BuckwheatModels_v1.R

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Tue Sep 27 18:13:03 2016

```
library(ggplot2)
library(GGally)
library(dplyr)
```

```
##
## Attaching package: 'dplyr'
```

```
## The following object is masked from 'package:GGally':
##
##     nasa
```

```
## The following objects are masked from 'package:stats':
##
##     filter, lag
```

```
## The following objects are masked from 'package:base':
##
##     intersect, setdiff, setequal, union
```

```
library(mvnormtest)
library(HH)
```

```
## Loading required package: lattice
```

```
## Loading required package: grid
```

```
## Loading required package: latticeExtra
```

```
## Loading required package: RColorBrewer
```

```
##
## Attaching package: 'latticeExtra'
```

```
## The following object is masked from 'package:ggplot2':
##
##     layer
```

```
## Loading required package: multcomp
```

```
## Loading required package: mvtnorm
```

```
## Loading required package: survival
```

```
## Loading required package: TH.data

## Loading required package: MASS

##
## Attaching package: 'MASS'

## The following object is masked from 'package:dplyr':
##
##     select

##
## Attaching package: 'TH.data'

## The following object is masked from 'package:MASS':
##
##     geyser

## Loading required package: gridExtra
```

```
library(Rcmdr)
```

```
## Warning: package 'Rcmdr' was built under R version 3.2.5

## Loading required package: splines

## Loading required package: RcmdrMisc

## Warning: package 'RcmdrMisc' was built under R version 3.2.5

## Loading required package: car

## Warning: package 'car' was built under R version 3.2.5

##
## Attaching package: 'car'

## The following objects are masked from 'package:HH':
##
##     logit, vif

## Loading required package: sandwich

## The Commander GUI is launched only in interactive sessions
```

```
library(nlme)
```

```
##
## Attaching package: 'nlme'

## The following object is masked from 'package:dplyr':
##
##     collapse
```

```r
library(car)
library(lmerTest)
```

```
## Warning: package 'lmerTest' was built under R version 3.2.5
```

```
## Loading required package: Matrix
```

```
## Loading required package: lme4
```

```
##
## Attaching package: 'lme4'
```

```
## The following object is masked from 'package:nlme':
##
##     lmList
```

```
##
## Attaching package: 'lmerTest'
```

```
## The following object is masked from 'package:lme4':
##
##     lmer
```

```
## The following object is masked from 'package:stats':
##
##     step
```

```r
# Create the  data frames

##Read in the data

setwd("D:/Iowa State University/Debinski Lab/Nectar data/Nectar analysis for manuscript")

  # Buckwheat volume, 2015-2016

volume.buck <- read.csv("Nectar_Vol_Buck.csv", header = T)
volume.buck <- data.frame(volume.buck[,1:7])
volume.buck$Date.Factor <- as.factor(volume.buck$Date.Factor)
volume.buck$Year.Factor <- as.factor(volume.buck$Year.Factor) # 1 = 2015, 2 = 2016
volume.buck$Heat <- as.factor(volume.buck$Heat) # 0 = control, 1 = heat treatment
volume.buck$Sample.Round <- as.factor(volume.buck$Sample.Round)
volume.buck$trans.vol <- log10(volume.buck$Volume)  #this doesn't work
head(volume.buck)
```

```
##        Date Date.Factor Year.Factor Plot Sample.Round Heat     Volume
## 1 6/18/2015           1           1  EC3            1    0 0.49090909
## 2 6/18/2015           1           1  EC3            2    0 0.05454545
## 3 6/18/2015           1           1  EC3            3    0 0.47272727
## 4 6/18/2015           1           1  EC3            4    0 0.20000000
## 5 6/18/2015           1           1  EC3            5    0 0.52727273
## 6 6/18/2015           1           1  EC3            6    0 0.16363636
```

```
##    trans.vol
## 1 -0.3089989
## 2 -1.2632414
## 3 -0.3253893
## 4 -0.6989700
## 5 -0.2779647
## 6 -0.7861202
```

```
  # Buckwheat sugar, 2015-2016

sugar.buck <- read.csv("Nectar_BRIX_Buck.csv", header = T, col.names = c("Date", "Date.Factor", "Year.Fa
sugar.buck <- data.frame(sugar.buck[,1:7])
sugar.buck$Date.Factor <- as.factor(sugar.buck$Date.Factor)
sugar.buck$Year.Factor <- as.factor(sugar.buck$Year.Factor)
sugar.buck$Heat <- as.factor(sugar.buck$Heat)
sugar.buck$Mass <- as.numeric(sugar.buck$Mass)
sugar.buck$BRIX <- as.numeric(sugar.buck$BRIX)
sugar.buck$trans.mass <- (sugar.buck$Mass^(1/3))
sugar.buck$trans.conc <- (sugar.buck$BRIX^(2))
head(sugar.buck)
```

```
##        Date Date.Factor Year.Factor Plot Heat BRIX Mass trans.mass
## 1 6/18/2015           1           1  EC3    0   20    3   1.442250
## 2 6/18/2015           1           1  EC3    0   23  146   5.265637
## 3 6/18/2015           1           1  EC3    0   25  193   5.778997
## 4 6/18/2015           1           1  EC3    0   25   64   4.000000
## 5 6/18/2015           1           1  EC3    0   25  210   5.943922
## 6 6/18/2015           1           1  EC3    0   26   48   3.634241
##   trans.conc
## 1        400
## 2        529
## 3        625
## 4        625
## 5        625
## 6        676
```

```
######  MODELS  ########

## VOLUME

# from last year
# volHS <- lme(Volume ~ Heat*Snow, random = ~1 | plot,weights = varIdent(form = ~1 | data_factor), data

# similar code for this year
# using both years the varIdent doesn't converge

# vol.mod1 <- lme(trans.vol ~ Heat, random = ~1 | Plot, weights = varIdent(form = ~1 | Date.Factor), da

  # transformed data for both years
vol.buck.mod <- lme(trans.vol ~ Heat, random = ~1 | Plot, data = volume.buck)
vol.buck.mod
```

```
## Linear mixed-effects model fit by REML
```

```
##   Data: volume.buck
##   Log-restricted-likelihood: -531.3879
##   Fixed: trans.vol ~ Heat
## (Intercept)       Heat1
## -0.75393907 -0.08517345
##
## Random effects:
##  Formula: ~1 | Plot
##          (Intercept) Residual
## StdDev: 3.690971e-05 0.470941
##
## Number of Observations: 791
## Number of Groups: 12
```

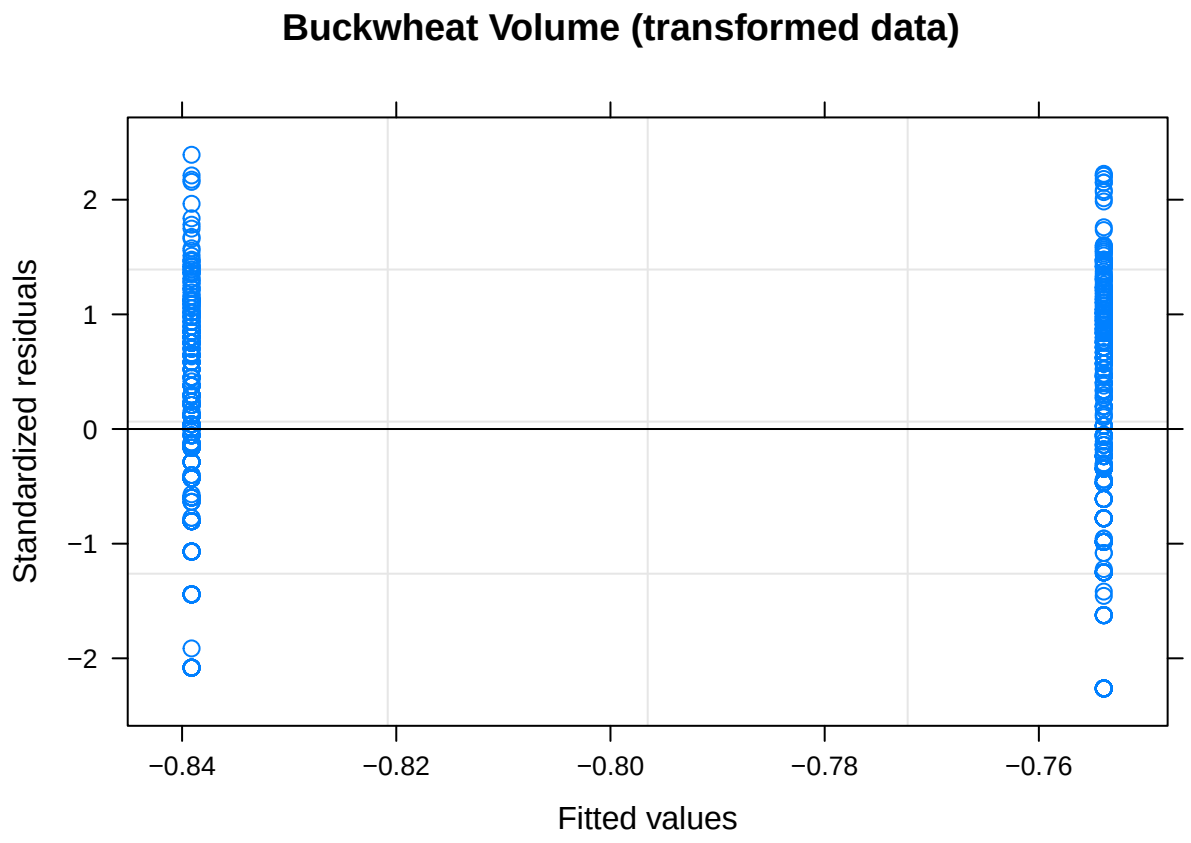
```
Anova(vol.buck.mod)
```

```
## Analysis of Deviance Table (Type II tests)
##
## Response: trans.vol
##       Chisq Df Pr(>Chisq)
## Heat 6.4678  1    0.01098 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
summary(vol.buck.mod)   #p-value = 0.0292
```

```
## Linear mixed-effects model fit by REML
##  Data: volume.buck
##        AIC      BIC    logLik
##   1070.776 1089.459 -531.3879
##
## Random effects:
##  Formula: ~1 | Plot
##          (Intercept) Residual
## StdDev: 3.690971e-05 0.470941
##
## Fixed effects: trans.vol ~ Heat
##                  Value  Std.Error  DF   t-value p-value
## (Intercept) -0.7539391 0.02357655 779 -31.97835  0.0000
## Heat1       -0.0851734 0.03349079  10  -2.54319  0.0292
##  Correlation:
##       (Intr)
## Heat1 -0.704
##
## Standardized Within-Group Residuals:
##         Min          Q1         Med          Q3         Max
## -2.26271414 -0.77851540  0.02882811  0.80159389  2.39170974
##
## Number of Observations: 791
## Number of Groups: 12
```

```r
plot(vol.buck.mod, main = "Buckwheat Volume (transformed data)")
```




```r
  # untransformed data for both years
vol.buck.mod2 <- lme(Volume ~ Heat, random = ~1 | Plot, data = volume.buck)
vol.buck.mod2
```

```
## Linear mixed-effects model fit by REML
##   Data: volume.buck
##   Log-restricted-likelihood: -173.1805
##   Fixed: Volume ~ Heat
## (Intercept)       Heat1
##  0.31492150 -0.08682837
##
## Random effects:
##  Formula: ~1 | Plot
##         (Intercept)  Residual
## StdDev:  0.04677673 0.2972938
##
## Number of Observations: 791
## Number of Groups: 12
```

```r
Anova(vol.buck.mod2)
```

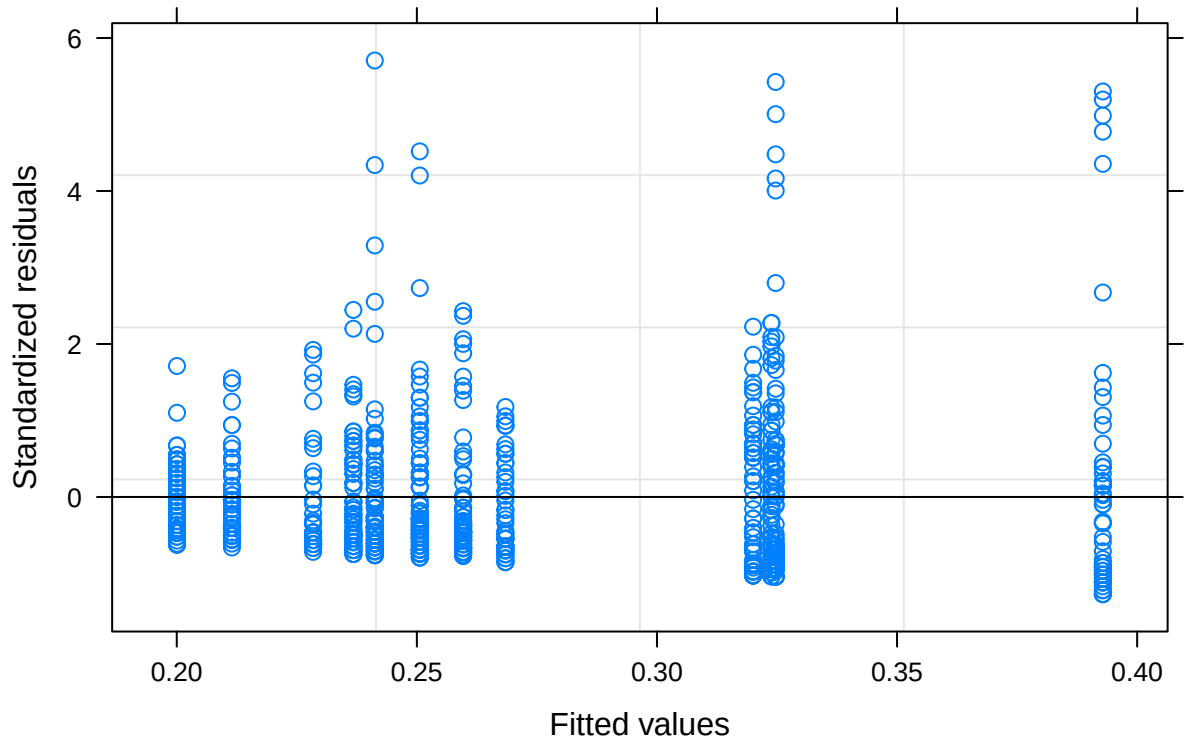
```
## Analysis of Deviance Table (Type II tests)
```

```
##
## Response: Volume
##       Chisq Df Pr(>Chisq)
## Heat 6.3017  1    0.01206 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
summary(vol.buck.mod2)   #p-value = 0.0309
```

```
## Linear mixed-effects model fit by REML
##  Data: volume.buck
##        AIC     BIC    logLik
##   354.3609 373.044 -173.1805
##
## Random effects:
##  Formula: ~1 | Plot
##         (Intercept)  Residual
## StdDev:  0.04677673 0.2972938
##
## Fixed effects: Volume ~ Heat
##                   Value  Std.Error  DF   t-value p-value
## (Intercept)  0.31492150 0.02437261 779 12.921122  0.0000
## Heat1       -0.08682837 0.03458858  10 -2.510319  0.0309
##  Correlation:
##       (Intr)
## Heat1 -0.705
##
## Standardized Within-Group Residuals:
##        Min         Q1        Med         Q3        Max
## -1.2704596 -0.6219106 -0.3229239  0.3909921  5.7056740
##
## Number of Observations: 791
## Number of Groups: 12
```

```
plot(vol.buck.mod2, main = "Buckwheat Volume (untransformed data")
```




```
  #transformed data 2015
volume.buck2015 <- as.data.frame(volume.buck[volume.buck$Year.Factor == "1",])
vol.mod2 <- lme(trans.vol ~ Heat, random = ~1 | Plot, weights = varIdent(form = ~1 | Date.Factor), data
anova(vol.mod2)
```

```
##             numDF denDF  F-value p-value
## (Intercept)     1   403 421.8873  <.0001
## Heat            1    10   9.4695  0.0117
```

```
Anova(vol.mod2)
```

```
## Analysis of Deviance Table (Type II tests)
##
## Response: trans.vol
##       Chisq Df Pr(>Chisq)
## Heat 9.4695  1   0.002089 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
summary(vol.mod2)  #p-value = 0.0117
```

```
## Linear mixed-effects model fit by REML
##  Data: volume.buck2015
##        AIC      BIC    logLik
```

```
##   125.6945 190.0697 -46.84725
##
## Random effects:
##  Formula: ~1 | Plot
##         (Intercept)  Residual
## StdDev:  0.06195314 0.2904425
##
## Variance function:
##  Structure: Different standard deviations per stratum
##  Formula: ~1 | Date.Factor
##  Parameter estimates:
##         2         5         8        11         1         4         7
## 1.0000000 0.7951472 1.1874828 1.1228430 1.0111732 0.7642782 0.7565219
##        10         3         6         9        12        13
## 1.2135565 0.6840098 0.5930416 0.6036827 1.2864805 1.8077578
## Fixed effects: trans.vol ~ Heat
##                  Value  Std.Error  DF    t-value p-value
## (Intercept) -0.3804754 0.03079426 403 -12.355397  0.0000
## Heat1       -0.1340735 0.04356911  10  -3.077261  0.0117
##  Correlation:
##       (Intr)
## Heat1 -0.707
##
## Standardized Within-Group Residuals:
##         Min          Q1         Med          Q3         Max
## -3.20473443 -0.67489877  0.07115152  0.67551925  2.07901456
##
## Number of Observations: 415
## Number of Groups: 12
```

```
  #untransformed data 2015
vol.mod2a <- lme(Volume ~ Heat, random = ~1 | Plot, weights = varIdent(form = ~1 | Date.Factor), data =
anova(vol.mod2a)
```

```
##             numDF denDF   F-value p-value
## (Intercept)     1   403 308.42313  <.0001
## Heat            1    10   6.09478  0.0332
```

```
Anova(vol.mod2a)
```

```
## Analysis of Deviance Table (Type II tests)
##
## Response: Volume
##       Chisq Df Pr(>Chisq)
## Heat 6.0948  1    0.01356 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
summary(vol.mod2a)  #p-value = 0.0332
```

```
## Linear mixed-effects model fit by REML
##  Data: volume.buck2015
```

```
##         AIC      BIC   logLik
##   -45.60808 18.76709 38.80404
##
## Random effects:
##  Formula: ~1 | Plot
##         (Intercept)  Residual
## StdDev:  0.06145187 0.3785301
##
## Variance function:
##  Structure: Different standard deviations per stratum
##  Formula: ~1 | Date.Factor
##  Parameter estimates:
##         2         5         8        11         1         4         7
## 1.0000000 0.7009815 0.3627515 0.3504414 0.3997509 0.4205258 0.5425622
##        10         3         6         9        12        13
## 0.5214868 0.3575878 0.4245534 0.5565554 0.5167885 2.4274328
## Fixed effects: Volume ~ Heat
##                  Value  Std.Error  DF   t-value p-value
## (Intercept)  0.4000833 0.02826061 403 14.156922  0.0000
## Heat1       -0.0986037 0.03994055  10 -2.468762  0.0332
##  Correlation:
##       (Intr)
## Heat1 -0.708
##
## Standardized Within-Group Residuals:
##        Min         Q1        Med         Q3        Max
## -2.7006398 -0.5155000  0.1443658  0.7696934  2.8270866
##
## Number of Observations: 415
## Number of Groups: 12
```

```
  #transformed data 2016
volume.buck2016 <- as.data.frame(volume.buck[volume.buck$Year.Factor == "2",])
vol.mod3 <- lme(trans.vol ~ Heat, random = ~1 | Plot, weights = varIdent(form = ~1 | Date.Factor), data
anova(vol.mod3)
```

```
##             numDF denDF   F-value p-value
## (Intercept)     1   364 2015.4180  <.0001
## Heat            1    10    0.2754  0.6111
```

```
Anova(vol.mod3)
```

```
## Analysis of Deviance Table (Type II tests)
##
## Response: trans.vol
##       Chisq Df Pr(>Chisq)
## Heat 0.2754  1     0.5997
```

```
summary(vol.mod3)   #p-value = 0.6111
```

```
## Linear mixed-effects model fit by REML
##  Data: volume.buck2016
```

```
##        AIC      BIC   logLik
##   196.4406 235.6832 -88.2203
##
## Random effects:
##  Formula: ~1 | Plot
##         (Intercept)  Residual
## StdDev:  0.07171566 0.3066336
##
## Variance function:
##  Structure: Different standard deviations per stratum
##  Formula: ~1 | Date.Factor
##  Parameter estimates:
##        14        15        16        17        18        19        20
## 1.0000000 0.9550926 1.1715632 0.9233733 0.8008654 0.8541176 1.4507221
## Fixed effects: trans.vol ~ Heat
##                  Value  Std.Error  DF    t-value p-value
## (Intercept) -1.1477658 0.03647853 364 -31.464145  0.0000
## Heat1       -0.0271514 0.05173514  10  -0.524816  0.6111
##  Correlation:
##       (Intr)
## Heat1 -0.705
##
## Standardized Within-Group Residuals:
##        Min         Q1        Med         Q3        Max
## -2.6499209 -0.6332651  0.1229705  0.6660094  2.4810839
##
## Number of Observations: 376
## Number of Groups: 12
```

```
  #untransformed data 2016
vol.mod3a <- lme(Volume ~ Heat, random = ~1 | Plot, weights = varIdent(form = ~1 | Date.Factor), data =
anova(vol.mod3a)
```

```
##             numDF denDF   F-value p-value
## (Intercept)     1   364 287.08152  <.0001
## Heat            1    10   0.87748   0.371
```

```
Anova(vol.mod3a)
```

```
## Analysis of Deviance Table (Type II tests)
##
## Response: Volume
##       Chisq Df Pr(>Chisq)
## Heat 0.8775  1     0.3489
```

```
summary(vol.mod3a)   #p-value = 0.371
```

```
## Linear mixed-effects model fit by REML
##  Data: volume.buck2016
##         AIC       BIC   logLik
##   -1084.738 -1045.496 552.3691
##
```

```
## Random effects:
##  Formula: ~1 | Plot
##         (Intercept)   Residual
## StdDev:  0.01385366 0.05509705
##
## Variance function:
##  Structure: Different standard deviations per stratum
##  Formula: ~1 | Date.Factor
##  Parameter estimates:
##        14        15        16        17        18        19        20
## 1.0000000 1.0401379 1.0005164 0.9689249 0.8500960 0.9858594 0.9526127
## Fixed effects: Volume ~ Heat
##                   Value   Std.Error  DF   t-value p-value
## (Intercept)  0.08776272 0.006927230 364 12.669237   0.000
## Heat1       -0.00919806 0.009819204  10 -0.936742   0.371
##  Correlation:
##       (Intr)
## Heat1 -0.705
##
## Standardized Within-Group Residuals:
##        Min         Q1        Med         Q3        Max
## -1.7464067 -0.6868649 -0.1148640  0.4937596  5.7237650
##
## Number of Observations: 376
## Number of Groups: 12
```

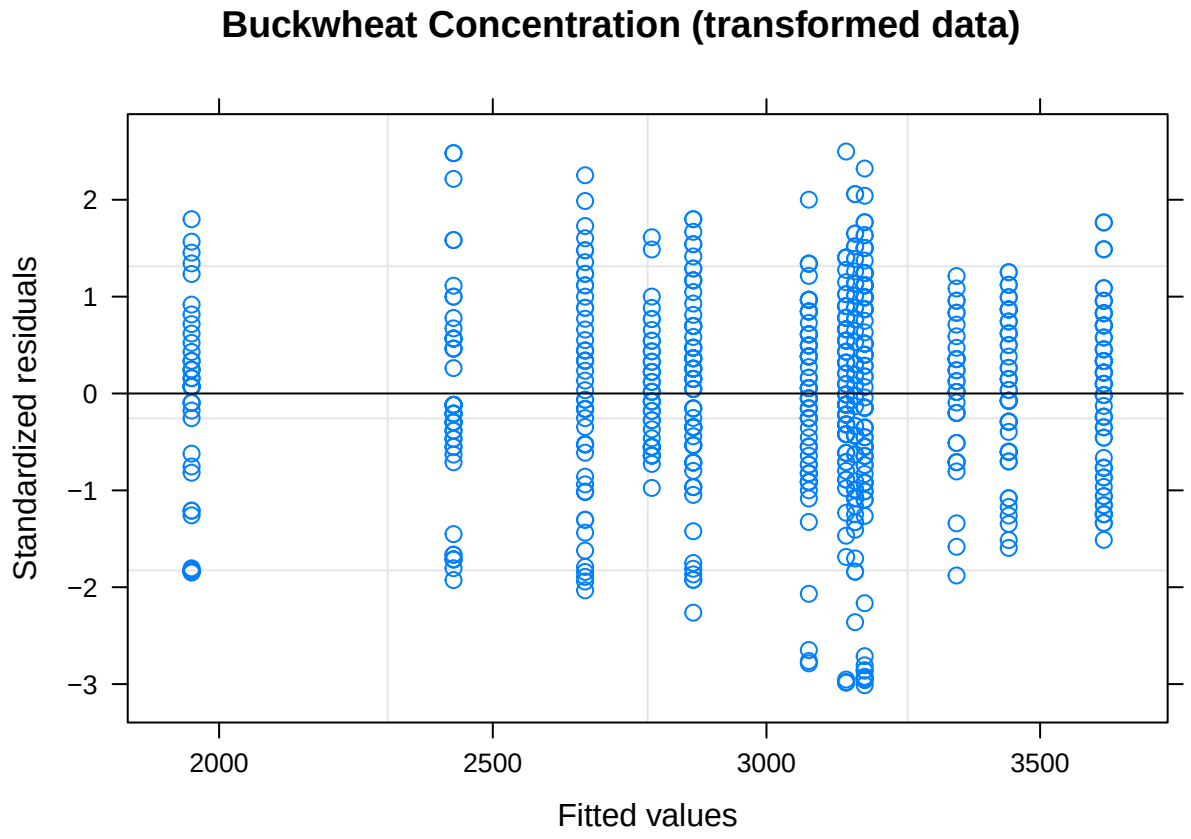
```
##  CONCENTRATION (BRIX)

#From last year
# brixHS <- lme(BRIX ~ Heat*Snow, random = ~1 | plot, weights = varIdent(form = ~1 | data_factor), data

# similar code for this year
# using both years the varIdent doesn't converge (for either BRIX or mass)

# conc.mod1 <- lme(trans.conc ~ Heat, random = ~1 | Plot, weights = varIdent(form = ~1 | Date.Factor),

conc.buck.mod <- lme(trans.conc ~ Heat, random = ~1 | Plot, data = sugar.buck, na.action(na.omit))
conc.buck.mod
```

```
## Linear mixed-effects model fit by REML
##   Data: sugar.buck
##   Log-restricted-likelihood: -5964.54
##   Fixed: trans.conc ~ Heat
## (Intercept)       Heat1
##   2647.1579    651.3845
##
## Random effects:
##  Formula: ~1 | Plot
##         (Intercept) Residual
## StdDev:    357.1489  1052.93
##
## Number of Observations: 712
## Number of Groups: 12
```

```r
summary(conc.buck.mod)  #p-value = 0.0149
```

```
## Linear mixed-effects model fit by REML
##  Data: sugar.buck
##        AIC      BIC   logLik
##   11937.08 11955.34 -5964.54
##
## Random effects:
##  Formula: ~1 | Plot
##         (Intercept) Residual
## StdDev:    357.1489  1052.93
##
## Fixed effects: trans.conc ~ Heat
##                 Value Std.Error  DF   t-value p-value
## (Intercept) 2647.1579  156.9807 700 16.862953  0.0000
## Heat1        651.3845  221.8326  10  2.936378  0.0149
##  Correlation:
##       (Intr)
## Heat1 -0.708
##
## Standardized Within-Group Residuals:
##        Min         Q1        Med         Q3        Max
## -3.0110652 -0.5523084  0.0472016  0.6968176  2.4981797
##
## Number of Observations: 712
## Number of Groups: 12
```

```r
plot(conc.buck.mod, main = "Buckwheat Concentration (transformed data)")
```




```
conc.buck.mod2 <- lme(BRIX ~ Heat, random = ~1 | Plot, data = sugar.buck, na.action(na.omit))
conc.buck.mod2
```

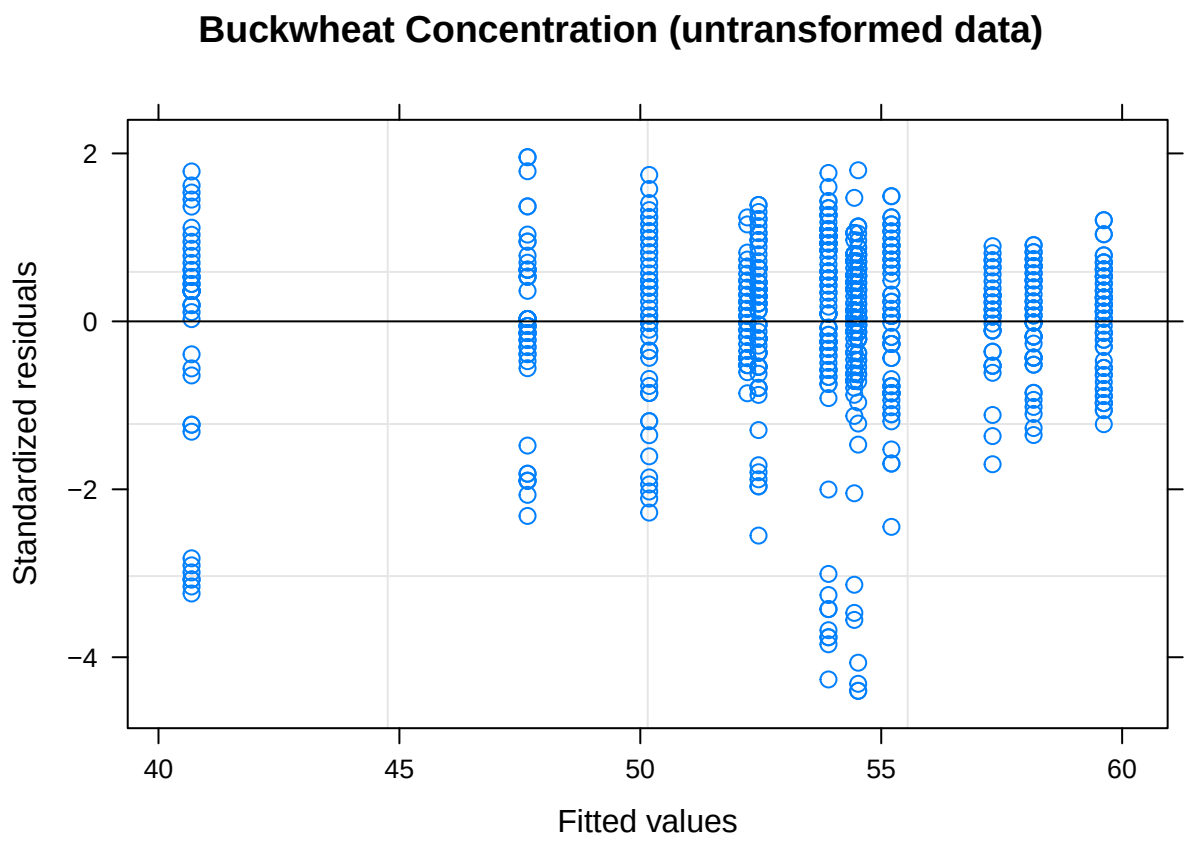
```
## Linear mixed-effects model fit by REML
##   Data: sugar.buck
##   Log-restricted-likelihood: -2783.912
##   Fixed: BRIX ~ Heat
## (Intercept)       Heat1
##   49.518534    7.026199
##
## Random effects:
##  Formula: ~1 | Plot
##         (Intercept) Residual
## StdDev:    4.028846  11.9369
##
## Number of Observations: 712
## Number of Groups: 12
```

```
summary(conc.buck.mod2)  #p-value = 0.0186
```

```
## Linear mixed-effects model fit by REML
##  Data: sugar.buck
##        AIC      BIC    logLik
##   5575.824 5594.085 -2783.912
##
```

```
## Random effects:
##  Formula: ~1 | Plot
##         (Intercept) Residual
## StdDev:    4.028846  11.9369
##
## Fixed effects: BRIX ~ Heat
##                Value Std.Error  DF   t-value p-value
## (Intercept) 49.51853  1.772039 700 27.944384  0.0000
## Heat1        7.02620  2.504084  10  2.805896  0.0186
##  Correlation:
##       (Intr)
## Heat1 -0.708
##
## Standardized Within-Group Residuals:
##        Min         Q1        Med         Q3        Max
## -4.3999655 -0.3817041  0.1300268  0.6264638  1.9553170
##
## Number of Observations: 712
## Number of Groups: 12
```

```
plot(conc.buck.mod2, main = "Buckwheat Concentration (untransformed data)")
```




```
sugar.buck2015 <- as.data.frame(sugar.buck[sugar.buck$Year.Factor == "1",])

conc.mod2 <- lme(trans.conc ~ Heat, random = ~1 | Plot, weights = varIdent(form = ~1 | Date.Factor), da
anova(conc.mod2)
```

```
##             numDF denDF   F-value p-value
## (Intercept)     1   404 1015.4242  <.0001
## Heat            1    10   19.0279  0.0014
```

```
summary(conc.mod2)  #p-value = 0.0014
```

```
## Linear mixed-effects model fit by REML
##  Data: sugar.buck2015
##        AIC      BIC    logLik
##   6843.961 6908.375 -3405.981
##
## Random effects:
##  Formula: ~1 | Plot
##         (Intercept) Residual
## StdDev:     304.473 1879.777
##
## Variance function:
##  Structure: Different standard deviations per stratum
##  Formula: ~1 | Date.Factor
##  Parameter estimates:
##         2         5         8        11         1         4         7
## 1.0000000 0.4169006 0.5532085 0.3346412 0.8691377 0.4274809 0.2809754
##        10         3         6         9        12        13
## 0.4542214 0.2683543 0.3022067 0.2881251 0.7716912 1.2707916
## Fixed effects: trans.conc ~ Heat
##                 Value Std.Error  DF   t-value p-value
## (Intercept) 2629.0679  135.1104 404 19.458670  0.0000
## Heat1        833.8349  191.1546  10  4.362098  0.0014
##  Correlation:
##       (Intr)
## Heat1 -0.707
##
## Standardized Within-Group Residuals:
##        Min         Q1        Med         Q3        Max
## -2.5865467 -0.8932383 -0.2966496  0.6091621  3.2818533
##
## Number of Observations: 416
## Number of Groups: 12
```

```
conc.mod2a <- lme(BRIX ~ Heat, random = ~1 | Plot, weights = varIdent(form = ~1 | Date.Factor), data = s
anova(conc.mod2a)
```

```
##             numDF denDF  F-value p-value
## (Intercept)     1   404 3931.882  <.0001
## Heat            1    10   18.935  0.0014
```

```
summary(conc.mod2a)  #p-value = 0.0014
```

```
## Linear mixed-effects model fit by REML
##  Data: sugar.buck2015
##        AIC      BIC    logLik
##   3002.675 3067.089 -1485.338
```

```
##
## Random effects:
##  Formula: ~1 | Plot
##         (Intercept) Residual
## StdDev:    2.806329 21.51373
##
## Variance function:
##  Structure: Different standard deviations per stratum
##  Formula: ~1 | Date.Factor
##  Parameter estimates:
##         2         5         8        11         1         4         7
## 1.0000000 0.3377868 0.3969761 0.2420296 0.8696390 0.3224826 0.2207496
##        10         3         6         9        12        13
## 0.3524626 0.2036835 0.2403494 0.2487222 0.6545165 1.7485778
## Fixed effects: BRIX ~ Heat
##                Value Std.Error  DF  t-value p-value
## (Intercept) 51.15570  1.239702 404 41.26450  0.0000
## Heat1        7.62942  1.753297  10  4.35147  0.0014
##  Correlation:
##       (Intr)
## Heat1 -0.707
##
## Standardized Within-Group Residuals:
##        Min         Q1        Med         Q3        Max
## -2.9090567 -0.8545994 -0.3060127  0.6318744  3.1983580
##
## Number of Observations: 416
## Number of Groups: 12
```

```
sugar.buck2016 <- as.data.frame(sugar.buck[sugar.buck$Year.Factor == "2",])

conc.mod3 <- lme(trans.conc ~ Heat, random = ~1 | Plot, weights = varIdent(form = ~1 | Date.Factor), da
anova(conc.mod3)
```

```
##             numDF denDF  F-value p-value
## (Intercept)     1   284 722.7912  <.0001
## Heat            1    10   0.9739   0.347
```

```
summary(conc.mod3)  # p-value = 0.347
```

```
## Linear mixed-effects model fit by REML
##  Data: sugar.buck2016
##        AIC      BIC    logLik
##   4812.049 4848.885 -2396.024
##
## Random effects:
##  Formula: ~1 | Plot
##         (Intercept) Residual
## StdDev:    385.4495 837.0617
##
## Variance function:
##  Structure: Different standard deviations per stratum
##  Formula: ~1 | Date.Factor
```

```
##  Parameter estimates:
##        14        15        16        17        18        19        20
## 1.0000000 0.9072052 0.9706501 0.8395561 1.0622368 0.9340299 1.0278693
## Fixed effects: trans.conc ~ Heat
##                 Value Std.Error  DF   t-value p-value
## (Intercept) 3157.3055  174.0631 284 18.138856   0.000
## Heat1        240.8274  244.0295  10  0.986878   0.347
##  Correlation:
##       (Intr)
## Heat1 -0.713
##
## Standardized Within-Group Residuals:
##          Min           Q1          Med           Q3          Max
## -2.350853771 -0.773380100 -0.002821791  0.708777987  2.537109911
##
## Number of Observations: 296
## Number of Groups: 12
```

```
conc.mod3a <- lme(BRIX ~ Heat, random = ~1 | Plot, weights = varIdent(form = ~1 | Date.Factor), data = s
anova(conc.mod3a)
```

```
##             numDF denDF   F-value p-value
## (Intercept)     1   284 2756.8499  <.0001
## Heat            1    10    1.0489  0.3299
```

```
summary(conc.mod3a)   #p-value = 0.3299
```

```
## Linear mixed-effects model fit by REML
##  Data: sugar.buck2016
##        AIC      BIC    logLik
##   2035.588 2072.424 -1007.794
##
## Random effects:
##  Formula: ~1 | Plot
##         (Intercept) Residual
## StdDev:    3.426216 7.849756
##
## Variance function:
##  Structure: Different standard deviations per stratum
##  Formula: ~1 | Date.Factor
##  Parameter estimates:
##        14        15        16        17        18        19        20
## 1.0000000 0.8471683 0.8617411 0.8016230 1.0280285 0.9058533 0.9018450
## Fixed effects: BRIX ~ Heat
##                Value Std.Error  DF  t-value p-value
## (Intercept) 55.81230  1.547155 284 36.07415  0.0000
## Heat1        2.22169  2.169322  10  1.02414  0.3299
##  Correlation:
##       (Intr)
## Heat1 -0.713
##
## Standardized Within-Group Residuals:
##        Min         Q1        Med         Q3        Max
```

```
## -2.7382428 -0.7815830  0.0267839  0.6998501  2.4280686
##
## Number of Observations: 296
## Number of Groups: 12
```

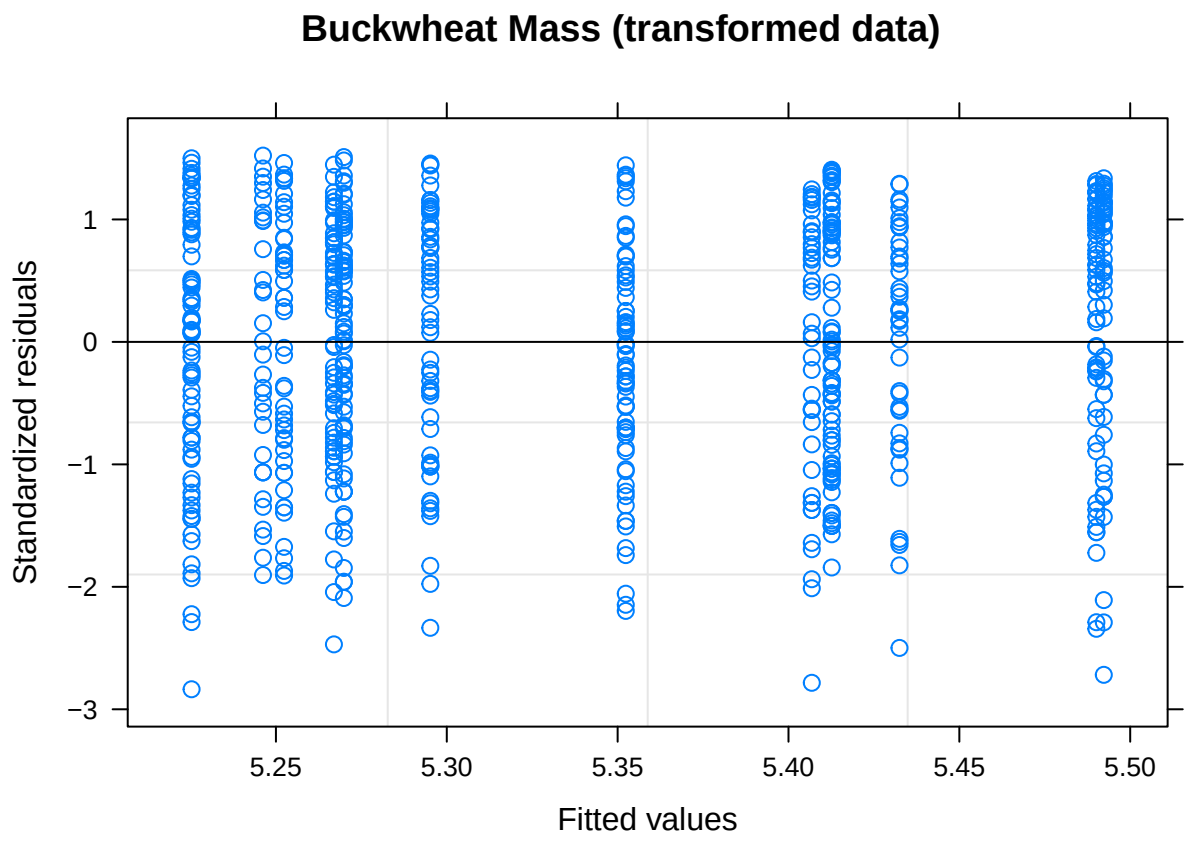
```
## MASS

# mass.mod1 <- lme(trans.mass ~ Heat, random = ~1 | Plot, weights = varIdent(form = ~1 | Date.Factor),

mass.buck.mod <- lme(trans.mass ~ Heat, random = ~1 | Plot, data = sugar.buck)
mass.buck.mod
```

```
## Linear mixed-effects model fit by REML
##   Data: sugar.buck
##   Log-restricted-likelihood: -1297.369
##   Fixed: trans.mass ~ Heat
## (Intercept)       Heat1
##   5.4311227  -0.1717983
##
## Random effects:
##  Formula: ~1 | Plot
##         (Intercept) Residual
## StdDev:  0.09505977 1.489698
##
## Number of Observations: 712
## Number of Groups: 12
```

```
summary(mass.buck.mod)  #p-value = 0.20
```

```
## Linear mixed-effects model fit by REML
##  Data: sugar.buck
##        AIC      BIC    logLik
##   2602.738 2620.999 -1297.369
##
## Random effects:
##  Formula: ~1 | Plot
##         (Intercept) Residual
## StdDev:  0.09505977 1.489698
##
## Fixed effects: trans.mass ~ Heat
##                 Value  Std.Error  DF  t-value p-value
## (Intercept)  5.431123 0.08915633 700 60.91685     0.0
## Heat1       -0.171798 0.12520957  10 -1.37209     0.2
##  Correlation:
##       (Intr)
## Heat1 -0.712
##
## Standardized Within-Group Residuals:
##        Min         Q1        Med         Q3        Max
## -2.8363561 -0.7814843  0.1274088  0.8972448  1.5213514
##
## Number of Observations: 712
## Number of Groups: 12
```

```
plot(mass.buck.mod, main = "Buckwheat Mass (transformed data)")
```




```
mass.buck.mod2 <- lme(Mass ~ Heat, random = ~1 | Plot, data = sugar.buck)
mass.buck.mod2
```

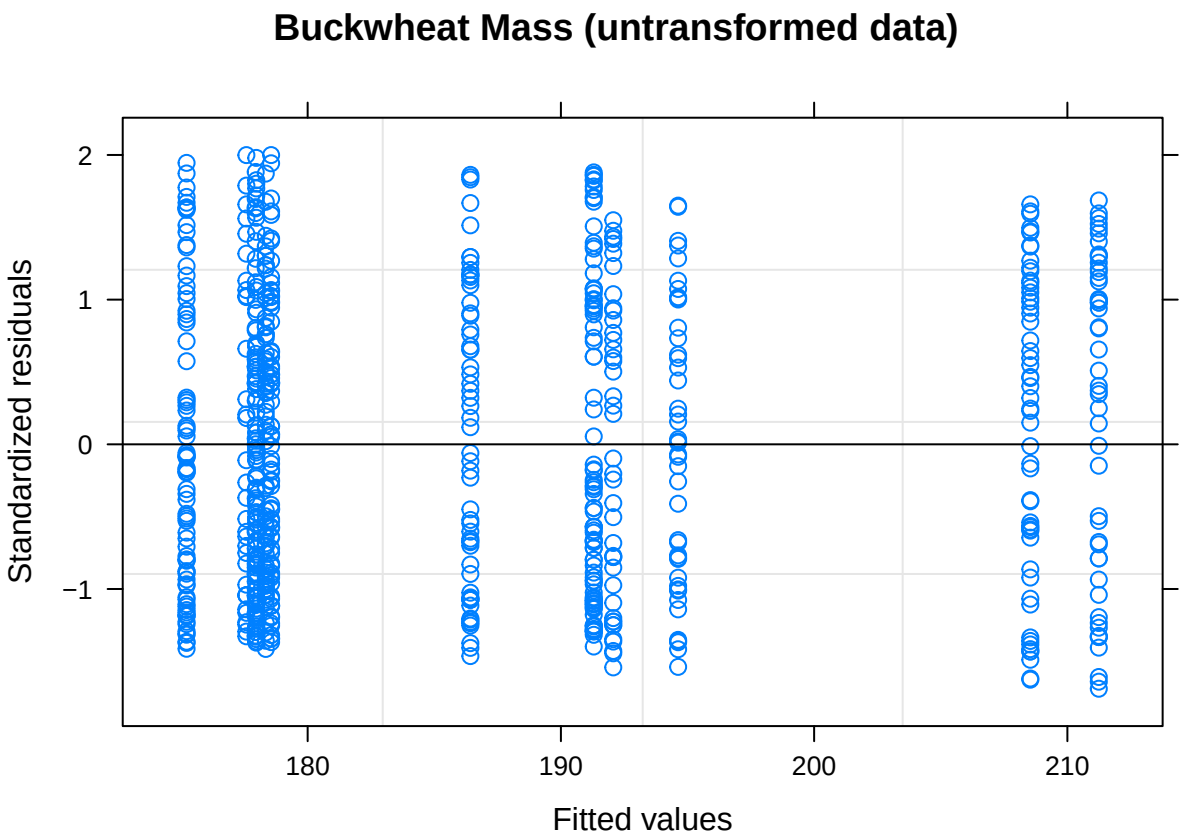
```
## Linear mixed-effects model fit by REML
##   Data: sugar.buck
##   Log-restricted-likelihood: -4434.288
##   Fixed: Mass ~ Heat
## (Intercept)       Heat1
##   195.95740   -16.94452
##
## Random effects:
##  Formula: ~1 | Plot
##         (Intercept) Residual
## StdDev:    13.99171 123.2673
##
## Number of Observations: 712
## Number of Groups: 12
```

```
summary(mass.buck.mod2)  #p-value = 0.02016
```

```
## Linear mixed-effects model fit by REML
##  Data: sugar.buck
```

```
##        AIC      BIC    logLik
##   8876.576 8894.837 -4434.288
##
## Random effects:
##  Formula: ~1 | Plot
##         (Intercept) Residual
## StdDev:    13.99171 123.2673
##
## Fixed effects: Mass ~ Heat
##                 Value Std.Error  DF   t-value p-value
## (Intercept) 195.95740  8.806914 700 22.250405  0.0000
## Heat1       -16.94452 12.395145  10 -1.367028  0.2016
##  Correlation:
##       (Intr)
## Heat1 -0.711
##
## Standardized Within-Group Residuals:
##        Min         Q1        Med         Q3        Max
## -1.6893404 -0.9001154 -0.1255971  0.9122207  1.9992599
##
## Number of Observations: 712
## Number of Groups: 12
```

```
plot(mass.buck.mod2, main = "Buckwheat Mass (untransformed data)")
```



```r
mass.mod2 <- lme(trans.mass ~ Heat, random = ~1 | Plot, weights = varIdent(form = ~1 | Date.Factor), da
anova(mass.mod2)
```

```
##             numDF denDF   F-value p-value
## (Intercept)     1   404 10605.977  <.0001
## Heat            1    10     1.977    0.19
```

```r
summary(mass.mod2) #p-value = 0.19
```

```
## Linear mixed-effects model fit by REML
##  Data: sugar.buck2015
##        AIC      BIC    logLik
##   1118.789 1183.203 -543.3943
##
## Random effects:
##  Formula: ~1 | Plot
##         (Intercept) Residual
## StdDev:   0.1766674 0.903998
##
## Variance function:
##  Structure: Different standard deviations per stratum
##  Formula: ~1 | Date.Factor
##  Parameter estimates:
##         2         5         8        11         1         4         7
## 1.0000000 0.7159227 1.1828480 1.2100191 2.0973375 0.7287451 0.7623626
##        10         3         6         9        12        13
## 1.4440755 0.5974103 0.5606354 0.5820022 1.8406041 2.5028369
## Fixed effects: trans.mass ~ Heat
##                 Value  Std.Error  DF  t-value p-value
## (Intercept)  6.641035 0.09001328 404 73.77839    0.00
## Heat1       -0.178883 0.12723179  10 -1.40596    0.19
##  Correlation:
##       (Intr)
## Heat1 -0.707
##
## Standardized Within-Group Residuals:
##         Min          Q1         Med          Q3         Max
## -3.59537217 -0.67316833 -0.06697464  0.56446961  1.86574815
##
## Number of Observations: 416
## Number of Groups: 12
```

```r
mass.mod2a <- lme(Mass ~ Heat, random = ~1 | Plot, weights = varIdent(form = ~1 | Date.Factor), data = s
anova(mass.mod2a)
```

```
##             numDF denDF   F-value p-value
## (Intercept)     1   404 1403.0201  <.0001
## Heat            1    10    2.2691  0.1629
```

```r
summary(mass.mod2a)  #p-value = 0.1629
```

```
## Linear mixed-effects model fit by REML
##  Data: sugar.buck2015
##        AIC      BIC   logLik
##   4981.961 5046.374 -2474.98
##
## Random effects:
##  Formula: ~1 | Plot
##         (Intercept) Residual
## StdDev:    21.05059 95.30663
##
## Variance function:
##  Structure: Different standard deviations per stratum
##  Formula: ~1 | Date.Factor
##  Parameter estimates:
##         2         5         8        11         1         4         7
## 1.0000000 0.9328244 0.9660392 1.0559108 1.5637361 0.8050958 0.8361191
##        10         3         6         9        12        13
## 1.1056249 0.6551229 0.7525897 0.7416482 1.3696292 1.9452555
## Fixed effects: Mass ~ Heat
##                 Value Std.Error  DF   t-value p-value
## (Intercept) 292.14490  10.60303 404 27.552966  0.0000
## Heat1       -22.58927  14.99600  10 -1.506353  0.1629
##  Correlation:
##       (Intr)
## Heat1 -0.707
##
## Standardized Within-Group Residuals:
##         Min          Q1         Med          Q3         Max
## -2.89621692 -0.78415146 -0.05777529  0.68466508  2.03231407
##
## Number of Observations: 416
## Number of Groups: 12
```

```
mass.mod3 <- lme(trans.mass ~ Heat, random = ~1 | Plot, weights = varIdent(form = ~1 | Date.Factor), da
anova(mass.mod3)
```

```
##             numDF denDF  F-value p-value
## (Intercept)     1   284 3764.813  <.0001
## Heat            1    10    1.135  0.3117
```

```
summary(mass.mod3)  #p-value = 0.3117
```

```
## Linear mixed-effects model fit by REML
##  Data: sugar.buck2016
##        AIC      BIC    logLik
##   837.8686 874.7044 -408.9343
##
## Random effects:
##  Formula: ~1 | Plot
##         (Intercept)  Residual
## StdDev:   0.1290959 0.9516536
##
## Variance function:
```

```
##  Structure: Different standard deviations per stratum
##  Formula: ~1 | Date.Factor
##  Parameter estimates:
##        14        15        16        17        18        19        20
## 1.0000000 0.7870183 1.0999676 1.0961914 0.9931868 1.0070202 1.5251281
## Fixed effects: trans.mass ~ Heat
##                 Value Std.Error  DF  t-value p-value
## (Intercept)  4.175659 0.0967089 284 43.17761  0.0000
## Heat1       -0.142588 0.1338137  10 -1.06557  0.3117
##  Correlation:
##       (Intr)
## Heat1 -0.723
##
## Standardized Within-Group Residuals:
##         Min          Q1         Med          Q3         Max
## -2.83447977 -0.75354260  0.01129988  0.72641908  2.34819680
##
## Number of Observations: 296
## Number of Groups: 12
```

```
mass.mod3a <- lme(Mass ~ Heat, random = ~1 | Plot, weights = varIdent(form = ~1 | Date.Factor), data = s
anova(mass.mod3a)
```

```
##             numDF denDF  F-value p-value
## (Intercept)     1   284 410.2778  <.0001
## Heat            1    10   1.3052  0.2799
```

```
summary(mass.mod3a)  #p-value = 0.2799
```

```
## Linear mixed-effects model fit by REML
##  Data: sugar.buck2016
##        AIC      BIC    logLik
##   3154.059 3190.894 -1567.029
##
## Random effects:
##  Formula: ~1 | Plot
##         (Intercept) Residual
## StdDev:    8.961541 50.60997
##
## Variance function:
##  Structure: Different standard deviations per stratum
##  Formula: ~1 | Date.Factor
##  Parameter estimates:
##        14        15        16        17        18        19        20
## 1.0000000 0.7794402 1.0561812 1.0602040 0.9083761 1.0099743 1.1634213
## Fixed effects: Mass ~ Heat
##                Value Std.Error  DF   t-value p-value
## (Intercept) 83.22323  5.605493 284 14.846728  0.0000
## Heat1       -8.87449  7.767799  10 -1.142471  0.2799
##  Correlation:
##       (Intr)
## Heat1 -0.722
##
```

```
## Standardized Within-Group Residuals:
##        Min         Q1        Med         Q3        Max
## -2.0256900 -0.8294104 -0.2060566  0.6645299  3.4472343
##
## Number of Observations: 296
## Number of Groups: 12
```