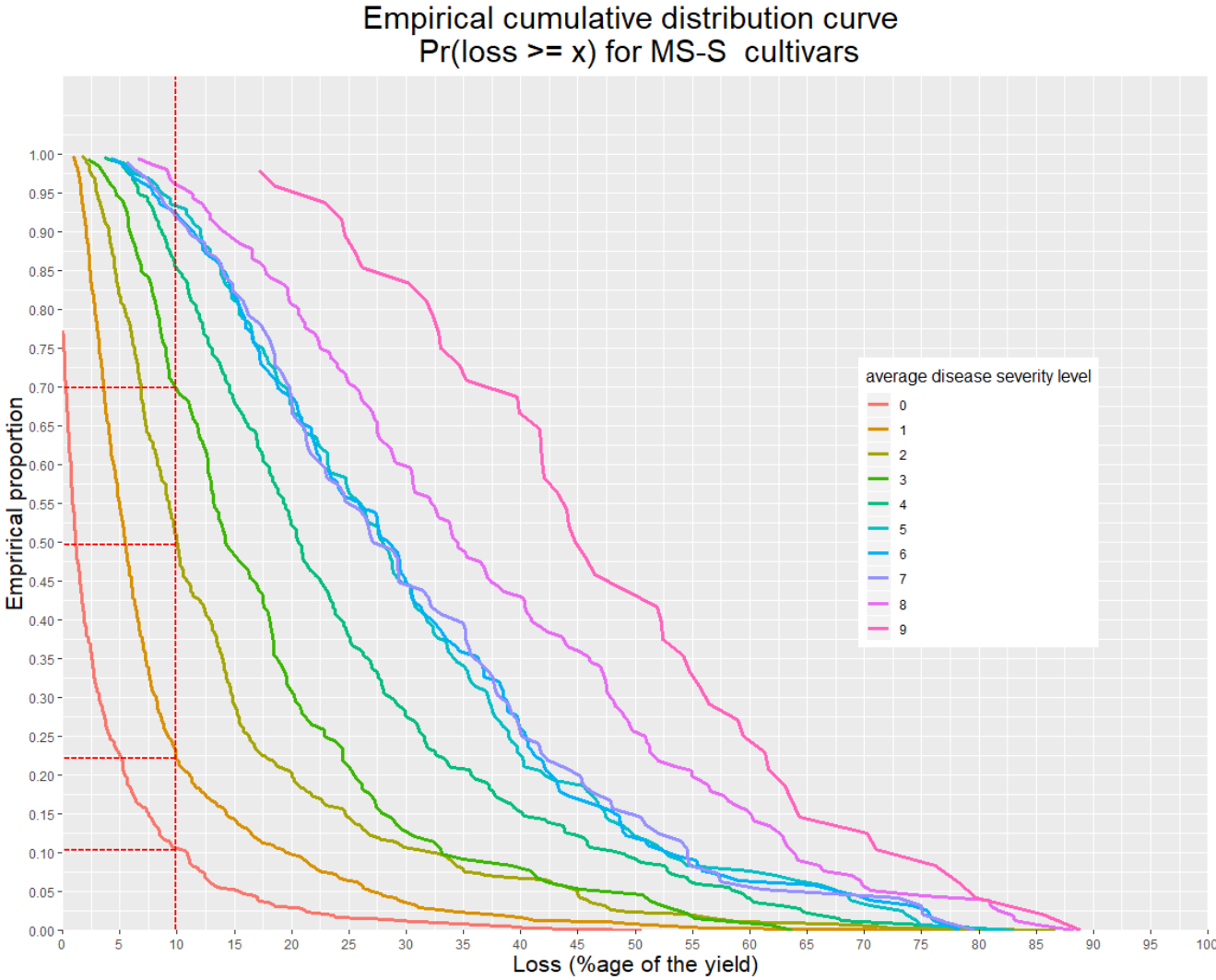

Yield-disease relationship
across different locations
Slope (kg per ha / disease point)
0
-10
-20
*
***
**
*
**
***
Diggora
Edillilie
Esperance
Galong
Goulburn
Hamilton
Junee
Kaniva
Katanning
Minyip
Monteagle
Rylington Park
S. Stirlings
Streatham
Wagga Wagga
Wangary
location
Signif. codes: '***' 0.001 ; '**' 0.01 ; '*' 0.05 ; '.' 0.1 ; ' ' 1

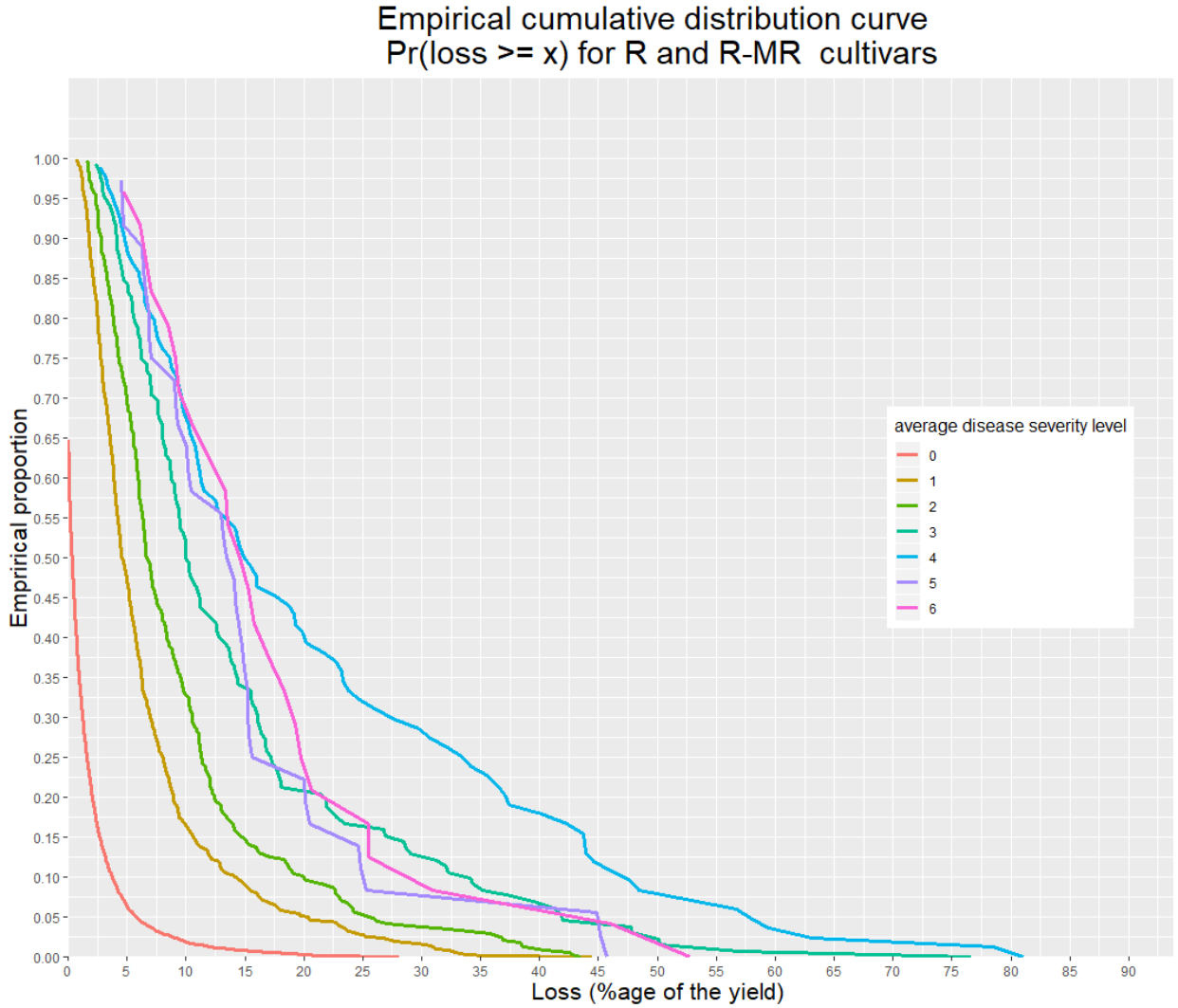

Empirical cumulative distribution curve
Pr(loss >= x)
Empirical proportion
1.00
0.95
0.90
0.85
0.80
0.75
0.70
0.65
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
Loss (%age of the yield)
average disease severity level
0
1
2
3
4
5
6
7
8
9

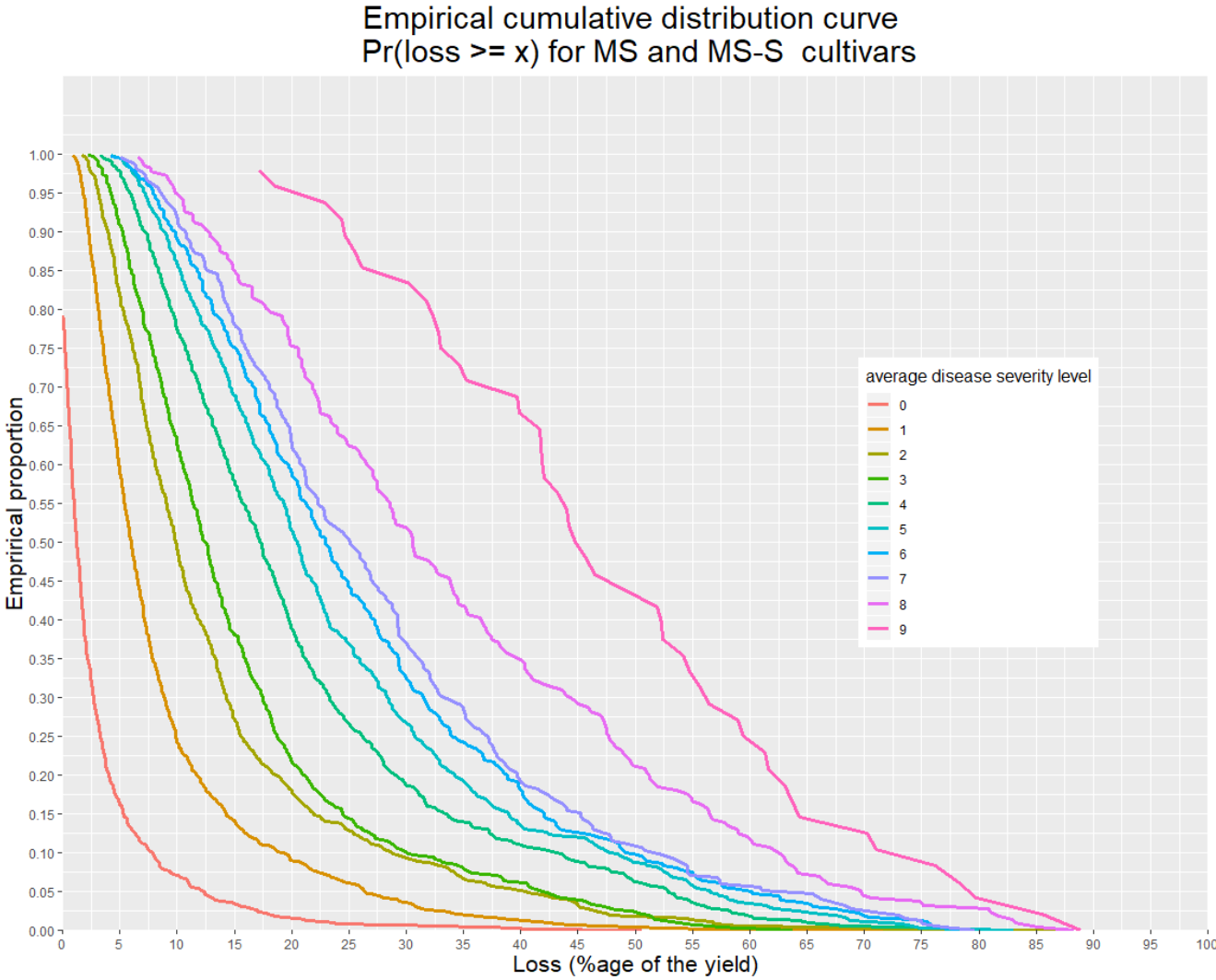

Empirical cumulative distribution curve
Pr(loss >= x) for R cultivars
Empirical proportion
Loss (%age of the yield)
average disease severity level
0
1
2
3
4
5
6

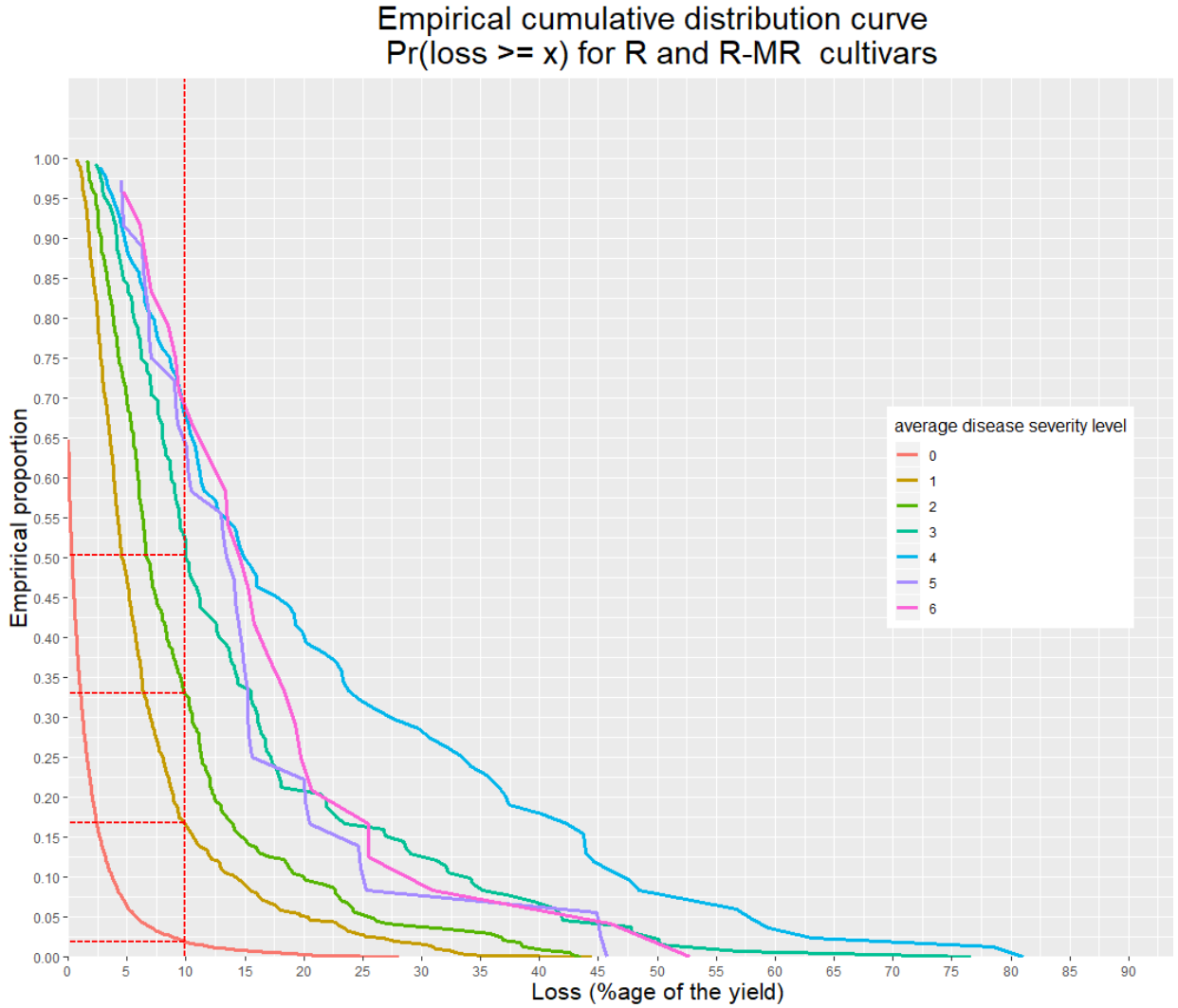

Empirical cumulative distribution curve
Pr(loss >= x) for MS-S cultivars
Empirical proportion
Loss (%age of the yield)
average disease severity level
0
1
2
3
4
5
6
7
8
9

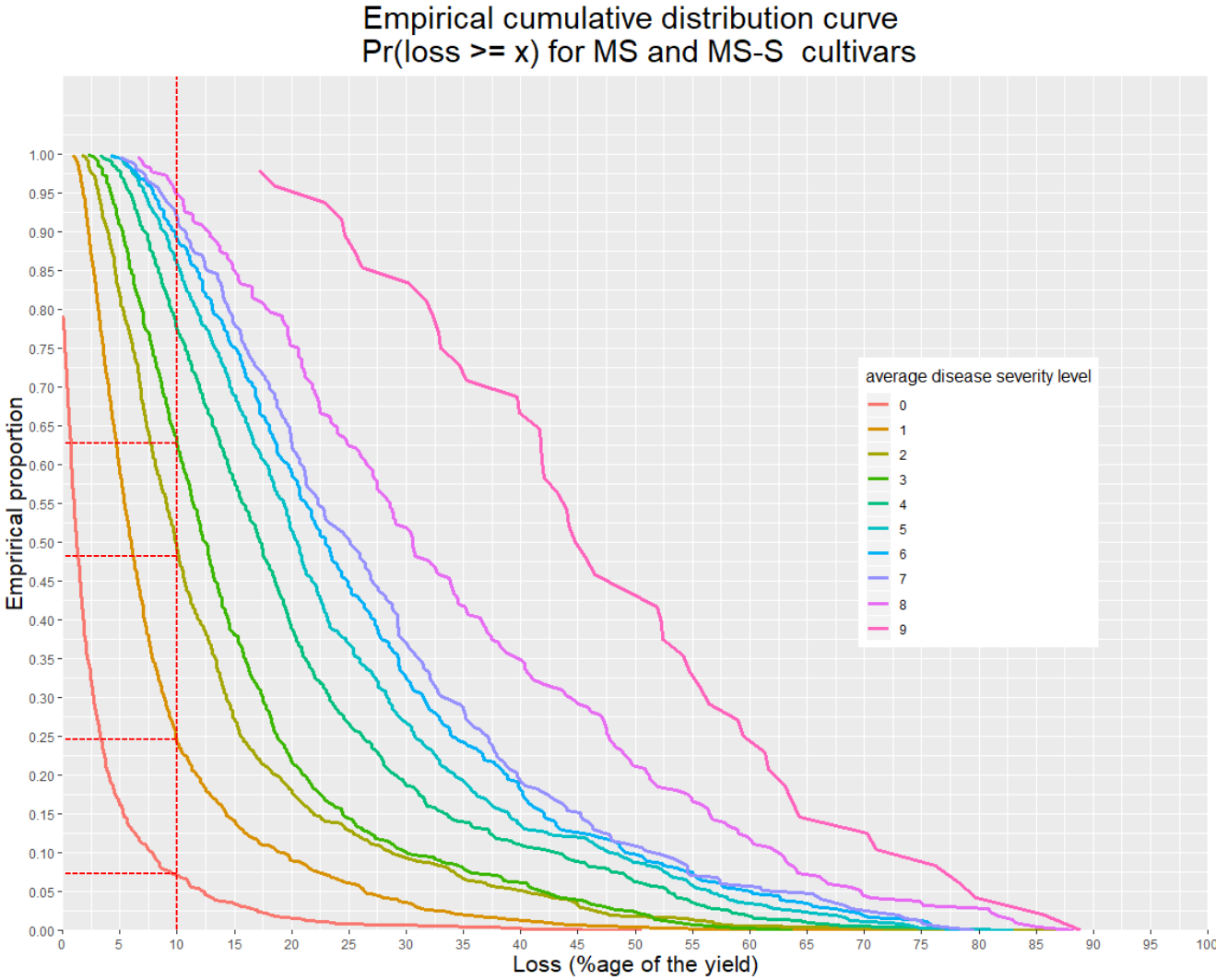

Empirical cumulative distribution curve
Pr(loss >= x) for R cultivars
Empirical proportion
Loss (%age of the yield)
average disease severity level
0
1
2
3
4
5
6

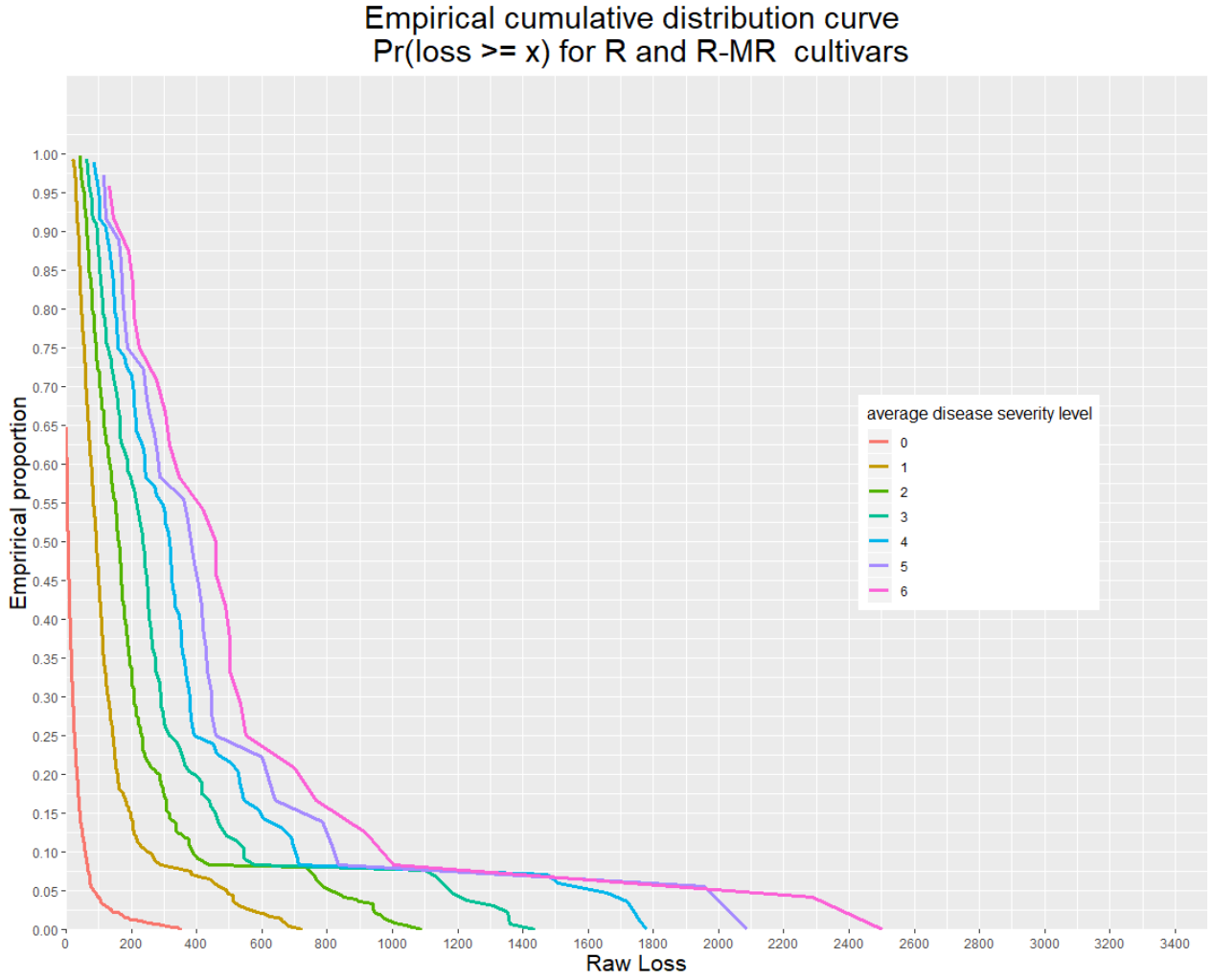

Empirical cumulative distribution curve
Pr(loss >= x) for MS-S cultivars
Empirical proportion
Loss (%age of the yield)
average disease severity level
0
1
2
3
4
5
6
7
8
9

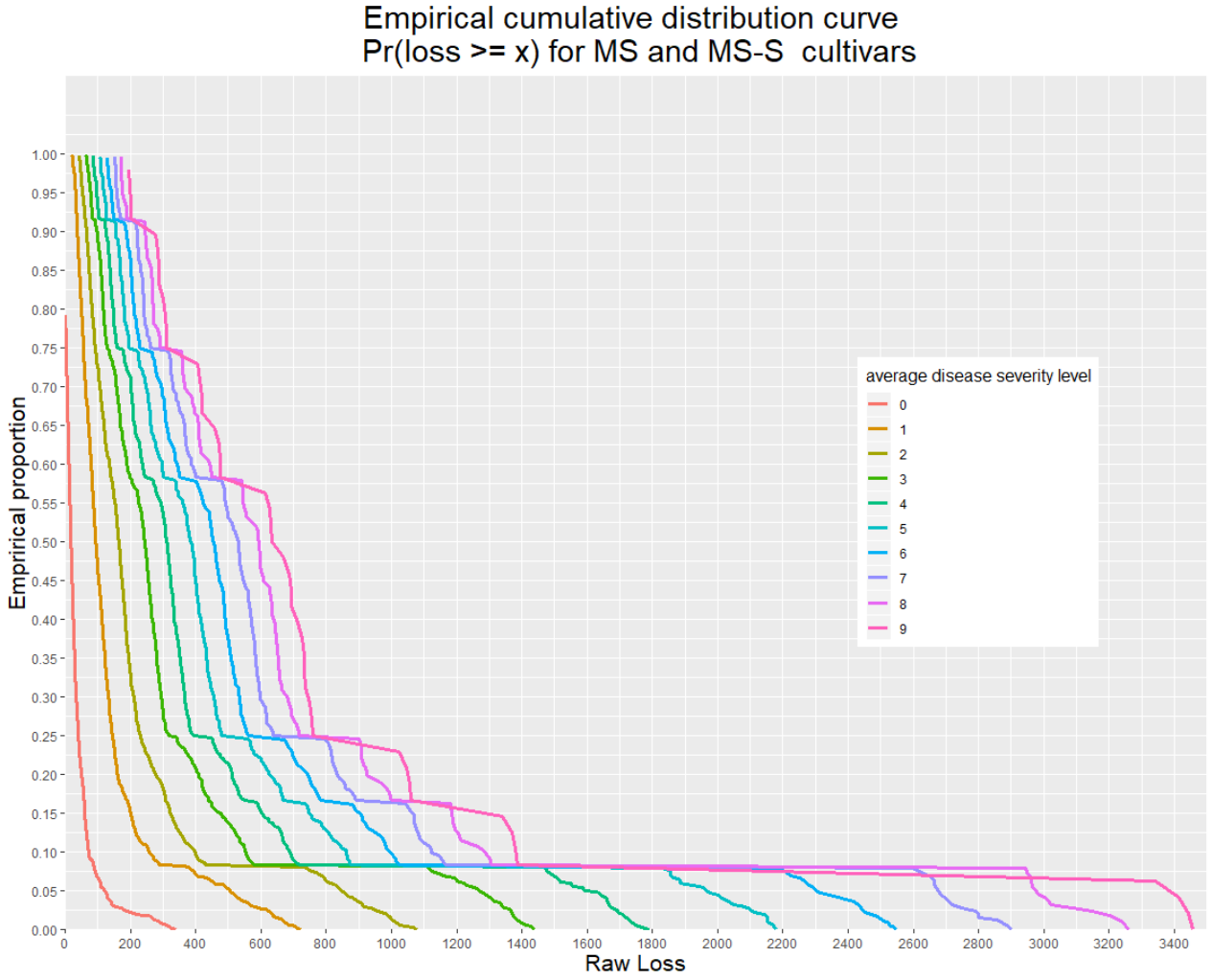

Empirical cumulative distribution curve
Pr(loss >= x) for R and R-MR cultivars
Empirical proportion
Loss (%age of the yield)
average disease severity level
0
1
2
3
4
5
6


Empirical cumulative distribution curve
Pr(loss >= x) for MS and MS-S cultivars
Empirical proportion
Loss (%age of the yield)
average disease severity level
0
1
2
3
4
5
6
7
8
9


Empirical cumulative distribution curve
Pr(loss >= x) for R and R-MR cultivars
Empirical proportion
Loss (%age of the yield)
average disease severity level
0
1
2
3
4
5
6


Empirical cumulative distribution curve
Pr(loss >= x) for MS and MS-S cultivars
Empirical proportion
Loss (%age of the yield)
average disease severity level
0
1
2
3
4
5
6
7
8
9


Empirical cumulative distribution curve
Pr(loss >= x) for R and R-MR cultivars
Emprirical proportion
Raw Loss
average disease severity level
0
1
2
3
4
5
6


Empirical cumulative distribution curve
Pr(loss >= x) for MS and MS-S cultivars
Emprirical proportion
Raw Loss
average disease severity level
0
1
2
3
4
5
6
7
8
9