Analysis of full data set

Wednesday, August 5, 2015

11:40 PM

Data can be found in GH exp data and analysis.

> GH<-read.delim("clipboard")

> attach(GH)

> names(GH)

[1] "Block" "Population" "Pop.Lat"

[4] "Pop.Database" "Light" "Herbivory"

[7] "Lat" "Long" "Date.of.First.Flower"

[10] "FlowerOrdDate" "Seeds.SH" "HarvestOrdDate"

[13] "Avg..tiller.length" "Mv.biomass" "AvgSeedMass"

[16] "Avg.SLA"

> library(lme4)

> library(car)

> library(sciplot)

> library(lmerTest)

##### DATE OF FIRST FLOWER

> m1<-lmer(FlowerOrdDate~Light\*Herbivory\*Lat+(1|Block),na.action=na.omit)

> Anova(m1)

Analysis of Deviance Table (Type II Wald chisquare tests)

Response: FlowerOrdDate

Chisq Df Pr(>Chisq)

Light 1.8263 1 0.1766

Herbivory 0.0668 1 0.7960

Lat 78.8789 1 <2e-16 \*\*\*

Light:Herbivory 0.1113 1 0.7386

Light:Lat 0.0089 1 0.9249

Herbivory:Lat 0.3884 1 0.5331

Light:Herbivory:Lat 0.1600 1 0.6891

---

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

> qqnorm(residuals(m1))

Machine generated alternative text:
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Normal Q-Q Plot
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-3 -2 -1 0 1 2 3
Theoretical Quantiles

> plot(residuals(m1),fitted(m1))

Machine generated alternative text:
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-40 -20 0 20 40
residuals(ml)

> step(m1)

Random effects:

Chi.sq Chi.DF elim.num p.value

(1 | Block) 80.3 1 0 <2e-16 \*\*\*

---

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Fixed effects:

Sum Sq Mean Sq NumDF DenDF F.value elim.num Pr(>F)

Light 275.04 275.04 1 28.5 1.88529 6 0.180

Herbivory 8.55 8.55 1 27.5 0.06952 5 0.794

Lat 11860.46 11860.46 1 341.4 79.48036 0 <2e-16 \*\*\*

Light:Herbivory 16.58 16.58 1 26.6 0.11135 3 0.741

Light:Lat 4.55 4.55 1 339.7 0.00893 2 0.925

Herbivory:Lat 58.40 58.40 1 340.6 0.41005 4 0.522

Light:Herbivory:Lat 24.07 24.07 1 338.7 0.16004 1 0.689

---

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Least squares means:

Estimate Standard Error DF t-value Lower CI Upper CI p-value

Differences of LSMEANS:

Estimate Standard Error DF t-value Lower CI Upper CI p-value

Final model:

lme4::lmer(formula = FlowerOrdDate ~ Lat + (1 | Block), REML = reml,

na.action = na.omit, contrasts = l)

Warning messages:

1: In model.matrix.default(mt, mf, contrasts) :

variable 'Herbivory' is absent, its contrast will be ignored

2: In model.matrix.default(mt, mf, contrasts) :

variable 'Light' is absent, its contrast will be ignored

3: In model.matrix.default(mt, mf, contrasts) :

variable 'Herbivory' is absent, its contrast will be ignored

4: In model.matrix.default(mt, mf, contrasts) :

variable 'Light' is absent, its contrast will be ignored

5: In model.matrix.default(mt, mf, contrasts) :

variable 'Herbivory' is absent, its contrast will be ignored

6: In model.matrix.default(mt, mf, contrasts) :

variable 'Light' is absent, its contrast will be ignored

7: In model.matrix.default(mt, mf, contrasts) :

variable 'Herbivory' is absent, its contrast will be ignored

> plot(Lat,FlowerOrdDate)

> FlowerReg<-lm(FlowerOrdDate~Lat)

> abline(FlowerReg)

Machine generated alternative text:
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33 34 35 36 37 38 39
Lat

> summary(m1)

Linear mixed model fit by REML ['merModLmerTest']

Formula: FlowerOrdDate ~ Light \* Herbivory \* Lat + (1 | Block)

REML criterion at convergence: 2987.703

Random effects:

Groups Name Variance Std.Dev.

Block (Intercept) 88.05 9.383

Residual 150.37 12.262

Number of obs: 376, groups: Block, 32

Fixed effects:

Estimate Std. Error t value Pr(>|t|)

(Intercept) 403.1078 28.6362 14.077 < 2e-16 \*\*\*

Lightshade -11.7565 38.0571 -0.309 0.758

HerbivoryY -27.1755 38.2915 -0.710 0.478

Lat -3.5412 0.7680 -4.611 5.69e-06 \*\*\*

Lightshade:HerbivoryY 19.0185 53.9868 0.352 0.725

Lightshade:Lat 0.2194 1.0203 0.215 0.830

HerbivoryY:Lat 0.7427 1.0272 0.723 0.470

Lightshade:HerbivoryY:Lat -0.5792 1.4478 -0.400 0.689

---

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Correlation of Fixed Effects:

(Intr) Lghtsh HrbvrY Lat Lgh:HY Lght:L HrbY:L

Lightshade -0.752

HerbivoryY -0.748 0.563

Lat -0.991 0.746 0.741

Lghtshd:HrY 0.530 -0.705 -0.709 -0.526

Lightshd:Lt 0.746 -0.991 -0.558 -0.753 0.699

HerbvryY:Lt 0.741 -0.558 -0.991 -0.748 0.703 0.563

Lghtsh:HY:L -0.526 0.698 0.703 0.530 -0.991 -0.705 -0.709

##########SEEDS PER SEED HEAD ##################################################################################################################################

> m2<-lmer(Seeds.SH~Light\*Herbivory\*Lat+(1|Block))

> Anova(m2)

Analysis of Deviance Table (Type II Wald chisquare tests)

Response: Seeds.SH

Chisq Df Pr(>Chisq)

Light 115.4501 1 < 2.2e-16 \*\*\*

Herbivory 37.1482 1 1.095e-09 \*\*\*

Lat 3.2198 1 0.07275 .

Light:Herbivory 0.0271 1 0.86925

Light:Lat 2.3268 1 0.12716

Herbivory:Lat 6.0157 1 0.01418 \*

Light:Herbivory:Lat 1.4956 1 0.22135

---

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

> qqnorm(residuals(m2))

Machine generated alternative text:
Normal Q-Q Plot
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-3 -2 -1 0 1 2 3
Theoretical Quantiles

> plot(residuals(m2),fitted(m2))

Machine generated alternative text:
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-40 -20 0 20 40
resduals(m2)

> step(m2)

Random effects:

Chi.sq Chi.DF elim.num p.value

(1 | Block) 7.48 1 0 0.006 \*\*

---

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Fixed effects:

Sum Sq Mean Sq NumDF DenDF F.value elim.num Pr(>F)

Light 22382.06 22382.06 1 29.6 119.228 0 6.79e-12 \*\*\*

Herbivory 8129.58 8129.58 1 335.6 9.335 0 0.00243 \*\*

Lat 705.42 705.42 1 332.9 3.293 0 0.07046 .

Light:Herbivory 5.63 5.63 1 28.5 0.027 2 0.87066

Light:Lat 737.19 737.19 1 331.8 2.323 3 0.12842

Herbivory:Lat 1319.15 1319.15 1 332.9 7.019 0 0.00845 \*\*

Light:Herbivory:Lat 327.96 327.96 1 330.7 1.496 1 0.22222

---

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Least squares means:

Light Herbivory Estimate Standard Error DF t-value Lower CI Upper CI p-value

Light ambient 1.0 NA 59.53 1.52 29.7 39.1 56.4 62.6 <2e-16 \*\*\*

Light shade 2.0 NA 35.96 1.52 29.5 23.7 32.9 39.1 <2e-16 \*\*\*

Herbivory N NA 1.0 54.41 1.52 29.7 35.8 51.3 57.5 <2e-16 \*\*\*

Herbivory Y NA 2.0 41.08 1.52 29.5 27.0 38.0 44.2 <2e-16 \*\*\*

---

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Differences of LSMEANS:

Estimate Standard Error DF t-value Lower CI Upper CI p-value

Light ambient-shade 23.6 2.16 29.6 10.92 19.16 28.0 <2e-16 \*\*\*

Herbivory N-Y 13.3 2.16 29.6 6.18 8.92 17.7 <2e-16 \*\*\*

---

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Final model:

lme4::lmer(formula = Seeds.SH ~ Light + Herbivory + Lat + (1 |

Block) + Herbivory:Lat, REML = reml, contrasts = l)

Machine generated alternative text:
120r—- I
O ambient/no herb
o ambient/herb
• shade/no herb
• shade/herb
Linear (ambient/no herb)
Linear (ambient/herb)
Linear (shade/no herb)
Linear (shade/herb)
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Latitude

Here's the same data, only shade treatments not separated out:

Machine generated alternative text:
• No herbivory
X Herbivory
Linear (No herbivory)
Linear (Herbivory)
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32,0 33.0
x
- 1 --
34.0 35.0 36.0 370 38.0
39.0
40.0
Latitude

> summary(m2)

Linear mixed model fit by REML ['lmerMod']

Formula: Seeds.SH ~ Light \* Herbivory \* Lat + (1 | Block)

REML criterion at convergence: 2997.085

Random effects:

Groups Name Variance Std.Dev.

Block (Intercept) 18.64 4.317

Residual 219.28 14.808

Number of obs: 365, groups: Block, 32

Fixed effects:

Estimate Std. Error t value

(Intercept) 132.862 34.691 3.830

Lightshade -13.809 46.274 -0.298

HerbivoryY -132.618 46.167 -2.873

Lat -1.809 0.937 -1.930

Lightshade:HerbivoryY 78.714 65.102 1.209

Lightshade:Lat -0.254 1.249 -0.203

HerbivoryY:Lat 3.236 1.246 2.596

Lightshade:HerbivoryY:Lat -2.149 1.757 -1.223

Correlation of Fixed Effects:

(Intr) Lghtsh HrbvrY Lat Lgh:HY Lght:L HrbY:L

Lightshade -0.750

HerbivoryY -0.751 0.563

Lat -0.998 0.748 0.750

Lghtshd:HrY 0.533 -0.711 -0.709 -0.532

Lightshd:Lt 0.748 -0.998 -0.562 -0.750 0.709

HerbvryY:Lt 0.750 -0.562 -0.998 -0.752 0.708 0.564

Lghtsh:HY:L -0.532 0.709 0.708 0.533 -0.998 -0.711 -0.709

###########HARVEST DATE (SENESCENCE) ###############################################################################################################################

> m3<-lmer(HarvestOrdDate~Light\*Herbivory\*Lat+(1|Block))

> Light<-as.factor(Light)

> Herbivory<-as.factor(Herbivory)

> Anova(m3)

Analysis of Deviance Table (Type II Wald chisquare tests)

Response: HarvestOrdDate

Chisq Df Pr(>Chisq)

Light 4.1487 1 0.04167 \*

Herbivory 0.0109 1 0.91692

Lat 19.6053 1 9.52e-06 \*\*\*

Light:Herbivory 0.7779 1 0.37778

Light:Lat 3.7434 1 0.05302 .

Herbivory:Lat 0.9059 1 0.34122

Light:Herbivory:Lat 0.8409 1 0.35913

---

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

> qqnorm(residuals(m3))

Machine generated alternative text:
Normal Q-Q Plot
0 0
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-3 -2 -1 0 1 2 3
Theoretical Quantiles

> plot(residuals(m3),fitted(m3))

Machine generated alternative text:
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resduals(m3)

####I attempted to remove the outlier and re-run the analysis in R using commands, but the results are strange. The row containing the data point causing the anomalous residual is removed, but when the model is re-run, the result is slightly different (but overall same conclusions), but there is a new abnormal residual corresponding to the previous row (which contains data from a different pot). Here is what occurred:

> which(residuals(m3)< -40)

[1] 316

> m3.2<-lmer(HarvestOrdDate~Light\*Herbivory\*Lat+(1|Block),data=harvest) ### the data frame "harvest" contains all GH data except for row 316.

> Anova(m3.2)

Analysis of Deviance Table (Type II Wald chisquare tests)

Response: HarvestOrdDate

Chisq Df Pr(>Chisq)

Light 4.1551 1 0.04151 \*

Herbivory 0.0115 1 0.91447

Lat 19.5916 1 9.589e-06 \*\*\*

Light:Herbivory 0.7841 1 0.37588

Light:Lat 3.7929 1 0.05147 .

Herbivory:Lat 0.9356 1 0.33342

Light:Herbivory:Lat 0.8754 1 0.34947

---

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

> plot(fitted(m3.2),residuals(m3.2))

> which(residuals(m3.2)< -40)

[1] 315

> harvest2<-harvest[-c(315),]

> m3.3<-lmer(HarvestOrdDate~Light\*Herbivory\*Lat+(1|Block),data=harvest2)

> Anova(m3.3)

Analysis of Deviance Table (Type II Wald chisquare tests)

Response: HarvestOrdDate

Chisq Df Pr(>Chisq)

Light 4.1546 1 0.04152 \*

Herbivory 0.0112 1 0.91554

Lat 19.5122 1 9.996e-06 \*\*\*

Light:Herbivory 0.7822 1 0.37646

Light:Lat 3.7919 1 0.05150 .

Herbivory:Lat 0.9229 1 0.33671

Light:Herbivory:Lat 0.8662 1 0.35201

---

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

> plot(fitted(m3.3),residuals(m3.3))

Machine generated alternative text:
0 0
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0
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0
0
0
0
290 300 310 320 330 340 350
I I
fitted(m3.3)

> which(residuals(m3.3)< -40)

[1] 314

###Not really sure what to do about this. Maybe do nothing because it is not obvious from data set what data point the outlier represents, so was likely not a data entry problem.

> step(m3)

Random effects:

Chi.sq Chi.DF elim.num p.value

(1 | Block) 310 1 0 <2e-16 \*\*\*

---

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Fixed effects:

Sum Sq Mean Sq NumDF DenDF F.value elim.num Pr(>F)

Light 272.762 272.762 1 30 4.401 0 0.0444 \*

Herbivory 0.712 0.712 1 29 0.014 4 0.9067

Lat 1308.746 1308.746 1 339 19.961 0 1.08e-05 \*\*\*

Light:Herbivory 48.713 48.713 1 28 0.756 2 0.3919

Light:Lat 206.369 206.369 1 338 3.161 5 0.0763 .

Herbivory:Lat 52.317 52.317 1 337 0.800 3 0.3717

Light:Herbivory:Lat 61.910 61.910 1 336 0.950 1 0.3304

---

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Least squares means:

Light Estimate Standard Error DF t-value Lower CI Upper CI p-value

Light ambient 1 307.25 2.99 30 102.59 301 313 <2e-16 \*\*\*

Light shade 2 316.13 2.99 30 105.59 310 322 <2e-16 \*\*\*

---

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Differences of LSMEANS:

Estimate Standard Error DF t-value Lower CI Upper CI p-value

Light ambient-shade -8.9 4.23 30.0 -2.1 -17.5 -0.235 0.04 \*

---

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Final model:

lme4::lmer(formula = HarvestOrdDate ~ Light + Lat + (1 | Block),

REML = reml, contrasts = l)

Warning messages:

1: In model.matrix.default(mt, mf, contrasts) :

variable 'Herbivory' is absent, its contrast will be ignored

2: In model.matrix.default(mt, mf, contrasts) :

variable 'Herbivory' is absent, its contrast will be ignored

3: In model.matrix.default(mt, mf, contrasts) :

variable 'Herbivory' is absent, its contrast will be ignored

4: In model.matrix.default(mt, mf, contrasts) :

variable 'Herbivory' is absent, its contrast will be ignored

Machine generated alternative text:
360
350
340
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32.0 33.0
• Ambient
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34.0 35.0 36.0 37.0 38.0 39.0 40.0
Latitude

> summary(m3)

Linear mixed model fit by REML ['merModLmerTest']

Formula: HarvestOrdDate ~ Light \* Herbivory \* Lat + (1 | Block)

REML criterion at convergence: 2686.124

Random effects:

Groups Name Variance Std.Dev.

Block (Intercept) 144.33 12.014

Residual 65.16 8.072

Number of obs: 372, groups: Block, 32

Fixed effects:

Estimate Std. Error t value Pr(>|t|)

(Intercept) 378.5104 19.4221 19.489 < 2e-16 \*\*\*

Lightshade -37.7400 25.7904 -1.463 0.144243

HerbivoryY -28.8197 25.7831 -1.118 0.264406

Lat -1.9936 0.5110 -3.902 0.000115 \*\*\*

Lightshade:HerbivoryY 26.7760 36.3188 0.737 0.461448

Lightshade:Lat 1.3659 0.6777 2.016 0.044637 \*

HerbivoryY:Lat 0.8963 0.6774 1.323 0.186712

Lightshade:HerbivoryY:Lat -0.9295 0.9536 -0.975 0.330399

---

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Correlation of Fixed Effects:

(Intr) Lghtsh HrbvrY Lat Lgh:HY Lght:L HrbY:L

Lightshade -0.753

HerbivoryY -0.753 0.567

Lat -0.971 0.731 0.732

Lghtshd:HrY 0.535 -0.710 -0.710 -0.519

Lightshd:Lt 0.732 -0.971 -0.552 -0.754 0.689

HerbvryY:Lt 0.733 -0.552 -0.971 -0.754 0.689 0.569

Lghtsh:HY:L -0.520 0.690 0.690 0.536 -0.971 -0.711 -0.710

######AVG TILLER LENGTH ################################################################################################################

> m4<-lmer(Avg..tiller.length~Light\*Herbivory\*Lat+(1|Block))

> Anova(m4)

Analysis of Deviance Table (Type II Wald chisquare tests)

Response: Avg..tiller.length

Chisq Df Pr(>Chisq)

Light 16.5593 1 4.715e-05 \*\*\*

Herbivory 7.9951 1 0.00469 \*\*

Lat 27.7815 1 1.358e-07 \*\*\*

Light:Herbivory 1.5434 1 0.21411

Light:Lat 0.1334 1 0.71491

Herbivory:Lat 0.1502 1 0.69838

Light:Herbivory:Lat 0.2031 1 0.65225

---

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

> qqnorm(residuals(m4))

Machine generated alternative text:
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-3 -2 -1 0 1 2 3
Theoretical Quantiles

> plot(fitted(m4),residuals(m4))

Machine generated alternative text:
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C
0 cc
0 0%
0
0
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0
o0
0
0
o 0
0
0
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0
o0
0
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0 0
0 0
0
C
00
0
0
0 0 0
0
0
0
0
o0
0
0
go o
0
I I I
I
I
40 60 80
100
120
fitted(m4)

> m4.2<-lmer(log(Avg..tiller.length)~Light\*Herbivory\*Lat+(1|Block))

> Anova(m4.2)

Analysis of Deviance Table (Type II Wald chisquare tests)

Response: log(Avg..tiller.length)

Chisq Df Pr(>Chisq)

Light 19.4924 1 1.010e-05 \*\*\*

Herbivory 10.1628 1 0.001433 \*\*

Lat 35.9894 1 1.984e-09 \*\*\*

Light:Herbivory 2.3757 1 0.123232

Light:Lat 0.4486 1 0.503007

Herbivory:Lat 0.1690 1 0.680987

Light:Herbivory:Lat 0.5205 1 0.470613

---

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

> qqnorm(residuals(m4.2))

Machine generated alternative text:
In
0
Normal Q-Q Plot
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In
9
0
0
0
C
-3
-2
0
1
2
3
Theoretical Quantiles

> plot(fitted(m4.2),residuals(m4.2))

Machine generated alternative text:
a
0
0
0 0
0 o 0 0 0
0
o 0 %000 o
%@ $JD° 000
0
0 0 0 0 @ %co o
0 0 000 00000 0 %c00 1J° 0
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3.6 3.8 4.0 4.2 4.4 4.6 4.8
fitted(m4 .2)

> m4.3<-lmer(sqrt(Avg..tiller.length)~Light\*Herbivory\*Lat+(1|Block))

> Anova(m4.3)

Analysis of Deviance Table (Type II Wald chisquare tests)

Response: sqrt(Avg..tiller.length)

Chisq Df Pr(>Chisq)

Light 18.2265 1 1.961e-05 \*\*\*

Herbivory 9.2279 1 0.002384 \*\*

Lat 32.7577 1 1.044e-08 \*\*\*

Light:Herbivory 1.9381 1 0.163873

Light:Lat 0.0091 1 0.923923

Herbivory:Lat 0.0003 1 0.986380

Light:Herbivory:Lat 0.3251 1 0.568537

---

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

> qqnorm(residuals(m4.3))

Machine generated alternative text:
Normal Q-Q Plot
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-3 -2 -1 0 1 2 3
Theoretical Quantiles

> plot(fitted(m4.3),residuals(m4.3))

Machine generated alternative text:
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off W000oW o0 00
oQ 0 0 0 0
a o000 %%o9Q5b & 0
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0o a
a c 8oQ9 o, 00 &% o% 0 c900 0
0 - 0 % cR% o 0
S a 0 ooOo&%00BOO 0 0
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Oo 0
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0 0 02 Sb 0S0o
0 00 0
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6 7 8 9 10 11
fitted(m43)

> step(m4)

Random effects:

Chi.sq Chi.DF elim.num p.value

(1 | Block) 149 1 0 <2e-16 \*\*\*

---

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Fixed effects:

Sum Sq Mean Sq NumDF DenDF F.value elim.num Pr(>F)

Light 3528.8 3528.8 1 29 16.261 0 0.000366 \*\*\*

Herbivory 2022.0 2022.0 1 29 7.853 0 0.008947 \*\*

Lat 6911.9 6911.9 1 342 27.924 0 2.25e-07 \*\*\*

Light:Herbivory 383.3 383.3 1 28 1.536 4 0.225551

Light:Lat 25.1 25.1 1 340 0.134 2 0.714814

Herbivory:Lat 37.5 37.5 1 341 0.118 3 0.731674

Light:Herbivory:Lat 50.6 50.6 1 339 0.203 1 0.652538

---

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Least squares means:

Light Herbivory Estimate Standard Error DF t-value Lower CI Upper CI p-value

Light ambient 1.0 NA 87.68 3.98 29.1 22.0 79.5 95.8 <2e-16 \*\*\*

Light shade 2.0 NA 64.88 3.98 29.0 16.3 56.7 73.0 <2e-16 \*\*\*

Herbivory N NA 1.0 84.20 3.98 29.1 21.1 76.1 92.3 <2e-16 \*\*\*

Herbivory Y NA 2.0 68.36 3.98 29.0 17.2 60.2 76.5 <2e-16 \*\*\*

---

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Differences of LSMEANS:

Estimate Standard Error DF t-value Lower CI Upper CI p-value

Light ambient-shade 22.8 5.65 29.0 4.03 11.23 34.4 4e-04 \*\*\*

Herbivory N-Y 15.8 5.65 29.0 2.80 4.28 27.4 0.009 \*\*

---

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Final model:

lme4::lmer(formula = Avg..tiller.length ~ Light + Herbivory +

Lat + (1 | Block), REML = reml, contrasts = l)

> summary(m4)

Linear mixed model fit by REML ['merModLmerTest']

Formula: Avg..tiller.length ~ Light \* Herbivory \* Lat + (1 | Block)

REML criterion at convergence: 3176.385

Random effects:

Groups Name Variance Std.Dev.

Block (Intercept) 225.5 15.02

Residual 249.4 15.79

Number of obs: 375, groups: Block, 32

Fixed effects:

Estimate Std. Error t value Pr(>|t|)

(Intercept) 203.9421 37.5533 5.431 1.05e-07 \*\*\*

Lightshade -44.1777 49.7365 -0.888 0.3750

HerbivoryY -37.9922 49.7365 -0.764 0.4455

Lat -3.0368 1.0048 -3.022 0.0027 \*\*

Lightshade:HerbivoryY 17.1906 69.9225 0.246 0.8059

Lightshade:Lat 0.7672 1.3289 0.577 0.5641

HerbivoryY:Lat 0.7880 1.3289 0.593 0.5536

Lightshade:HerbivoryY:Lat -0.8412 1.8668 -0.451 0.6525

---

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Correlation of Fixed Effects:

(Intr) Lghtsh HrbvrY Lat Lgh:HY Lght:L HrbY:L

Lightshade -0.755

HerbivoryY -0.755 0.570

Lat -0.987 0.746 0.746

Lghtshd:HrY 0.537 -0.711 -0.711 -0.530

Lightshd:Lt 0.747 -0.987 -0.564 -0.756 0.702

HerbvryY:Lt 0.747 -0.564 -0.987 -0.756 0.702 0.572

Lghtsh:HY:L -0.531 0.703 0.703 0.538 -0.987 -0.712 -0.712

Machine generated alternative text:
Ambient, no herbivory
o Ambient, herbivory
• Shade, no herbivory
• Shade, herbivory
Linear (Ambient, no herbivory)
Linear (Ambient, herbivory)
Linear (Shade, no herbivory)
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37.0 38.0 39.0 40.0
Latitude

#########Mv BIOMASS######################################################################################################################

> m5<-lmer(Mv.biomass~Light\*Herbivory\*Lat+(1|Block))

> Anova(m5)

Analysis of Deviance Table (Type II Wald chisquare tests)

Response: Mv.biomass

Chisq Df Pr(>Chisq)

Light 416.2581 1 < 2.2e-16 \*\*\*

Herbivory 58.2884 1 2.264e-14 \*\*\*

Lat 4.8523 1 0.0276094 \*

Light:Herbivory 13.6228 1 0.0002235 \*\*\*

Light:Lat 0.9203 1 0.3374069

Herbivory:Lat 2.0507 1 0.1521381

Light:Herbivory:Lat 2.4377 1 0.1184481

---

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

> qqnorm(residuals(m5))

Machine generated alternative text:
Normal Q-Q Plot
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-3 -2 -1 0 1 2 3
Theoretical Quantiles

> plot(fitted(m5),residuals(m5))

Machine generated alternative text:
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fitted(m5)

> m5.3<-lmer(sqrt(Mv.biomass)~Light\*Herbivory\*Lat+(1|Block))

> qqnorm(residuals(m5.3))

Machine generated alternative text:
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Normal Q-Q Plot
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Theoretical Quantiles

> plot(fitted(m5.3),residuals(m5.3))

Machine generated alternative text:
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0
0
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2
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0
4
5
6

> Anova(m5.3)

Analysis of Deviance Table (Type II Wald chisquare tests)

Response: sqrt(Mv.biomass)

Chisq Df Pr(>Chisq)

Light 439.9080 1 < 2.2e-16 \*\*\*

Herbivory 57.6818 1 3.081e-14 \*\*\*

Lat 7.4522 1 0.006336 \*\*

Light:Herbivory 1.6065 1 0.204984

Light:Lat 0.0173 1 0.895354

Herbivory:Lat 0.4202 1 0.516820

Light:Herbivory:Lat 1.8224 1 0.177030

---

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

> step(m5.3)

Random effects:

Chi.sq Chi.DF elim.num p.value

(1 | Block) 14.9 1 0 1e-04 \*\*\*

---

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Fixed effects:

Sum Sq Mean Sq NumDF DenDF F.value elim.num Pr(>F)

Light 266.4527 266.4527 1 29.1 431.0860 0 < 2e-16 \*\*\*

Herbivory 37.7109 37.7109 1 29.1 56.4833 0 2.73e-08 \*\*\*

Lat 4.8916 4.8916 1 344.3 7.5100 0 0.00646 \*\*

Light:Herbivory 1.0505 1.0505 1 28.0 1.6119 4 0.21468

Light:Lat 0.0297 0.0297 1 342.2 0.0173 2 0.89549

Herbivory:Lat 0.2743 0.2743 1 343.2 0.4487 3 0.50342

Light:Herbivory:Lat 1.1895 1.1895 1 341.2 1.8224 1 0.17793

---

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Least squares means:

Light Herbivory Estimate Standard Error DF t-value Lower CI Upper CI p-value

Light ambient 1.0 NA 5.3801 0.0953 29.0 56.5 5.19 5.57 <2e-16 \*\*\*

Light shade 2.0 NA 2.5709 0.0954 29.1 27.0 2.38 2.77 <2e-16 \*\*\*

Herbivory N NA 1.0 4.4839 0.0954 29.1 47.0 4.29 4.68 <2e-16 \*\*\*

Herbivory Y NA 2.0 3.4670 0.0953 29.0 36.4 3.27 3.66 <2e-16 \*\*\*

---

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Differences of LSMEANS:

Estimate Standard Error DF t-value Lower CI Upper CI p-value

Light ambient-shade 2.8 0.135 29.1 20.76 2.53 3.09 <2e-16 \*\*\*

Herbivory N-Y 1.0 0.135 29.1 7.52 0.74 1.29 <2e-16 \*\*\*

---

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Final model:

lme4::lmer(formula = sqrt(Mv.biomass) ~ Light + Herbivory + Lat +

(1 | Block), REML = reml, contrasts = l)

> summary(m5.3)

Linear mixed model fit by REML ['merModLmerTest']

Formula: sqrt(Mv.biomass) ~ Light \* Herbivory \* Lat + (1 | Block)

REML criterion at convergence: 956.7899

Random effects:

Groups Name Variance Std.Dev.

Block (Intercept) 0.08585 0.2930

Residual 0.65269 0.8079

Number of obs: 377, groups: Block, 32

Fixed effects:

Estimate Std. Error t value Pr(>|t|)

(Intercept) 10.16400 1.87513 5.420 1.12e-07 \*\*\*

Lightshade -5.13077 2.49852 -2.054 0.0408 \*

HerbivoryY -4.70971 2.49850 -1.885 0.0603 .

Lat -0.11304 0.05059 -2.235 0.0261 \*

Lightshade:HerbivoryY 5.08611 3.52634 1.442 0.1501

Lightshade:Lat 0.05820 0.06737 0.864 0.3882

HerbivoryY:Lat 0.09526 0.06737 1.414 0.1583

Lightshade:HerbivoryY:Lat -0.12833 0.09506 -1.350 0.1779

---

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Correlation of Fixed Effects:

(Intr) Lghtsh HrbvrY Lat Lgh:HY Lght:L HrbY:L

Lightshade -0.750

HerbivoryY -0.751 0.563

Lat -0.997 0.748 0.748

Lghtshd:HrY 0.532 -0.709 -0.709 -0.530

Lightshd:Lt 0.749 -0.997 -0.562 -0.751 0.706

HerbvryY:Lt 0.749 -0.562 -0.997 -0.751 0.706 0.564

Lghtsh:HY:L -0.531 0.707 0.707 0.532 -0.997 -0.709 -0.709

Machine generated alternative text:
70
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Linear (Shade, no herblvory)
10 Linear (Shade, herbivory)
0
32.0 33.0 34.0 35.0 360 37.0 380 39.0 40.0•‘
•
Latitude

##### SEED MASS################################################################################################################################

> m6<-lmer(AvgSeedMass~Light\*Herbivory\*Lat+(1|Block))

> Anova(m6)

Analysis of Deviance Table (Type II Wald chisquare tests)

Response: AvgSeedMass

Chisq Df Pr(>Chisq)

Light 18.1399 1 2.053e-05 \*\*\*

Herbivory 0.2923 1 0.58873

Lat 34.6701 1 3.906e-09 \*\*\*

Light:Herbivory 0.6328 1 0.42633

Light:Lat 4.1569 1 0.04146 \*

Herbivory:Lat 0.0459 1 0.83041

Light:Herbivory:Lat 0.6087 1 0.43529

---

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

> qqnorm(residuals(m6))

Machine generated alternative text:
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Normal Q-Q Plot
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-3 -2 -1 0 1 2 3
Theoretical Quantiles

> plot(residuals(m6),fitted(m6))

Machine generated alternative text:
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resduals(m6)

> step(m6)

Random effects:

Chi.sq Chi.DF elim.num p.value

(1 | Block) 25.6 1 0 4e-07 \*\*\*

---

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Fixed effects:

Sum Sq Mean Sq NumDF DenDF F.value elim.num Pr(>F)

Light 3.90e-07 3.90e-07 1 557.1 5.7704 0 0.0166 \*

Herbivory 6.15e-09 6.15e-09 1 24.9 0.2959 4 0.5913

Lat 7.65e-07 7.65e-07 1 536.3 34.7031 0 6.79e-09 \*\*\*

Light:Herbivory 1.42e-08 1.42e-08 1 24.0 0.6359 3 0.4330

Light:Lat 9.08e-08 9.08e-08 1 536.3 4.1409 0 0.0424 \*

Herbivory:Lat 1.01e-09 1.01e-09 1 540.2 0.0459 2 0.8304

Light:Herbivory:Lat 1.34e-08 1.34e-08 1 537.6 0.6087 1 0.4356

---

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Least squares means:

Light Estimate Standard Error DF t-value Lower CI Upper CI p-value

Light ambient 1.0 0.0005 0.0000 25.7 27.0600 5e-04 6e-04 <2e-16 \*\*\*

Light shade 2.0 0.0007 0.0000 25.6 33.1600 6e-04 7e-04 <2e-16 \*\*\*

---

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Differences of LSMEANS:

Estimate Standard Error DF t-value Lower CI Upper CI p-value

Light ambient-shade 0.0 0.0000 25.7 -4.3 -2e-04 -1e-04 2e-04 \*\*\*

---

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Final model:

lme4::lmer(formula = AvgSeedMass ~ Light + Lat + (1 | Block) +

Light:Lat, REML = reml, contrasts = l)

Warning messages:

1: In model.matrix.default(mt, mf, contrasts) :

variable 'Herbivory' is absent, its contrast will be ignored

2: In model.matrix.default(mt, mf, contrasts) :

variable 'Herbivory' is absent, its contrast will be ignored

3: In model.matrix.default(mt, mf, contrasts) :

variable 'Herbivory' is absent, its contrast will be ignored

> summary(m6)

Linear mixed model fit by REML ['merModLmerTest']

Formula: AvgSeedMass ~ Light \* Herbivory \* Lat + (1 | Block)

REML criterion at convergence: -5190.653

Random effects:

Groups Name Variance Std.Dev.

Block (Intercept) 4.697e-09 6.854e-05

Residual 2.207e-08 1.486e-04

Number of obs: 364, groups: Block, 32

Fixed effects:

Estimate Std. Error t value Pr(>|t|)

(Intercept) 9.609e-04 3.487e-04 2.756 0.00605 \*\*

Lightshade 1.069e-03 4.652e-04 2.298 0.02194 \*

HerbivoryY 3.642e-04 4.641e-04 0.785 0.43291

Lat -1.192e-05 9.403e-06 -1.268 0.20535

Lightshade:HerbivoryY -5.555e-04 6.554e-04 -0.848 0.39702

Lightshade:Lat -2.495e-05 1.254e-05 -1.990 0.04713 \*

HerbivoryY:Lat -8.804e-06 1.251e-05 -0.704 0.48184

Lightshade:HerbivoryY:Lat 1.378e-05 1.766e-05 0.780 0.43563

---

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Correlation of Fixed Effects:

(Intr) Lghtsh HrbvrY Lat Lgh:HY Lght:L HrbY:L

Lightshade -0.750

HerbivoryY -0.751 0.563

Lat -0.996 0.747 0.748

Lghtshd:HrY 0.532 -0.710 -0.708 -0.530

Lightshd:Lt 0.747 -0.996 -0.561 -0.750 0.707

HerbvryY:Lt 0.749 -0.561 -0.996 -0.752 0.705 0.564

Lghtsh:HY:L -0.530 0.707 0.706 0.533 -0.996 -0.710 -0.708

Machine generated alternative text:
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#############SLA###############################################################################################################################

> m7<-lmer(Avg.SLA~Light\*Herbivory\*Lat+(1|Block))

> Anova(m7)

Analysis of Deviance Table (Type II Wald chisquare tests)

Response: Avg.SLA

Chisq Df Pr(>Chisq)

Light 155.6467 1 < 2.2e-16 \*\*\*

Herbivory 3.6365 1 0.05653 .

Lat 25.5650 1 4.277e-07 \*\*\*

Light:Herbivory 0.0019 1 0.96480

Light:Lat 0.5230 1 0.46959

Herbivory:Lat 0.1632 1 0.68625

Light:Herbivory:Lat 1.5989 1 0.20606

---

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

> qqnorm(residuals(m7))

Machine generated alternative text:
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Theoretical Quantiles

> plot(fitted(m7),residuals(m7))

Machine generated alternative text:
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0
0
oc9
oo 0
0
400
450
500 550
600 650
fitted(m7)

> step(m7)

Random effects:

Chi.sq Chi.DF elim.num p.value

(1 | Block) 26.5 1 0 3e-07 \*\*\*

---

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Fixed effects:

Sum Sq Mean Sq NumDF DenDF F.value elim.num Pr(>F)

Light 5.49e+05 5.49e+05 1 30.0 1.44e+02 0 5.33e-13 \*\*\*

Herbivory 1.30e+04 1.30e+04 1 29.1 3.78e+00 5 0.0616 .

Lat 9.24e+04 9.24e+04 1 344.3 2.56e+01 0 6.93e-07 \*\*\*

Light:Herbivory 6.23e+00 6.23e+00 1 28.1 1.95e-03 2 0.9651

Light:Lat 1.66e+03 1.66e+03 1 343.2 4.60e-01 4 0.4980

Herbivory:Lat 5.89e+02 5.89e+02 1 342.2 1.63e-01 3 0.6871

Light:Herbivory:Lat 5.78e+03 5.78e+03 1 341.4 1.60e+00 1 0.2069

---

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Least squares means:

Light Estimate Standard Error DF t-value Lower CI Upper CI p-value

Light ambient 1.0 437.38 8.19 30.0 53.40 421 454 <2e-16 \*\*\*

Light shade 2.0 576.68 8.20 30.1 70.35 560 593 <2e-16 \*\*\*

---

Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Differences of LSMEANS:

Estimate Standard Error DF t-value Lower CI Upper CI p-value

Light ambient-shade -139 11.6 30 -12 -163 -116 <2e-16 \*\*\*

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Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Final model:

lme4::lmer(formula = Avg.SLA ~ Light + Lat + (1 | Block), REML = reml,

contrasts = l)

Warning messages:

1: In model.matrix.default(mt, mf, contrasts) :

variable 'Herbivory' is absent, its contrast will be ignored

2: In model.matrix.default(mt, mf, contrasts) :

variable 'Herbivory' is absent, its contrast will be ignored

3: In model.matrix.default(mt, mf, contrasts) :

variable 'Herbivory' is absent, its contrast will be ignored

> summary(m7)

Linear mixed model fit by REML ['merModLmerTest']

Formula: Avg.SLA ~ Light \* Herbivory \* Lat + (1 | Block)

REML criterion at convergence: 4144.55

Random effects:

Groups Name Variance Std.Dev.

Block (Intercept) 713.2 26.71

Residual 3612.3 60.10

Number of obs: 377, groups: Block, 32

Fixed effects:

Estimate Std. Error t value Pr(>|t|)

(Intercept) 586.051 139.627 4.197 3.44e-05 \*\*\*

Lightshade 402.142 186.046 2.162 0.0313 \*

HerbivoryY 240.126 186.044 1.291 0.1977

Lat -4.338 3.764 -1.153 0.2499

Lightshade:HerbivoryY -329.769 262.577 -1.256 0.2100

Lightshade:Lat -7.049 5.012 -1.406 0.1605

HerbivoryY:Lat -5.920 5.012 -1.181 0.2384

Lightshade:HerbivoryY:Lat 8.943 7.072 1.264 0.2069

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Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Correlation of Fixed Effects:

(Intr) Lghtsh HrbvrY Lat Lgh:HY Lght:L HrbY:L

Lightshade -0.750

HerbivoryY -0.751 0.563

Lat -0.996 0.748 0.748

Lghtshd:HrY 0.532 -0.709 -0.709 -0.530

Lightshd:Lt 0.748 -0.996 -0.561 -0.751 0.706

HerbvryY:Lt 0.748 -0.561 -0.996 -0.751 0.706 0.564

Lghtsh:HY:L -0.530 0.706 0.706 0.532 -0.996 -0.709 -0.709

Machine generated alternative text:
900
800
700
600
400
300
200
100
0—
Ambient
• Shade
Linear (Ambient)
Linear (Shade)
S.
0
0 c
32.0 33.0 34.0 35.0 36.0 37.0 38.0 390 400
Latitude

So basically, what's going on here is that there is a positive relationship between latitude and herbivory and latitude when plants grown under ambient light and herbivory. Otherwise the lines show a negative/no relationship. Of course, seeds/seed head number is reduced overall when light reduced.

None of this seems right…need to figure out how to deal with weird residual.

Diagnostics for sqrt transform look best, but conclusions the same whether transformed or not.

Also looked at log transform for these data, but sqrt diagnostics looked better.