Appendix 4C - Tests, diagnostic plots and assumption testing

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Setup

```
library(lmerTest)
library(ggplot2)
library(car)
library(data.table)
library(bestNormalize)
library(emmeans)
library(tidyverse)
library(ggpubr)
library(rcompanion)
library(corrplot)
library(ggcorrplot)
library(Hmisc)
library(PerformanceAnalytics)
library(FSA)
library(RcmdrMisc)
library(MuMIn)

knitr::opts_knit$set(root.dir = "C:/Users/lhamberg/Dropbox/UAVthermalpaper/R_files/Mark")
```

4.3.

4.3.1. Surface temperature change over time

4.3.1.1. Gravel pit site in July and September

Ecological attributes table (prep)

```
AllS <-read.csv("AllSites.csv")
AllS <- filter(AllS, Treatment != "DS", Treatment != "WD")
AllS_GP <- filter(AllS, Field == "PE")
AllS_16 <- filter(AllS, Field == "YA2016")
AllS_15 <- filter(AllS, Field == "YA2015")
```

Gravel pit - ecological attributes tables and tests

```
#ground cover - assumptions met
```

```
ex1 <- AllS_GP %>%
  group_by(Treatment) %>%
  summarise(mean(Ground.cover), sd(Ground.cover))
head(ex1)
```

```
## # A tibble: 2 x 3
##   Treatment `mean(Ground.cover)` `sd(Ground.cover)`
##   <fct>                   <dbl>              <dbl>
## 1 C                       0.432              0.221
## 2 ST                      0.696              0.144
```

```
mod <- lm(Ground.cover ~ Treatment, data = AllS_GP)
anv <- aov(Ground.cover ~ Treatment, data = AllS_GP)
emmeans(mod, pairwise ~ Treatment, adjust = "Tukey")
```

```
## $emmeans
##  Treatment emmean     SE df lower.CL upper.CL
##  C          0.432 0.0835  8    0.239    0.625
##  ST         0.696 0.0835  8    0.503    0.889
##
## Confidence level used: 0.95
##
## $contrasts
##  contrast estimate    SE df t.ratio p.value
##  C - ST     -0.264 0.118  8 -2.235  0.0558
```

```
shapiro.test(anv$residuals)
```

```
##
##  Shapiro-Wilk normality test
##
## data:  anv$residuals
## W = 0.94992, p-value = 0.6676
```

```
leveneTest((AllS_GP$Ground.cover ~ AllS_GP$Plot_type))
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value Pr(>F)
## group  1  1.0609 0.3331
##        8
```

```
outlierTest(mod)
```

```
## No Studentized residuals with Bonferonni p < 0.05
## Largest |rstudent|:
##    rstudent unadjusted p-value Bonferonni p
## 5 -2.199255           0.063801      0.63801
```

```
#NF Sp. richness - assumptions met
ex1 <- AllS_GP %>%
  group_by(Treatment) %>%
  summarise(mean(NF..sp..rich.), sd(NF..sp..rich.))
head(ex1)
```

```
## # A tibble: 2 x 3
##   Treatment `mean(NF..sp..rich.)` `sd(NF..sp..rich.)`
##   <fct>                     <dbl>               <dbl>
## 1 C                          3.8                2.77
## 2 ST                        11                  3.61
```

```
mod <- lm(NF..sp..rich. ~ Treatment, data = AllS_GP)
anv <- aov(NF..sp..rich. ~ Treatment, data = AllS_GP)
emmeans(mod, pairwise ~ Treatment, adjust = "Tukey")
```

```
## $emmeans
##  Treatment emmean   SE df lower.CL upper.CL
##  C            3.8 1.44  8    0.482     7.12
##  ST          11.0 1.44  8    7.682    14.32
##
## Confidence level used: 0.95
##
## $contrasts
##  contrast estimate   SE df t.ratio p.value
##  C - ST       -7.2 2.03  8 -3.539  0.0076
```

```
shapiro.test(anv$residuals)
```

```
##
##  Shapiro-Wilk normality test
##
## data:  anv$residuals
## W = 0.92147, p-value = 0.3694
```

```
leveneTest((AllS_GP$NF..sp..rich. ~ AllS_GP$Plot_type))
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value Pr(>F)
## group  1  0.1748 0.6869
##        8
```

```
outlierTest(mod)
```

```
## No Studentized residuals with Bonferonni p < 0.05
## Largest |rstudent|:
```

```
##   rstudent unadjusted p-value Bonferonni p
## 8 2.059964           0.078369      0.78369
```

```
#All Sp. richness - assumptions met
ex1 <- AllS_GP %>%
  group_by(Treatment) %>%
  summarise(mean(totSRich), sd(totSRich))
head(ex1)
```

```
## # A tibble: 2 x 3
##   Treatment `mean(totSRich)` `sd(totSRich)`
##   <fct>                <dbl>          <dbl>
## 1 C                     14.8           4.02
## 2 ST                    29.2           4.49
```

```
mod <- lm(totSRich ~ Treatment, data = AllS_GP)
anv <- aov(totSRich ~ Treatment, data = AllS_GP)
emmeans(mod, pairwise ~ Treatment, adjust = "Tukey")
```

```
## $emmeans
##  Treatment emmean   SE df lower.CL upper.CL
##  C           14.8 1.91  8     10.4     19.2
##  ST          29.2 1.91  8     24.8     33.6
##
## Confidence level used: 0.95
##
## $contrasts
##  contrast estimate  SE df t.ratio p.value
##  C - ST      -14.4 2.7  8 -5.337  0.0007
```

```
shapiro.test(anv$residuals)
```

```
##
##  Shapiro-Wilk normality test
##
## data:  anv$residuals
## W = 0.89087, p-value = 0.1734
```

```
leveneTest(AllS_GP$totSRich ~ AllS_GP$Plot_type)
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value Pr(>F)
## group  1       0      1
##        8
```

```
outlierTest(mod)
```

```
## No Studentized residuals with Bonferonni p < 0.05
## Largest |rstudent|:
##    rstudent unadjusted p-value Bonferonni p
## 2 -2.369359           0.049653      0.49653
```

```
#All Sp. diversity - assumptions met
ex1 <- AllS_GP %>%
  group_by(Treatment) %>%
  summarise(mean(Total.diversity), sd(Total.diversity))
head(ex1)
```

```
## # A tibble: 2 x 3
##   Treatment `mean(Total.diversity)` `sd(Total.diversity)`
##   <fct>                       <dbl>                 <dbl>
## 1 C                            5.18                  2.20
## 2 ST                           11.0                  2.68
```

```
mod <- lm(Total.diversity ~ Treatment, data = AllS_GP)
anv <- aov(Total.diversity ~ Treatment, data = AllS_GP)
emmeans(mod, pairwise ~ Treatment, adjust = "Tukey")
```

```
## $emmeans
##  Treatment emmean  SE df lower.CL upper.CL
##  C           5.18 1.1  8     2.65     7.71
##  ST         11.03 1.1  8     8.50    13.56
##
## Confidence level used: 0.95
##
## $contrasts
##  contrast estimate   SE df t.ratio p.value
##  C - ST      -5.85 1.55  8 -3.769  0.0055
```

```
shapiro.test(anv$residuals)
```

```
##
##  Shapiro-Wilk normality test
##
## data:  anv$residuals
## W = 0.96338, p-value = 0.8236
```

```
leveneTest(AllS_GP$Total.diversity ~ AllS_GP$Plot_type)
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value Pr(>F)
## group  1  0.0018 0.9671
##        8
```

```
outlierTest(mod)
```

```
## No Studentized residuals with Bonferonni p < 0.05
## Largest |rstudent|:
##   rstudent unadjusted p-value Bonferonni p
## 2 -2.35459           0.050744      0.50744
```

Temp over time Gravel pit - July

```
TV <-read.csv("ThermVegAvgNo3rd.csv")
sumPEJuly <- read.csv("f_hours.csv")

TV <- filter(TV, Field == "PE", Month == "July")
```

LM and LMER at different times

12 pm

```
TV12 <- filter(TV, Flight_hour == "12")

mod <-lm(Avg ~ Plot_type, data = TV12)

summary(mod)
```

```
##
## Call:
## lm(formula = Avg ~ Plot_type, data = TV12)
##
## Residuals:
##    Min     1Q Median     3Q    Max
## -7.070 -2.643  1.285  2.090  5.230
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)   31.920      1.760  18.135 8.78e-08 ***
## Plot_typeST   -6.210      2.489  -2.495   0.0372 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.936 on 8 degrees of freedom
## Multiple R-squared:  0.4376, Adjusted R-squared:  0.3673
## F-statistic: 6.224 on 1 and 8 DF,  p-value: 0.03724
```

```
anova(mod)
```

```
## Analysis of Variance Table
##
## Response: Avg
##           Df Sum Sq Mean Sq F value  Pr(>F)
## Plot_type  1  96.41   96.41   6.224 0.03724 *
## Residuals  8 123.92   15.49
## ---
```

```
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
r.squaredGLMM(mod)
```

```
## Warning: 'r.squaredGLMM' now calculates a revised statistic. See the help
## page.
```

```
##            R2m       R2c
## [1,] 0.4088294 0.4088294
```

```
em <-emmeans(mod, pairwise ~ Plot_type, adjust = "Tukey")
em
```

```
## $emmeans
##  Plot_type emmean   SE df lower.CL upper.CL
##  PC          31.9 1.76  8     27.9     36.0
##  ST          25.7 1.76  8     21.7     29.8
##
## Confidence level used: 0.95
##
## $contrasts
##  contrast estimate   SE df t.ratio p.value
##  PC - ST      6.21 2.49  8 2.495   0.0372
```

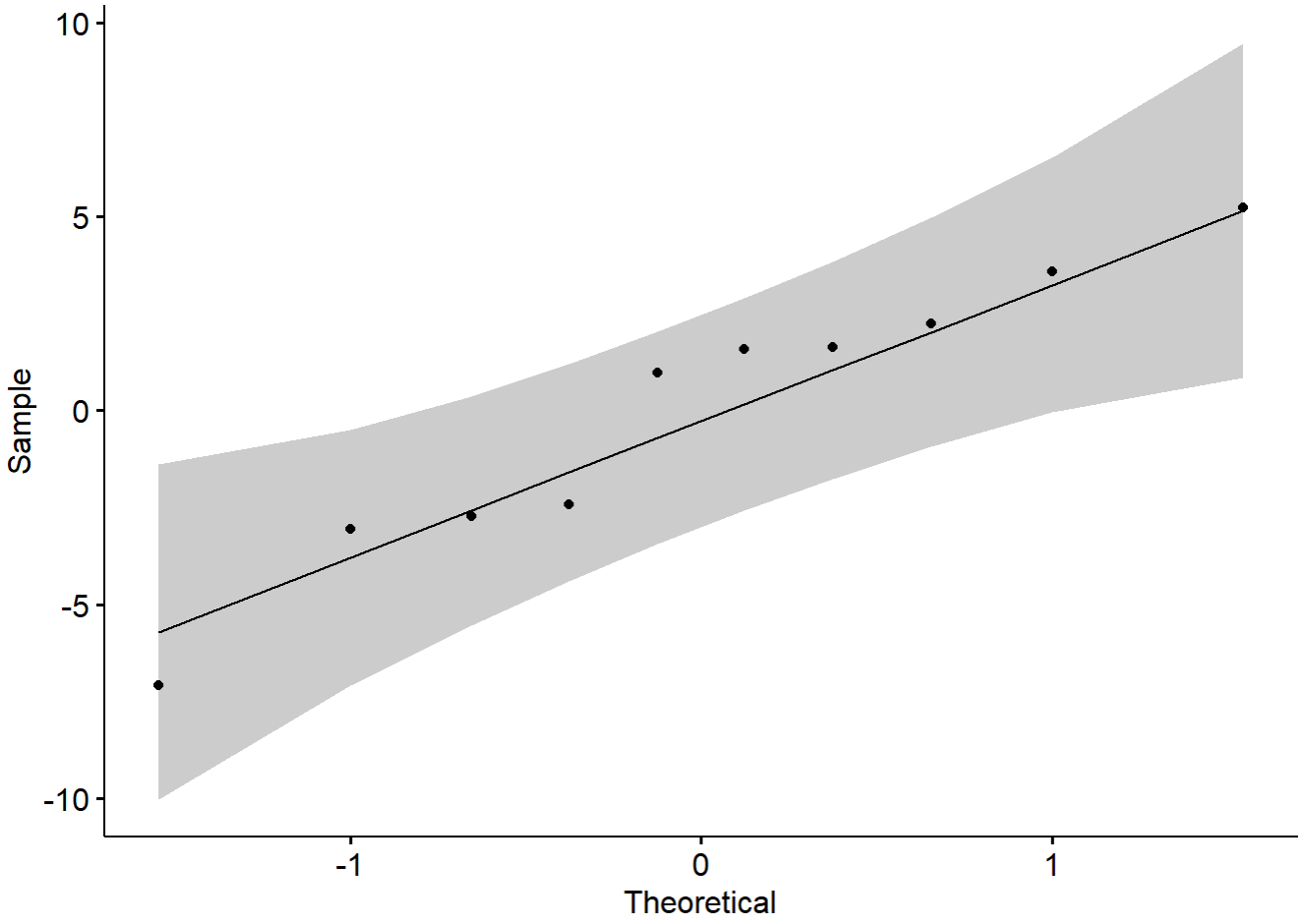
```
sumPEJuly[c(1:2),c(2:7)] <- summary(em)$emmeans

leveneTest((TV12$Avg ~ TV12$Plot_type))
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value Pr(>F)
## group  1  1.2517 0.2957
##        8
```

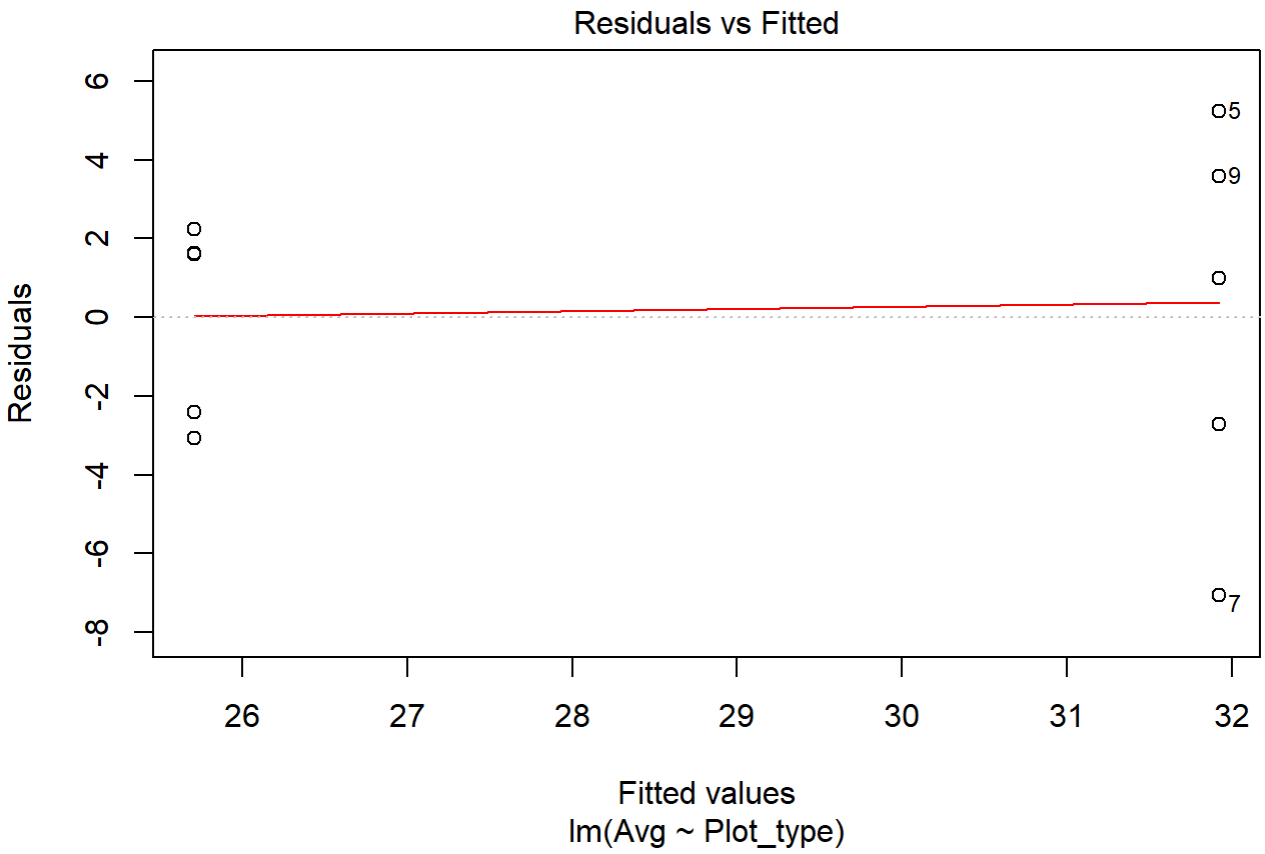
```
DT <- data.table(TV12)
DT[, .(W = shapiro.test(Avg)$statistic, P.value = shapiro.test(Avg)$p.value),
   by = .(Plot_type)]
```

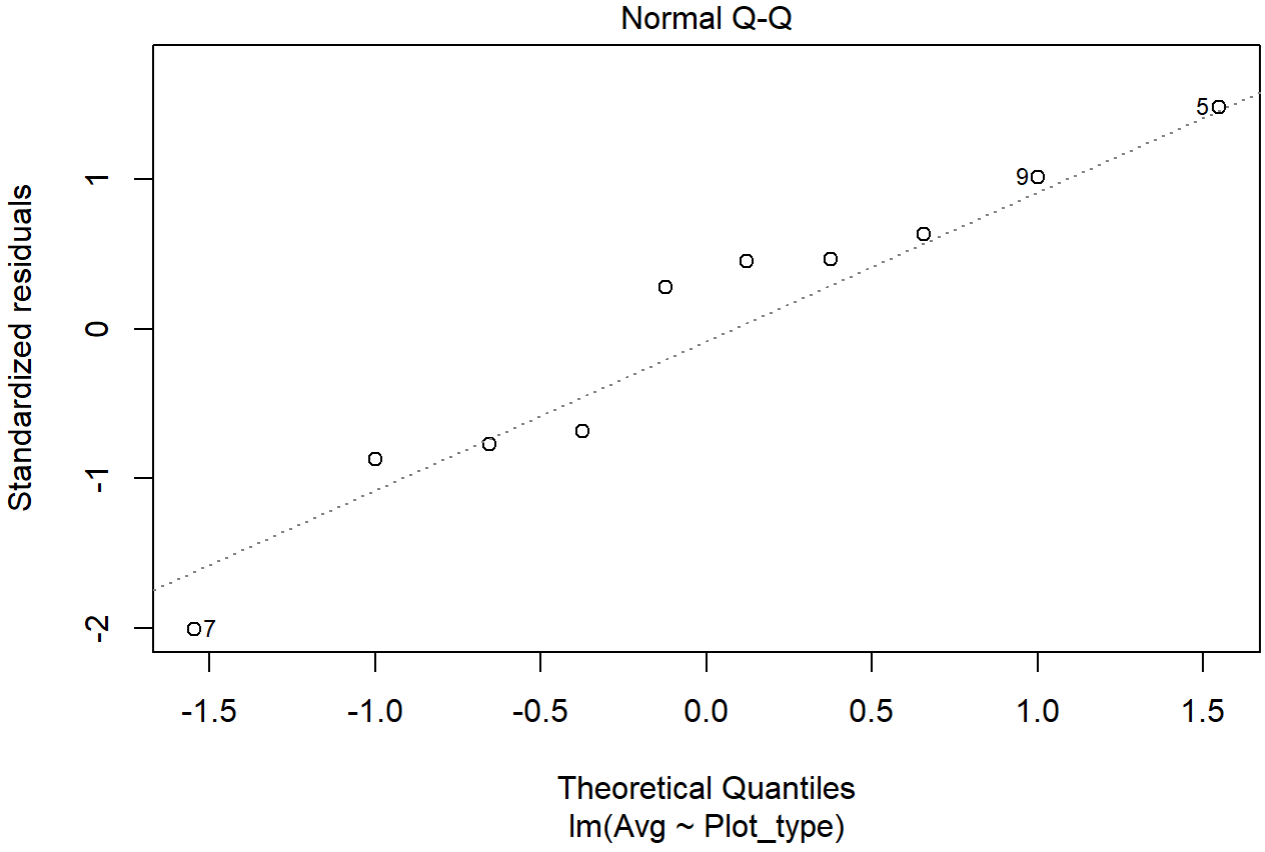
```
##    Plot_type         W    P.value
## 1:        PC 0.9542422 0.76742981
## 2:        ST 0.7970585 0.07666602
```

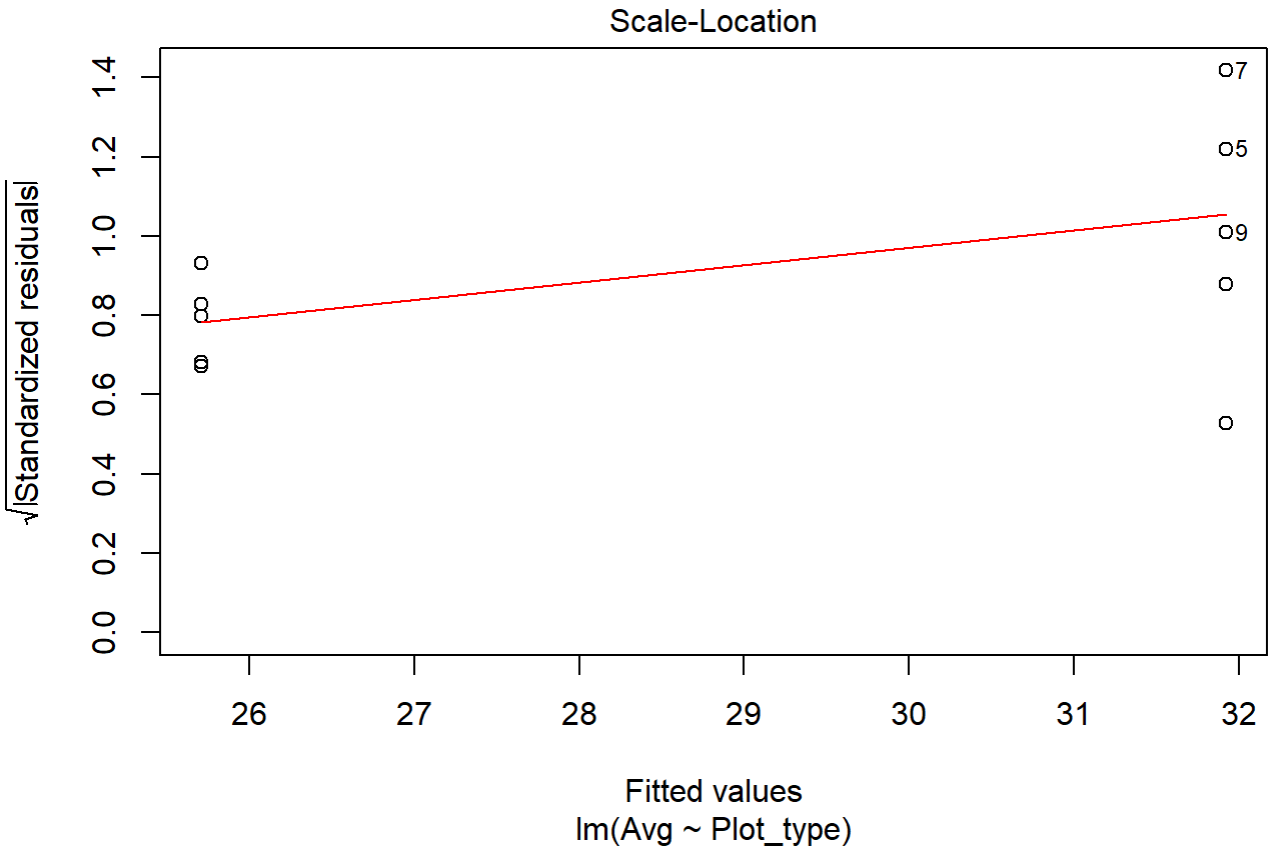
```
ggqqplot(residuals(mod))
```

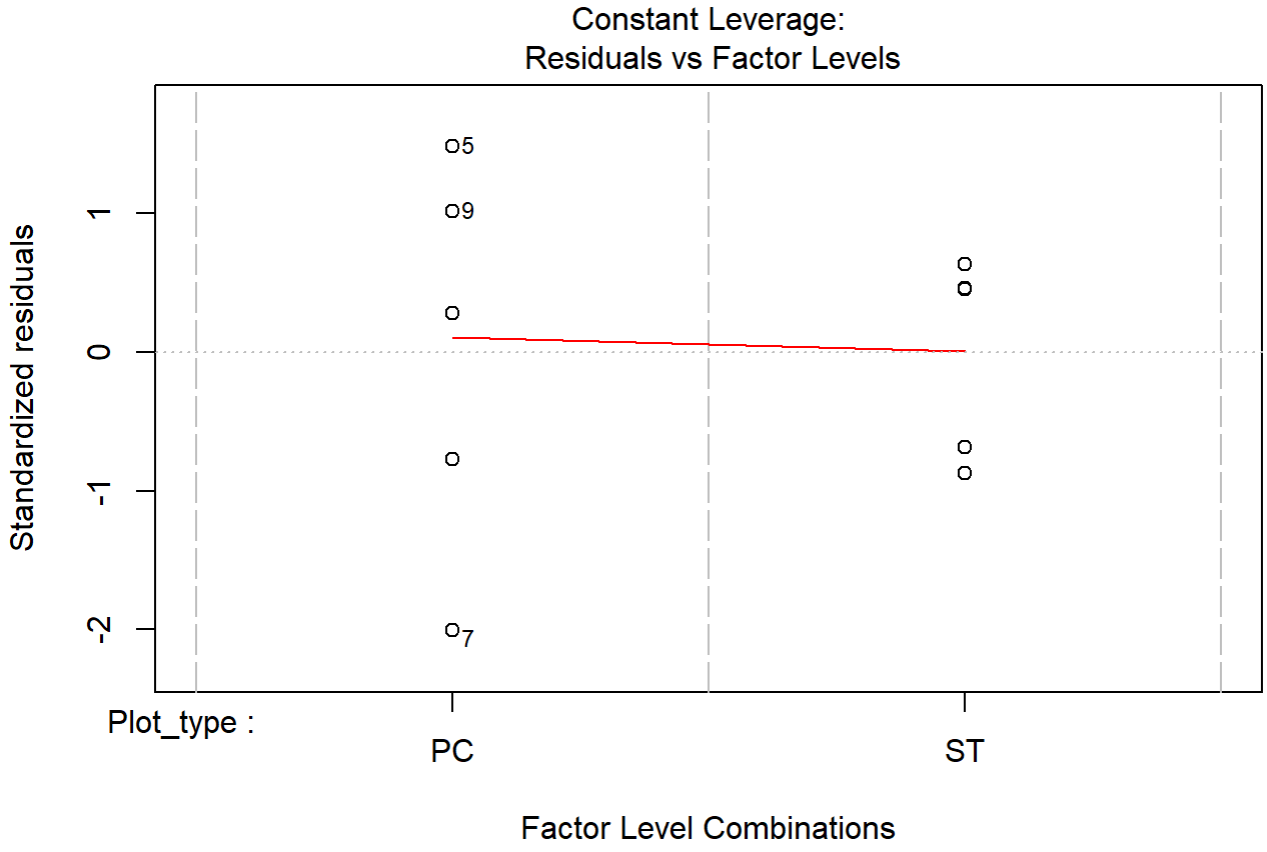



```
plot(mod)
```

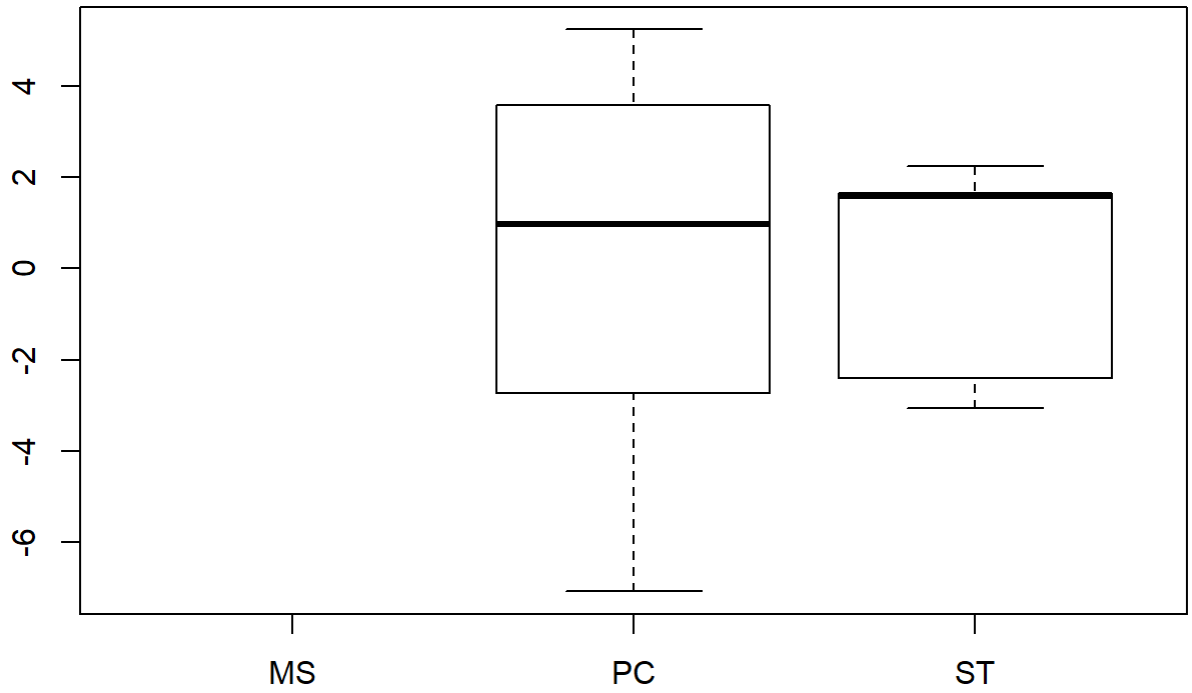

Residuals vs Fitted
Residuals
6
4
2
0
-2
-4
-6
-8
5
9
7
26
27
28
29
30
31
32
Fitted values
lm(Avg ~ Plot_type)


Normal Q-Q
Standardized residuals
1
0
-1
-2
5
9
7
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
Theoretical Quantiles
lm(Avg ~ Plot_type)

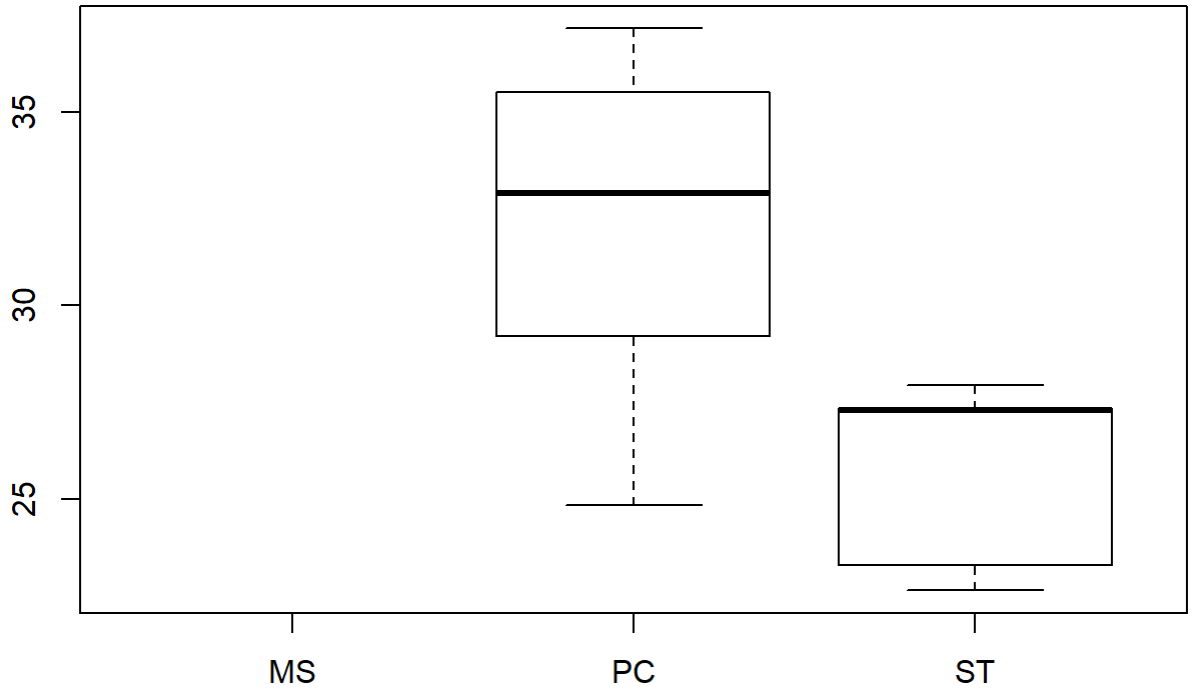

Scale-Location
√|Standardized residuals|
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
26
27
28
29
30
31
32
7
5
9
Fitted values
lm(Avg ~ Plot_type)


Constant Leverage:
Residuals vs Factor Levels
Standardized residuals
1
0
-1
-2
5
9
7
Plot_type :
PC
ST
Factor Level Combinations

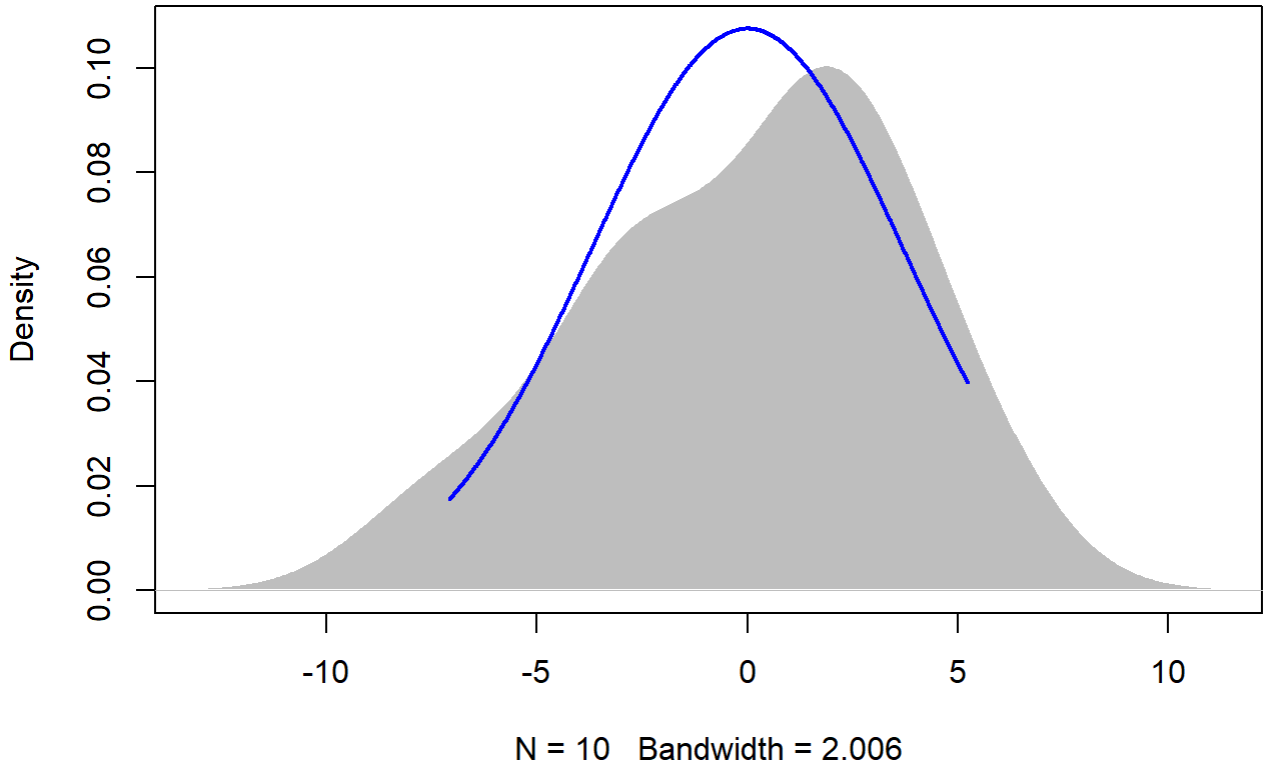
```
boxplot(residuals(mod) ~ TV12$Plot_type)
```




```
boxplot(TV12$Avg~ TV12$Plot_type)
```




```
plotNormalDensity(resid(mod))
```



14

```
TV14 <- filter(TV, Flight_hour == "14")

mod <-lmer(Avg ~ Plot_type * Date + (1|Plot_id), data = TV14)

mod2 <-lm(Avg ~ Plot_type * Date, data = TV14)


summary(mod)
```

```
## Linear mixed model fit by REML. t-tests use Satterthwaite's method [
## lmerModLmerTest]
## Formula: Avg ~ Plot_type * Date + (1 | Plot_id)
##    Data: TV14
##
## REML criterion at convergence: 94.1
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -1.32709 -0.50654  0.07787  0.42687  1.93352
##
## Random effects:
##  Groups   Name        Variance Std.Dev.
##  Plot_id  (Intercept) 38.615   6.214
##  Residual              6.232   2.496
```

```
## Number of obs: 20, groups:  Plot_id, 5
##
## Fixed effects:
##                            Estimate Std. Error      df t value Pr(>|t|)
## (Intercept)                  34.150      2.995   4.963  11.403 9.52e-05
## Plot_typeST                 -10.130      1.579  12.000  -6.416 3.32e-05
## Date2019-07-15                4.250      1.579  12.000   2.692   0.0196
## Plot_typeST:Date2019-07-15    1.720      2.233  12.000   0.770   0.4560
##
## (Intercept)                ***
## Plot_typeST                ***
## Date2019-07-15             *
## Plot_typeST:Date2019-07-15
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##             (Intr) Plt_ST D2019-
## Plot_typeST -0.264
## D2019-07-15 -0.264  0.500
## P_ST:D2019-  0.186 -0.707 -0.707
```

```
r.squaredGLMM(mod)
```

```
##            R2m       R2c
## [1,] 0.3982452 0.9163749
```

```
anova(mod, ddf="Kenward-Roger")
```

```
## Type III Analysis of Variance Table with Kenward-Roger's method
##                Sum Sq Mean Sq NumDF DenDF F value    Pr(>F)
## Plot_type      429.66  429.66     1    12 68.9410 2.564e-06 ***
## Date           130.56  130.56     1    12 20.9488 0.0006357 ***
## Plot_type:Date   3.70    3.70     1    12  0.5934 0.4560224
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
em <-emmeans(mod, pairwise ~ Plot_type, adjust = "Tukey")
```

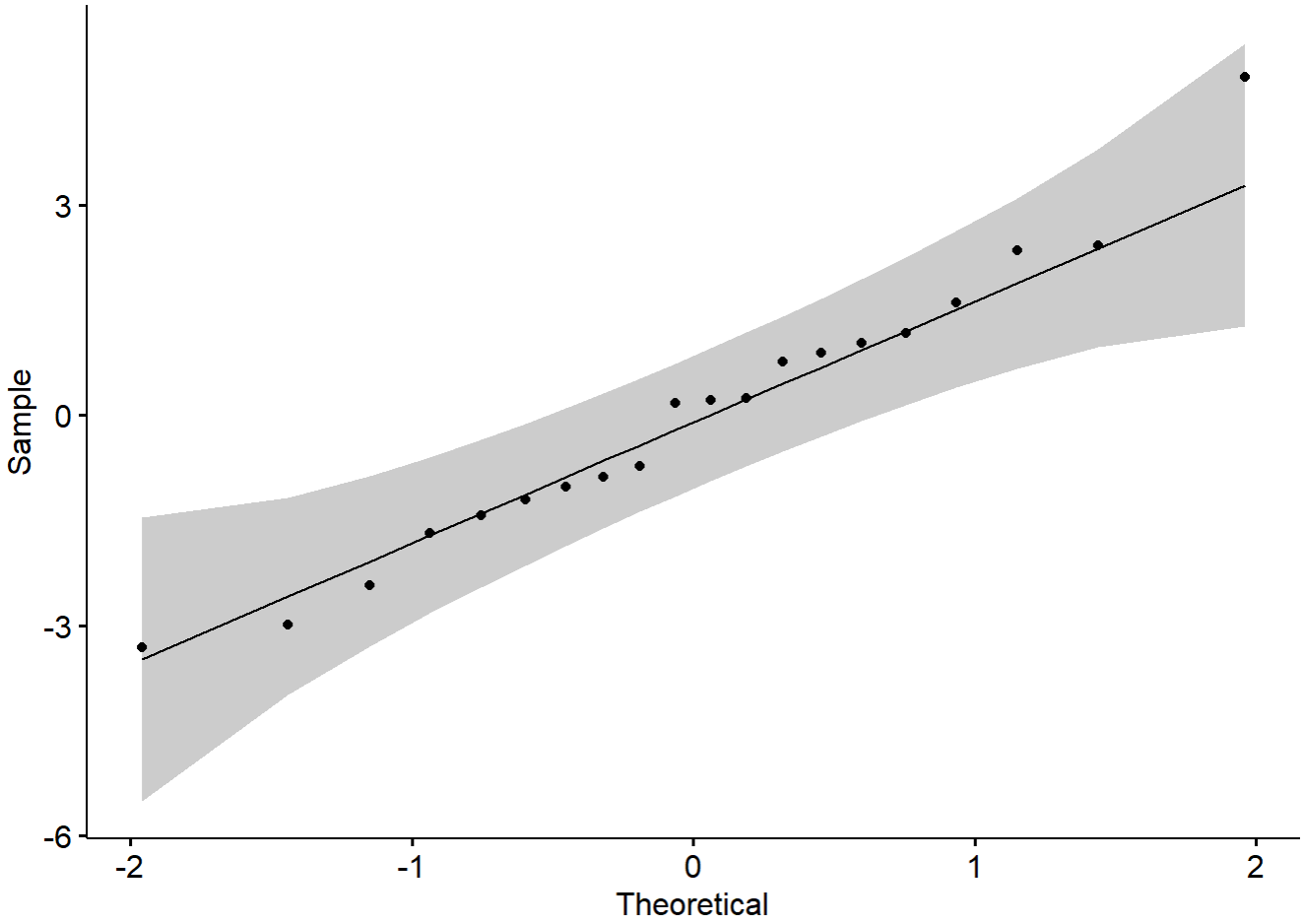
```
## NOTE: Results may be misleading due to involvement in interactions
```

```
em
```

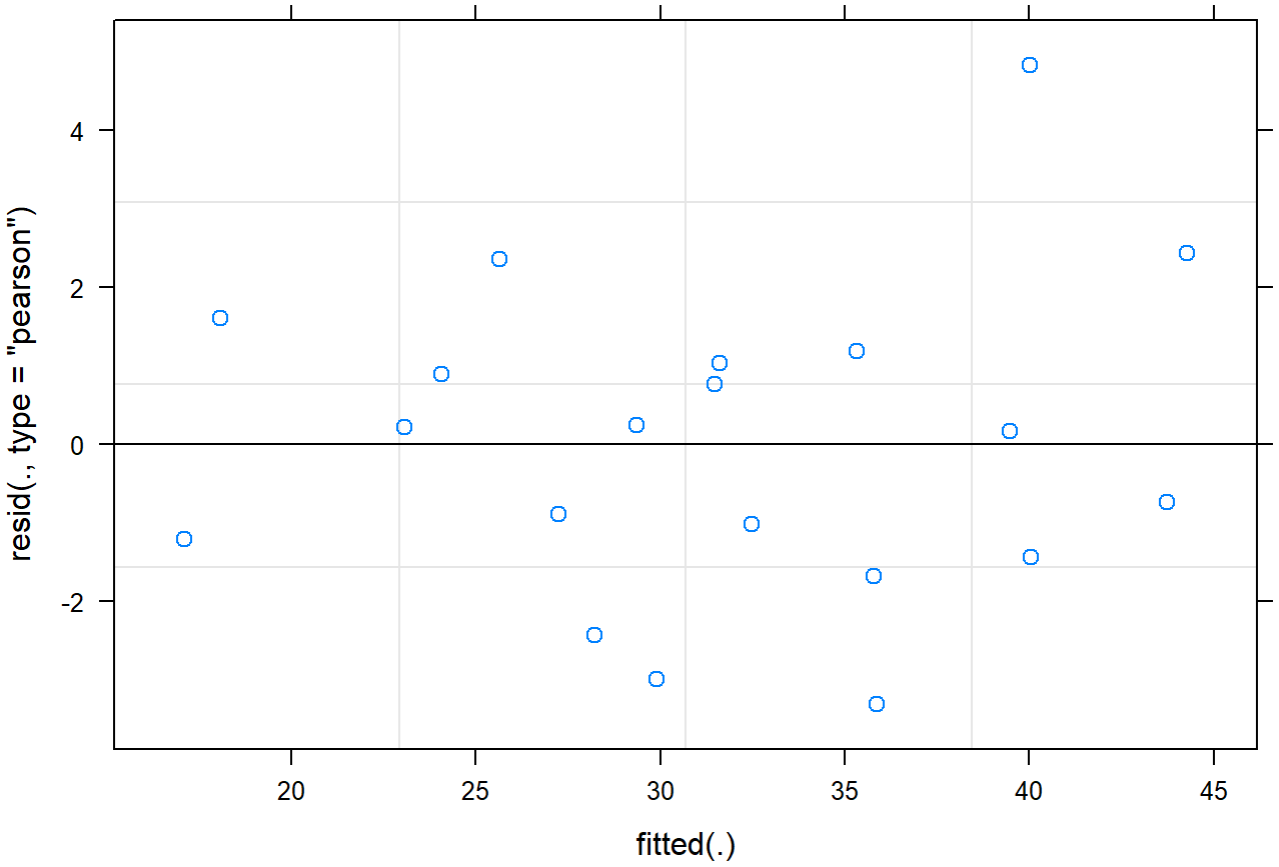
```
## $emmeans
##  Plot_type emmean   SE   df lower.CL upper.CL
##  PC          36.3 2.89 4.31     28.5     44.1
##  ST          27.0 2.89 4.31     19.2     34.8
##
```

```
## Results are averaged over the levels of: Date
## Degrees-of-freedom method: kenward-roger
## Confidence level used: 0.95
##
## $contrasts
##  contrast estimate   SE df t.ratio p.value
##  PC - ST      9.27 1.12 12 8.303   <.0001
##
## Results are averaged over the levels of: Date
```

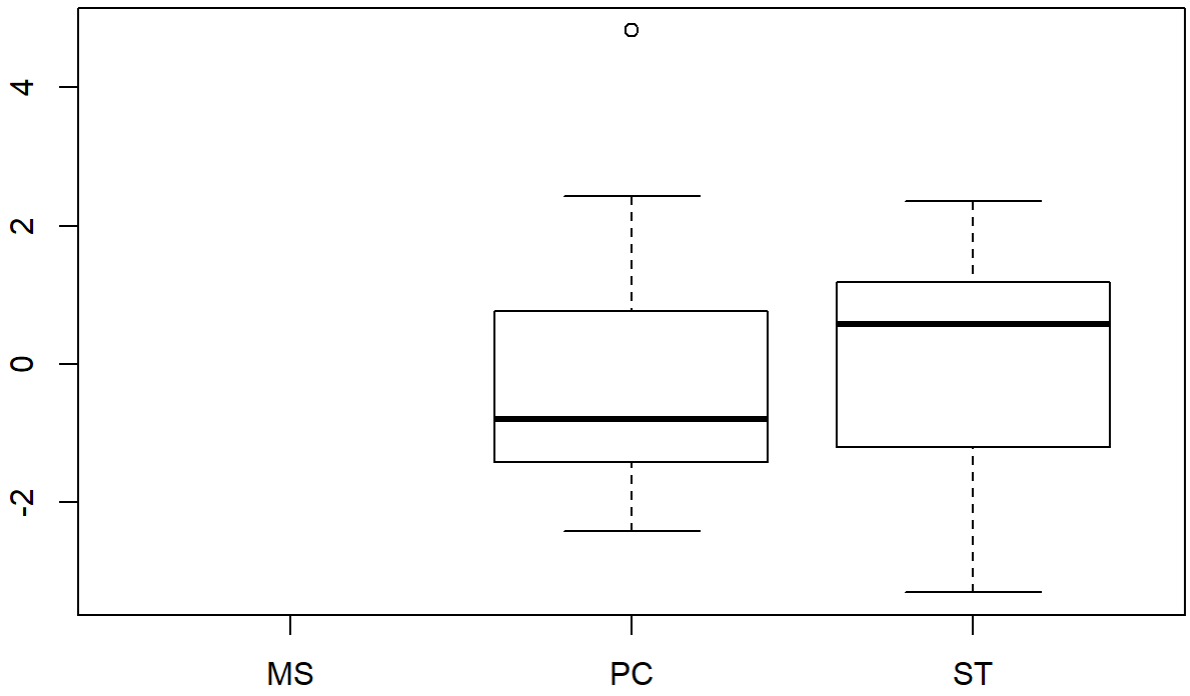
```
sumPEJuly[c(3:4),c(2:7)] <- summary(em)$emmeans

ggqqplot(residuals(mod))
```



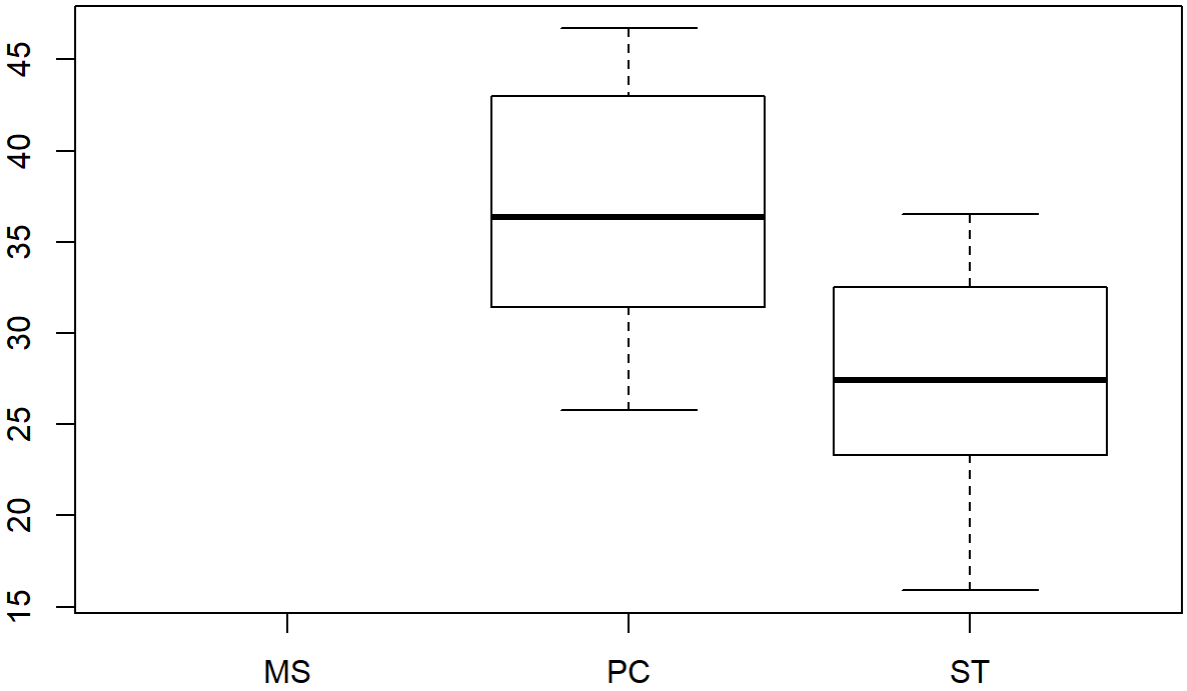

```
plot(mod)
```



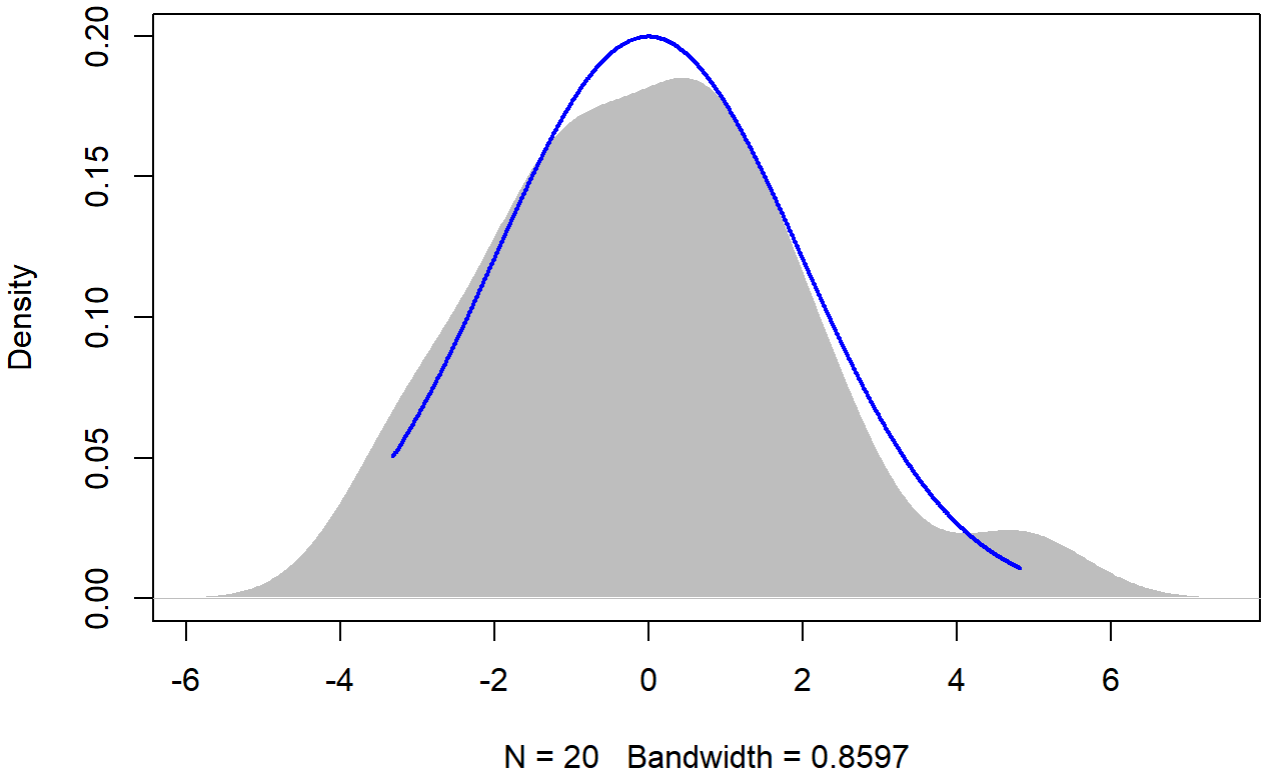

```
boxplot(residuals(mod) ~ TV14$Plot_type)
```




```
boxplot(TV14$Avg~ TV14$Plot_type)
```




```
plotNormalDensity(resid(mod))
```



16

```
TV16 <- filter(TV, Flight_hour == "16")

mod <-lmer(Avg ~ Plot_type * Date + (1|Plot_id), data = TV16)

r.squaredGLMM(mod)
```

```
##            R2m       R2c
## [1,] 0.4550164 0.7621518
```

```
anova(mod, ddf="Kenward-Roger")
```

```
## Type III Analysis of Variance Table with Kenward-Roger's method
##                 Sum Sq Mean Sq NumDF DenDF F value    Pr(>F)
## Plot_type      195.625 195.625     1    12 20.0661 0.0007531 ***
## Date           145.530 145.530     1    12 14.9276 0.0022538 **
## Plot_type:Date  13.203  13.203     1    12  1.3543 0.2671452
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

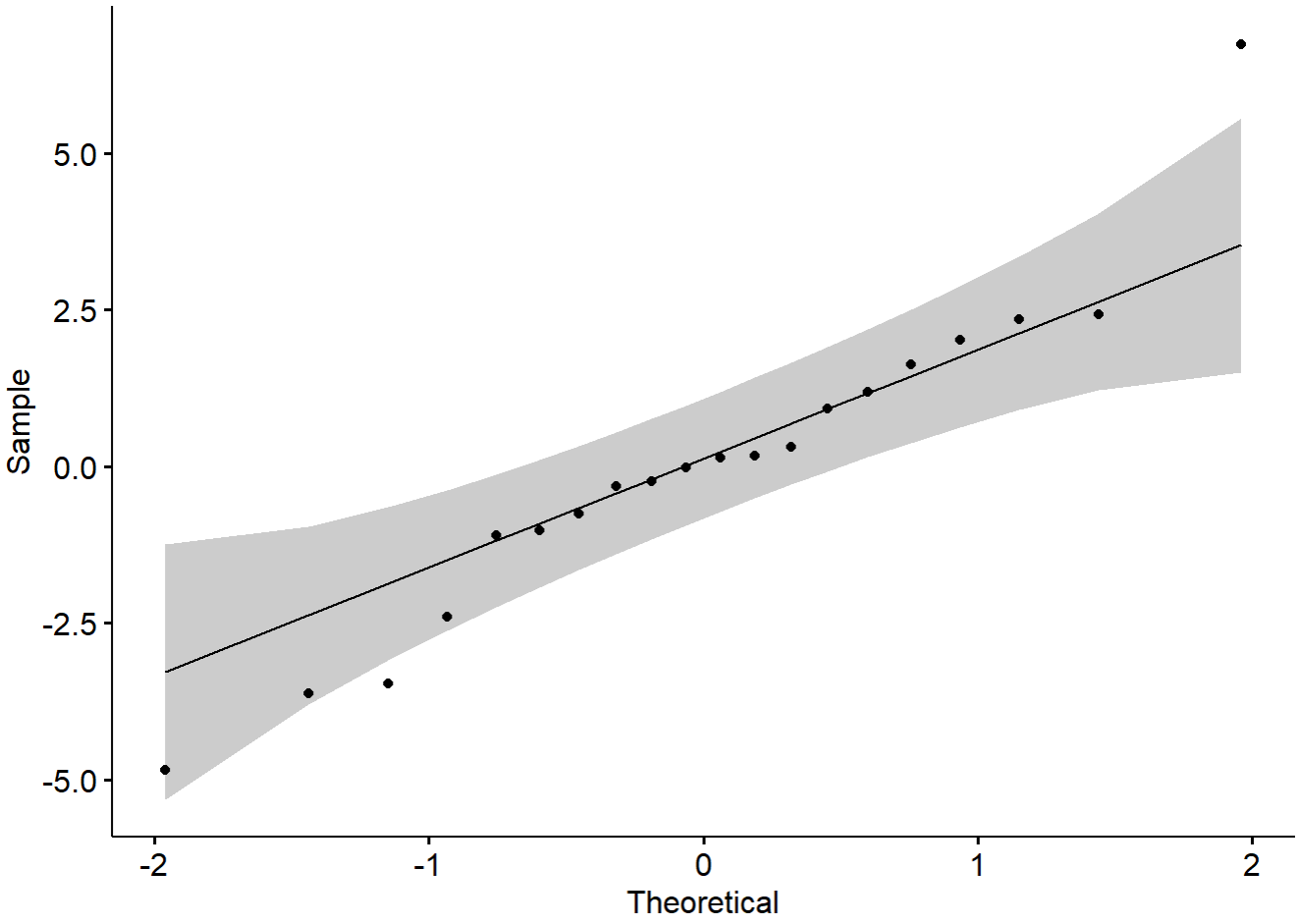
```
em <-emmeans(mod, pairwise ~ Plot_type, adjust = "Tukey")
```

```
## NOTE: Results may be misleading due to involvement in interactions
```

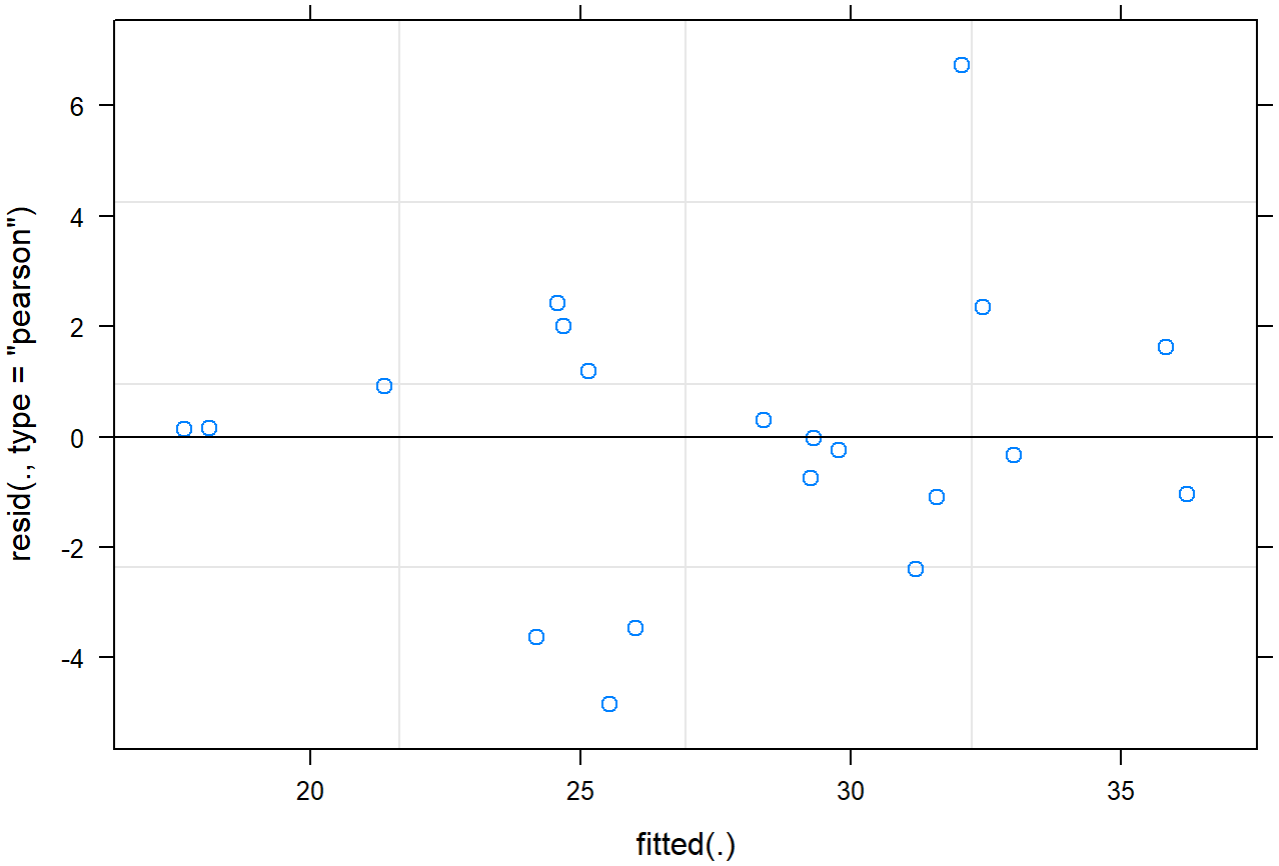
```
em
```

```
## $emmeans
##  Plot_type emmean   SE   df lower.CL upper.CL
##  PC          31.0 1.87 5.36     26.2     35.7
##  ST          24.7 1.87 5.36     20.0     29.4
##
## Results are averaged over the levels of: Date
## Degrees-of-freedom method: kenward-roger
## Confidence level used: 0.95
##
## $contrasts
##  contrast estimate  SE df t.ratio p.value
##  PC - ST      6.25 1.4 12 4.480   0.0008
##
## Results are averaged over the levels of: Date
```

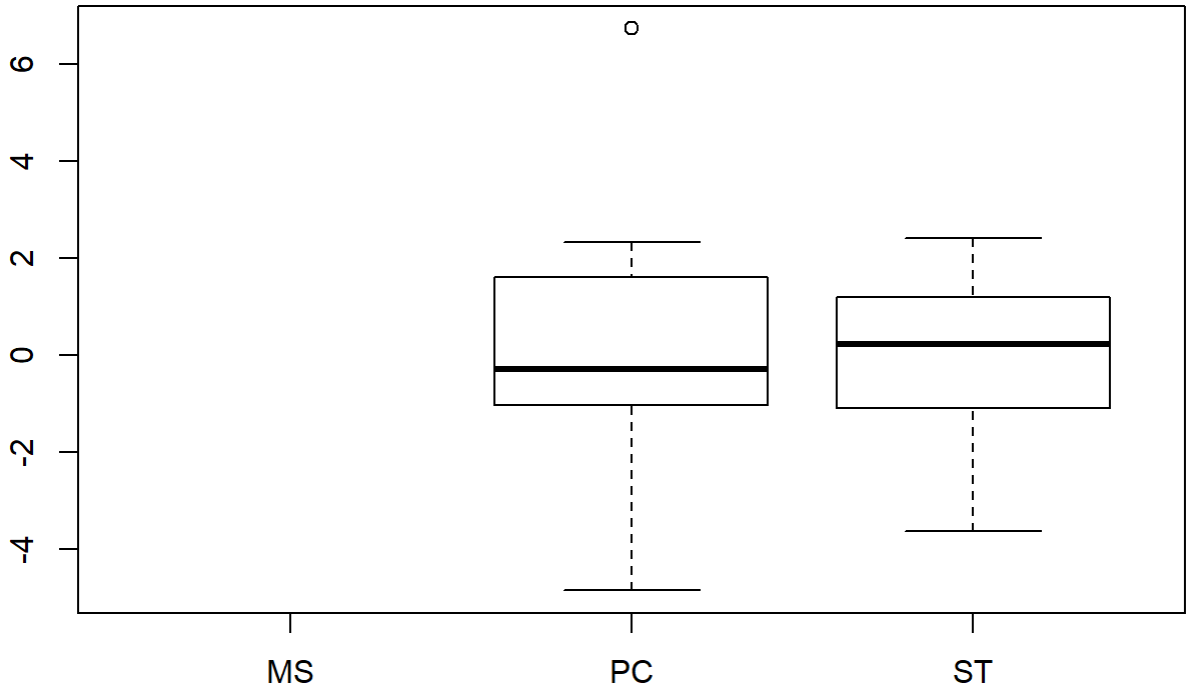
```
sumPEJuly[c(5:6),c(2:7)] <- summary(em)$emmeans

ggqqplot(residuals(mod))
```



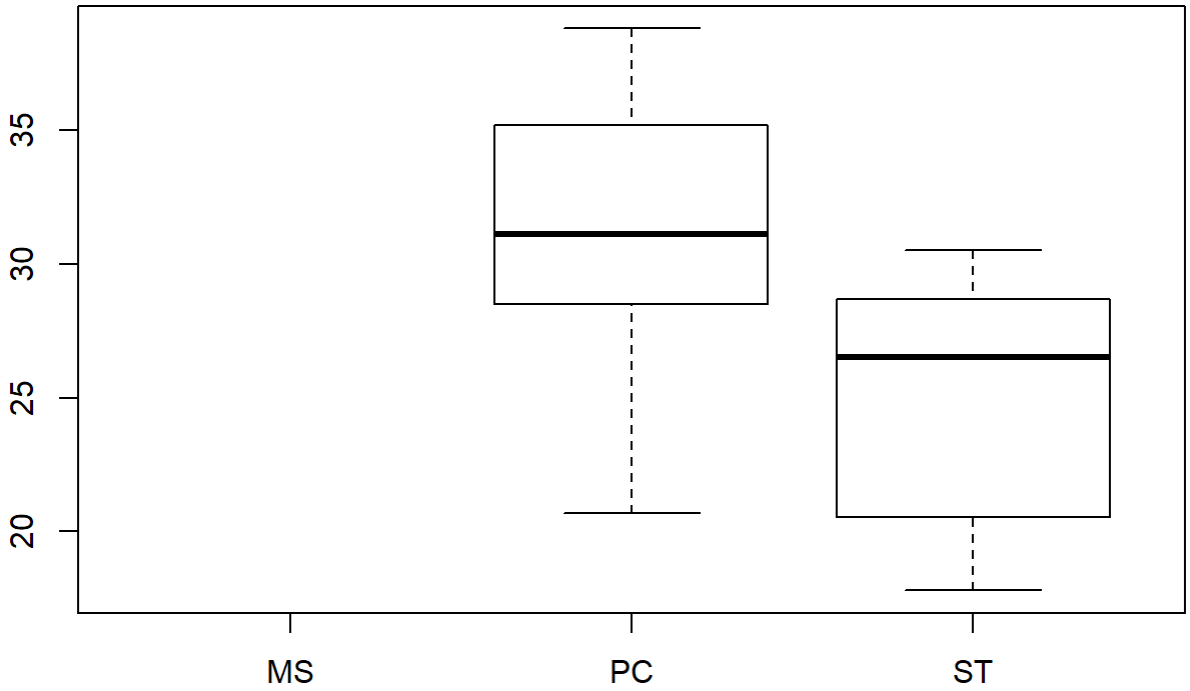

```
plot(mod)
```



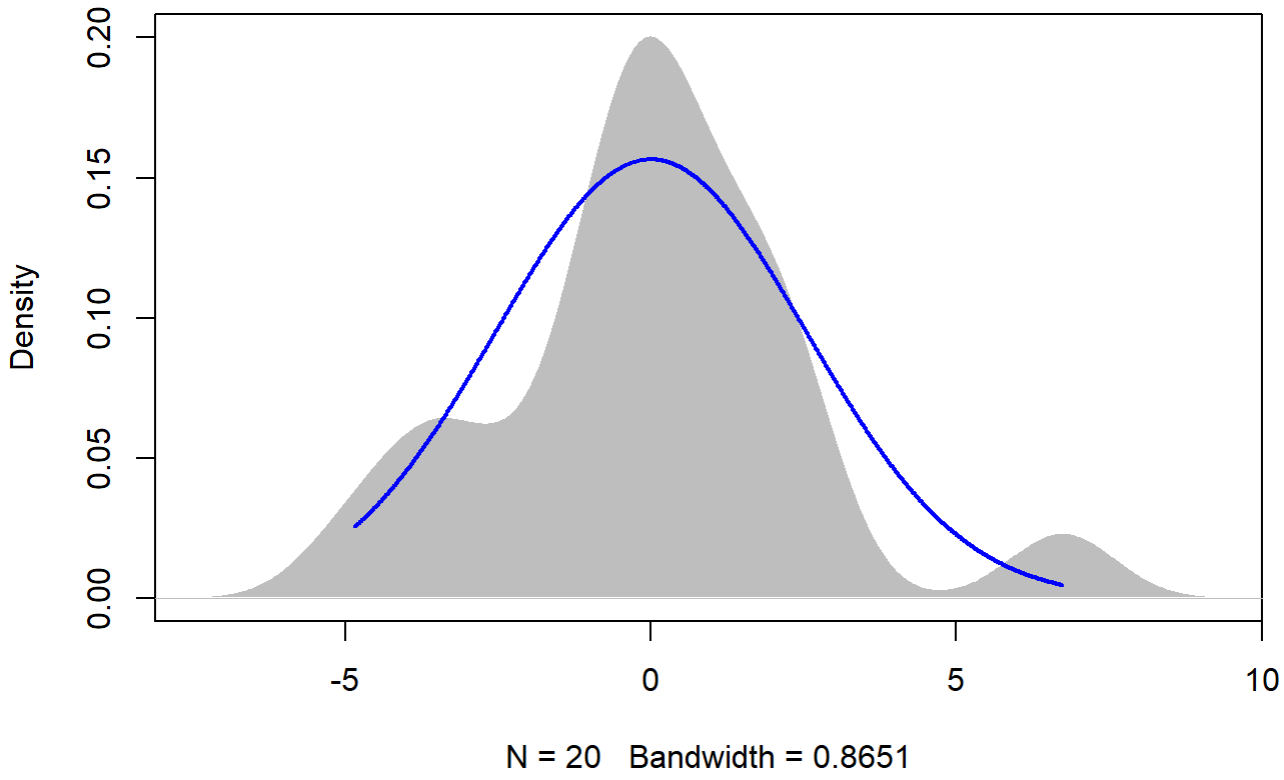

```
boxplot(residuals(mod) ~ TV16$Plot_type)
```




```
boxplot(TV16$Avg~ TV16$Plot_type)
```




```
plotNormalDensity(resid(mod))
```



20

```
TV20 <- filter(TV, Flight_hour == "20")

mod <-lmer(Avg ~ Plot_type * Date + (1|Plot_id), data = TV20)
summary(mod)
```

```
## Linear mixed model fit by REML. t-tests use Satterthwaite's method [
## lmerModLmerTest]
## Formula: Avg ~ Plot_type * Date + (1 | Plot_id)
##    Data: TV20
##
## REML criterion at convergence: 67.2
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -1.87894 -0.41645 -0.09418  0.57234  1.38254
##
## Random effects:
##  Groups   Name        Variance Std.Dev.
##  Plot_id  (Intercept) 0.7224   0.8499
##  Residual             2.1001   1.4492
## Number of obs: 20, groups:  Plot_id, 5
##
## Fixed effects:
##                            Estimate Std. Error      df t value Pr(>|t|)
```

```
## (Intercept)                  9.5400     0.7513 13.3722  12.698 7.68e-09
## Plot_typeST                 -1.2400     0.9165 12.0000  -1.353    0.201
## Date2019-07-15              14.8600     0.9165 12.0000  16.213 1.59e-09
## Plot_typeST:Date2019-07-15  -0.1700     1.2962 12.0000  -0.131    0.898
##
## (Intercept)                ***
## Plot_typeST
## Date2019-07-15             ***
## Plot_typeST:Date2019-07-15
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##             (Intr) Plt_ST D2019-
## Plot_typeST -0.610
## D2019-07-15 -0.610  0.500
## P_ST:D2019-  0.431 -0.707 -0.707
```

```
r.squaredGLMM(mod)
```

```
##            R2m       R2c
## [1,] 0.9535278 0.9654219
```

```
anova(mod, ddf="Kenward-Roger")
```

```
## Type III Analysis of Variance Table with Kenward-Roger's method
##                 Sum Sq Mean Sq NumDF DenDF  F value    Pr(>F)
## Plot_type         8.78    8.78     1    12   4.1799   0.06349 .
## Date           1091.50 1091.50     1    12 519.7479 3.009e-11 ***
## Plot_type:Date    0.04    0.04     1    12   0.0172   0.89783
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
em <-emmeans(mod, pairwise ~ Plot_type, adjust = "Tukey")
```

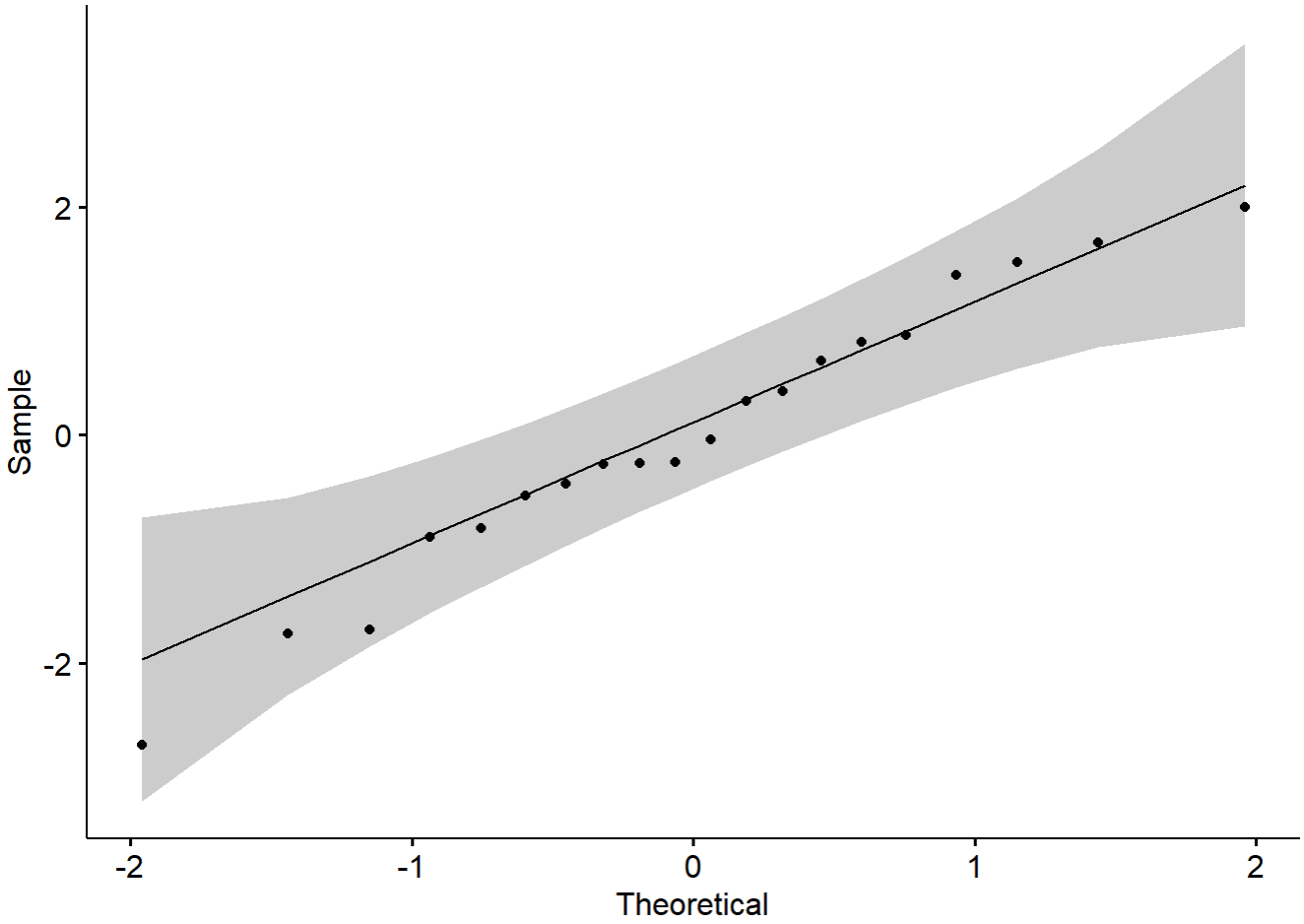
```
## NOTE: Results may be misleading due to involvement in interactions
```

```
em
```

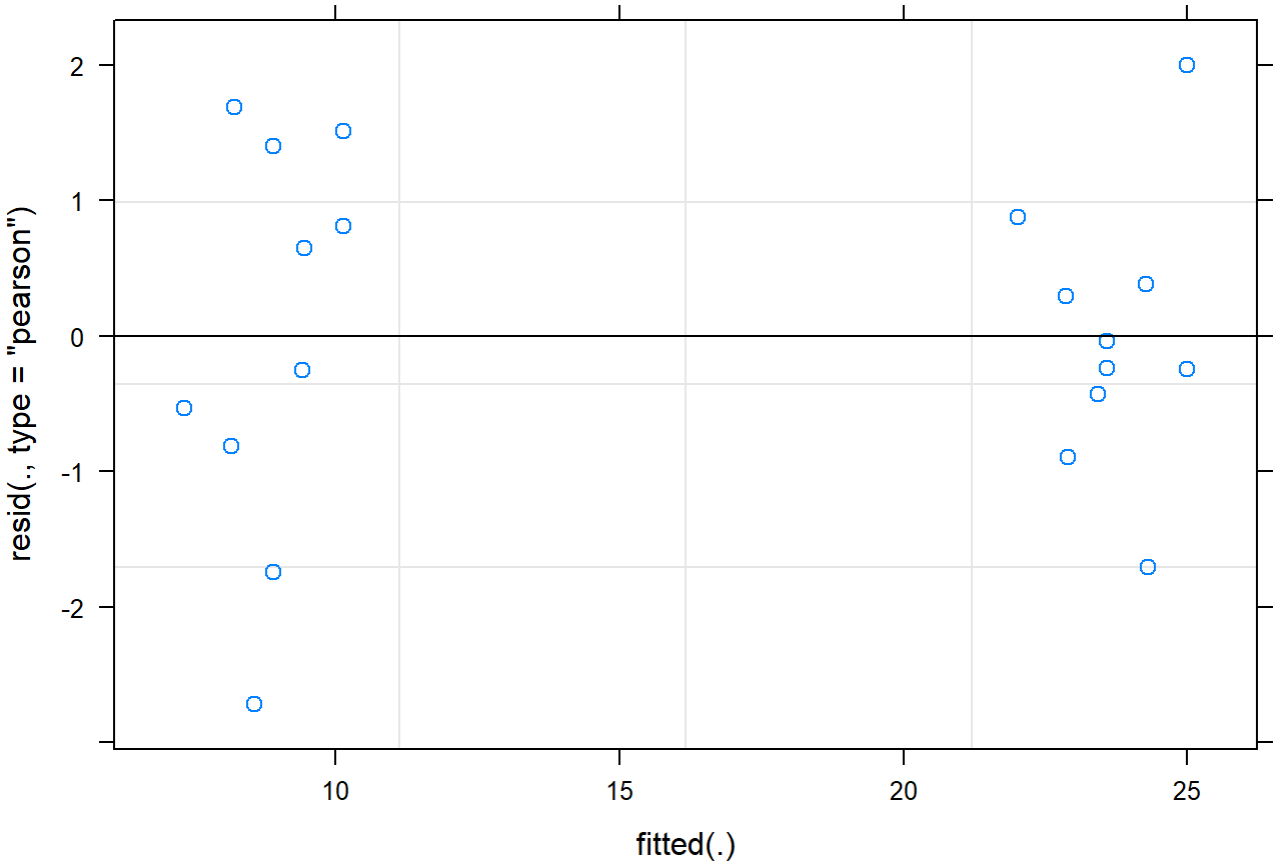
```
## $emmeans
##  Plot_type emmean    SE   df lower.CL upper.CL
##  PC          17.0 0.595 7.63     15.6     18.4
##  ST          15.6 0.595 7.63     14.3     17.0
##
## Results are averaged over the levels of: Date
## Degrees-of-freedom method: kenward-roger
## Confidence level used: 0.95
##
```

```
## $contrasts
##  contrast estimate    SE df t.ratio p.value
##  PC - ST      1.32 0.648 12 2.044   0.0635
##
## Results are averaged over the levels of: Date
```

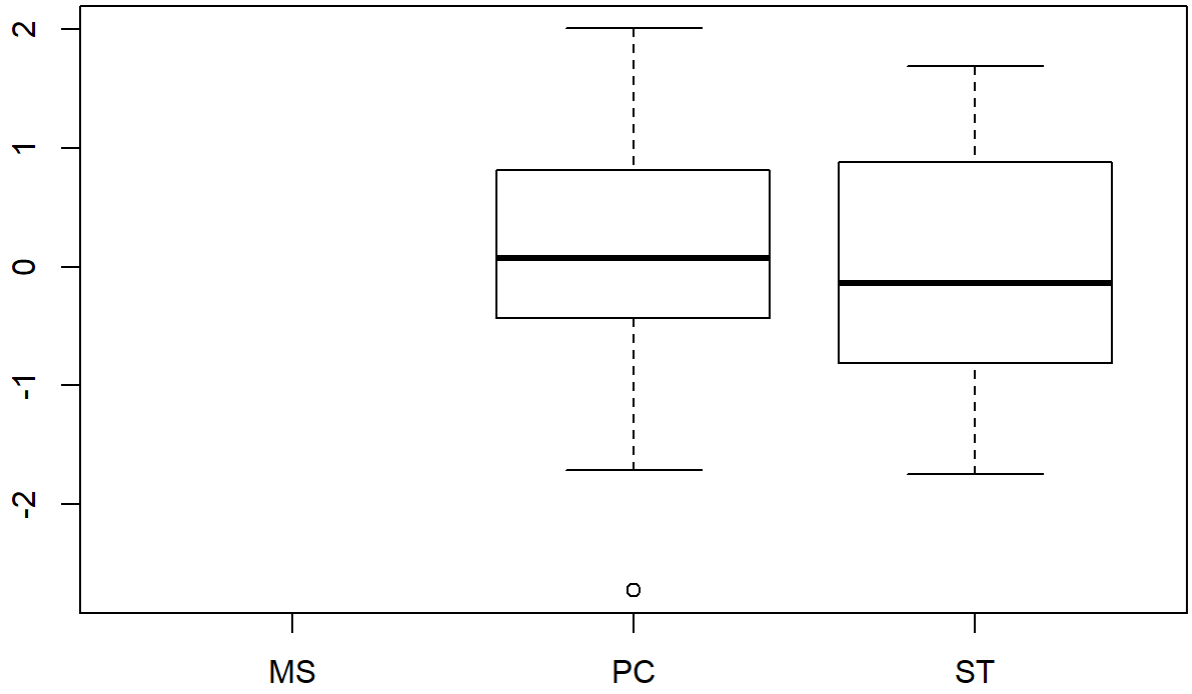
```
sumPEJuly[c(7:8),c(2:7)] <- summary(em)$emmeans

ggqqplot(residuals(mod))
```



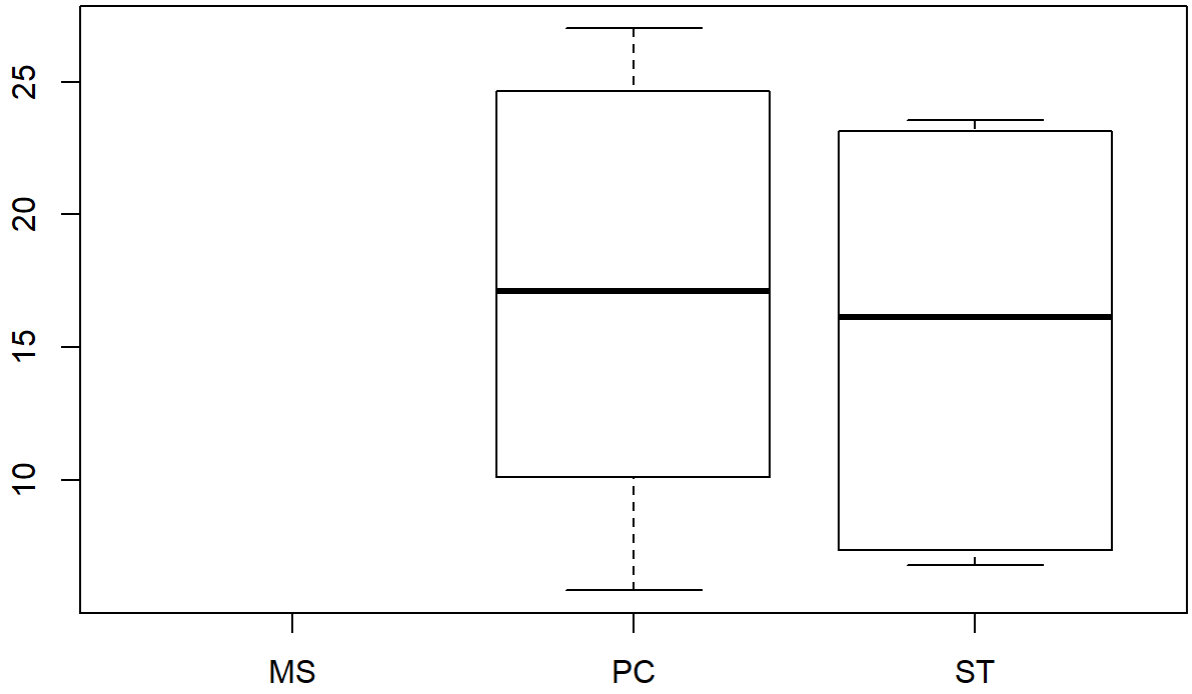

```
plot(mod)
```



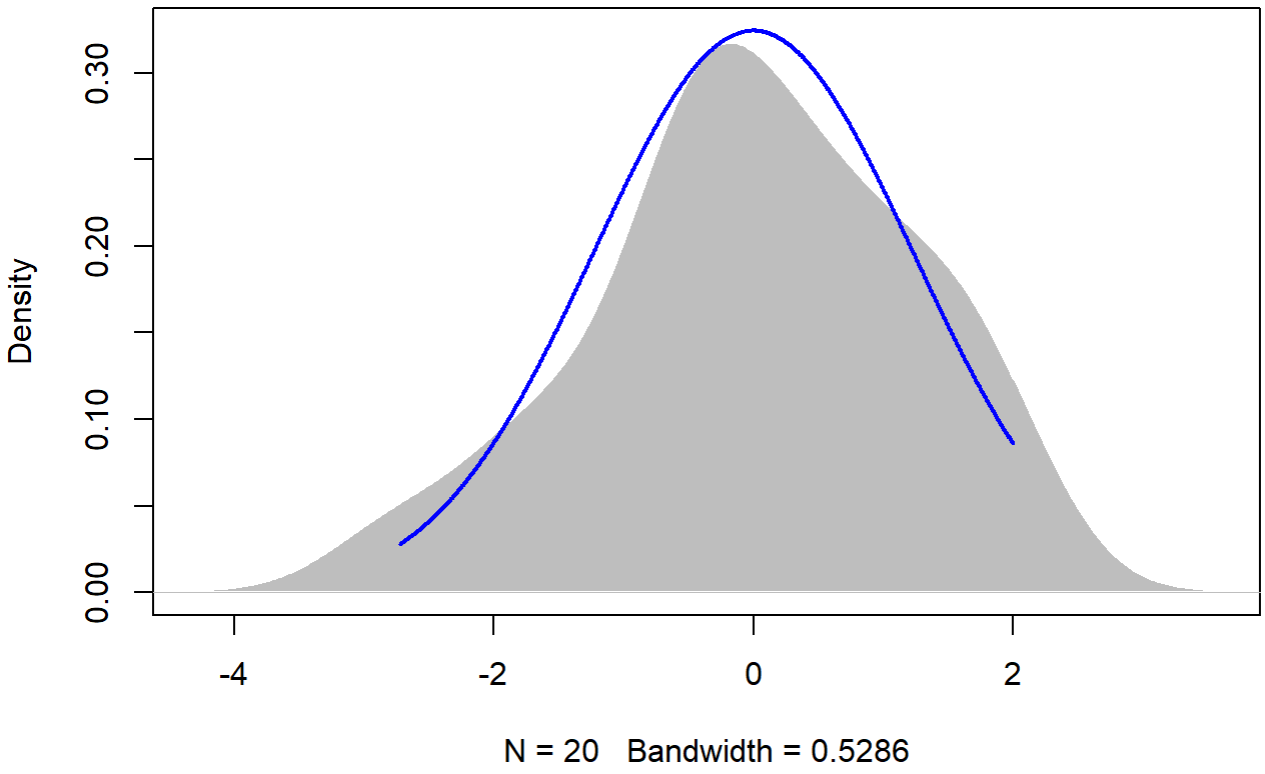

```
boxplot(residuals(mod) ~ TV20$Plot_type)
```




```
boxplot(TV20$Avg~ TV20$Plot_type)
```




```
plotNormalDensity(resid(mod))
```



Graph over time - Gravel pit July

```
sumPEJuly[,'Plot_type']<-factor(sumPEJuly[,'Plot_type'])

pd <- position_dodge(0.3)

tiff("GravelJuly.tiff", width = 7, height = 5, units = 'in', res = 100)

ggplot(sumPEJuly, aes(x=Flight_hour, y=emmeans, colour=Plot_type)) +
  geom_errorbar(aes(ymin=lower.CL, ymax=Upper.cl), width=.3, position=position_dodge(width=0.3
)) +
  geom_point(position=pd, size=3, shape=21, fill="white") +
  geom_line(position=pd, linetype = "dashed") +
  xlab("Time of day (24-hr format)") +
  ylab(expression("EM Mean Surface Temperature  " ( degree*C))) +
  scale_colour_hue(name="Plot type",
                   breaks=c("1", "2"),
                   labels=c("Passive Control", "Topsoil Recipient"),
                   l=40) +
  expand_limits(y=0) +
  scale_y_continuous(breaks=c(0, 5, 10, 15, 20, 25, 30, 35, 40, 45)) +
  scale_x_continuous(breaks=c(12,14,16,18,20)) +
  theme_bw() +
  theme(legend.position=c(0.8,0.8), legend.title = element_text(size = 14),
        legend.text = element_text(size = 12), text = element_text(size=14), axis.text = eleme
nt_text(color = "black", size=14)) +
```

```
  annotate(geom="label",x = 12.3,  y = 15,
           label = "p = 0.037\n R^2 = 0.41\n(2, 1)", fontface = "plain", col ="black", size =
4, fill = "white") +
  annotate(geom="label",x = 14,  y = 15,
           label = "p < 0.001\n mR^2 = 0.40\n (4, 2)", fontface = "plain", col ="black", size
= 4, fill = "white") +
  annotate(geom="label",x = 16,  y = 15,
           label = "p < 0.001\n mR^2 = 0.46\n (4, 2)", fontface = "plain", col ="black", size
= 4, fill = "white") +
  annotate(geom="label",x = 19.7,  y = 10,
           label = "p = 0.063\n (4, 2)", fontface = "plain", col ="black", size = 4, fill = "w
hite")

dev.off()
```

```
## png
##   2
```

Temp over time - Gravel pit September

```
TV <-read.csv("ThermVegAvg.csv")
sumPESeptember <- read.csv("f_hours.csv")

TV <- filter(TV, Field == "PE", Month == "September")
```

12 (fulfills homoskedacity, but not normality - Kruskal-Wallis used instead of ANOVA)

```
TV12 <- filter(TV, Flight_hour == "12")

mod <-lm(Avg ~ Plot_type, data = TV12)

kruskal.test(Avg ~ Plot_type, data = TV12)
```

```
##
##  Kruskal-Wallis rank sum test
##
## data:  Avg by Plot_type
## Kruskal-Wallis chi-squared = 1.8436, df = 1, p-value = 0.1745
```

```
em <-emmeans(mod, pairwise ~ Plot_type, adjust = "Tukey")
em
```

```
## $emmeans
##  Plot_type emmean   SE df lower.CL upper.CL
##  PC          20.1 1.89  8     15.7     24.5
##  ST          16.1 1.89  8     11.7     20.5
##
## Confidence level used: 0.95
##
## $contrasts
```

```
##  contrast estimate   SE df t.ratio p.value
##  PC - ST      4.01 2.68  8 1.500   0.1720
```

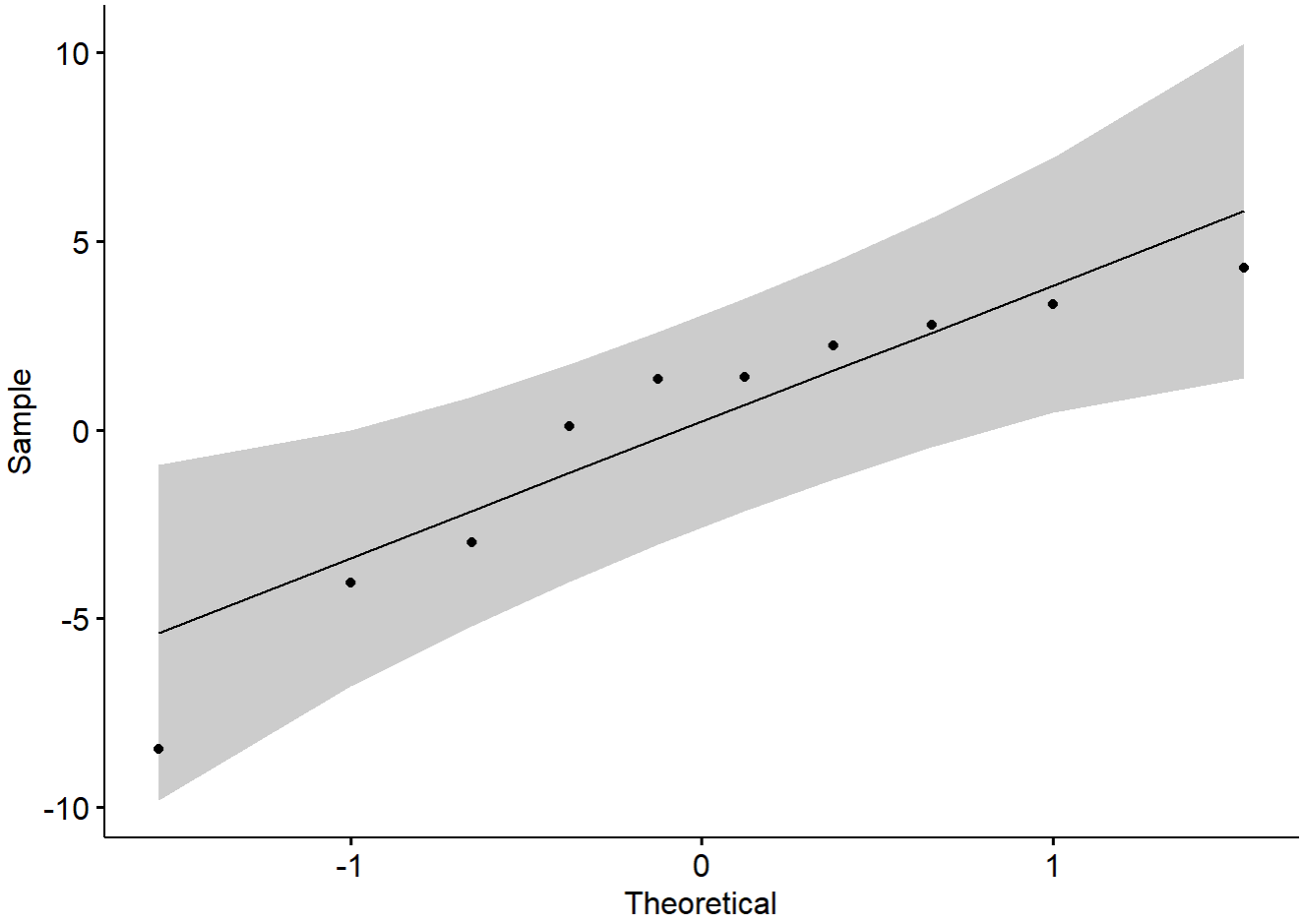
```
sumPESeptember[c(1:2),c(2:7)] <- summary(em)$emmeans

leveneTest((TV12$Avg ~ TV12$Plot_type))
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value Pr(>F)
## group  1  0.0239  0.881
##        8
```

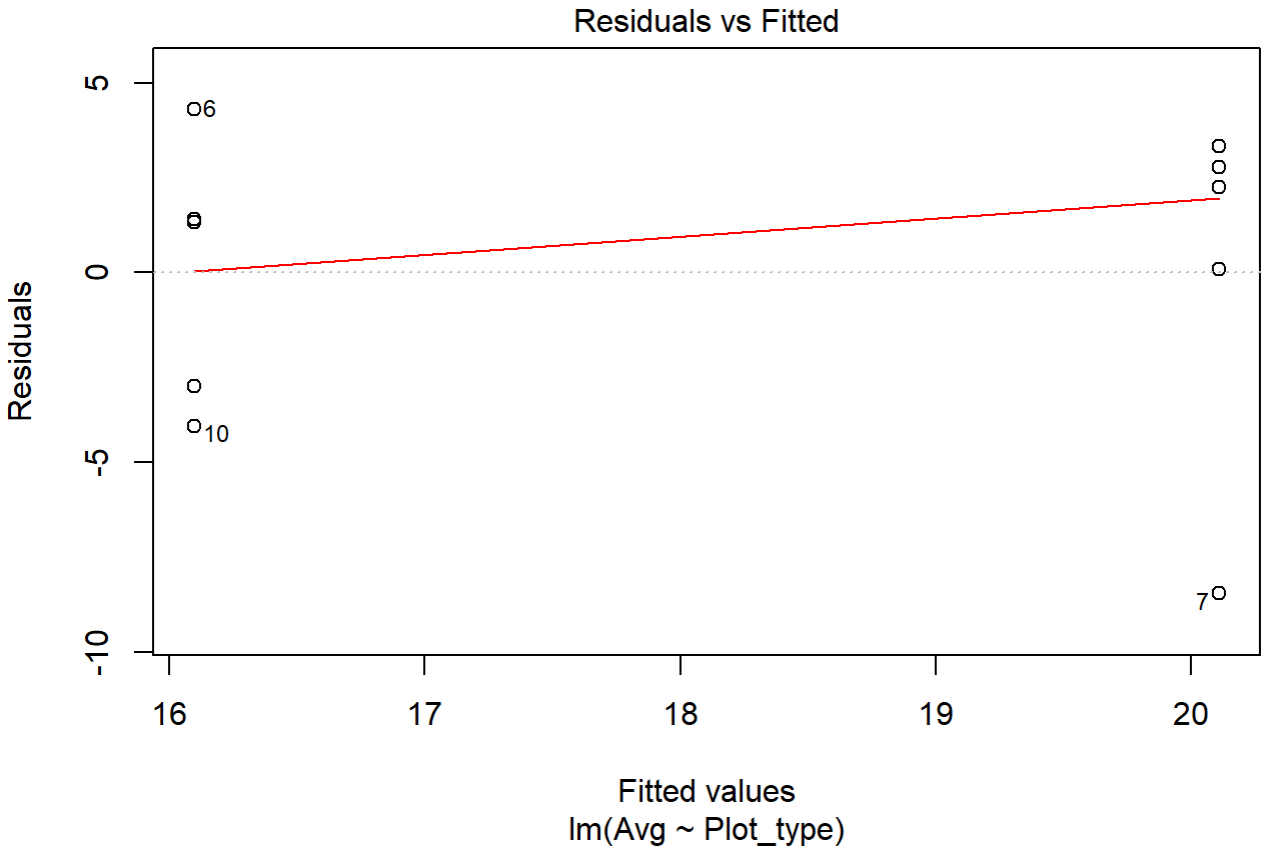
```
DT <- data.table(TV12)
DT[, .(W = shapiro.test(Avg)$statistic, P.value = shapiro.test(Avg)$p.value),
   by = .(Plot_type)]
```

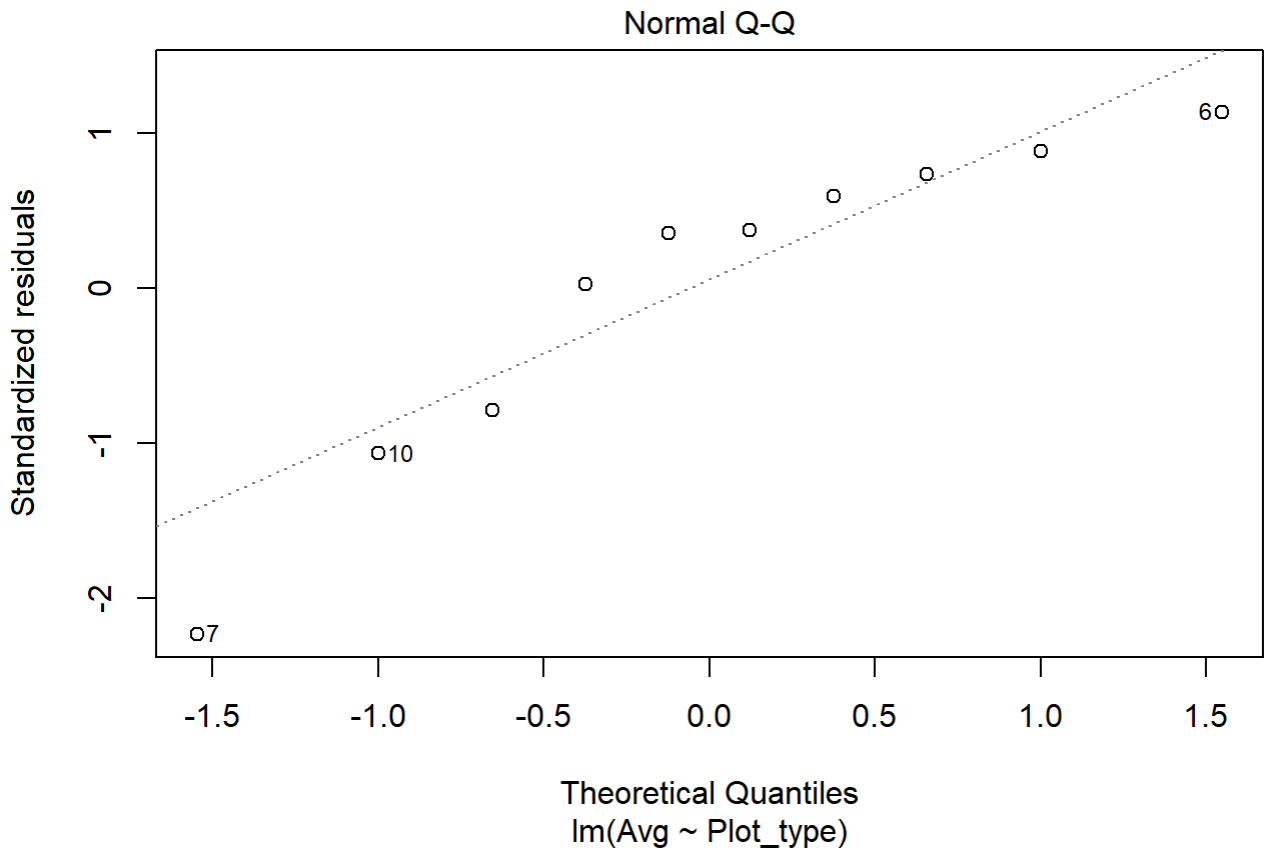
```
##    Plot_type         W    P.value
## 1:        PC 0.7552581 0.03326987
## 2:        ST 0.9177968 0.51582755
```

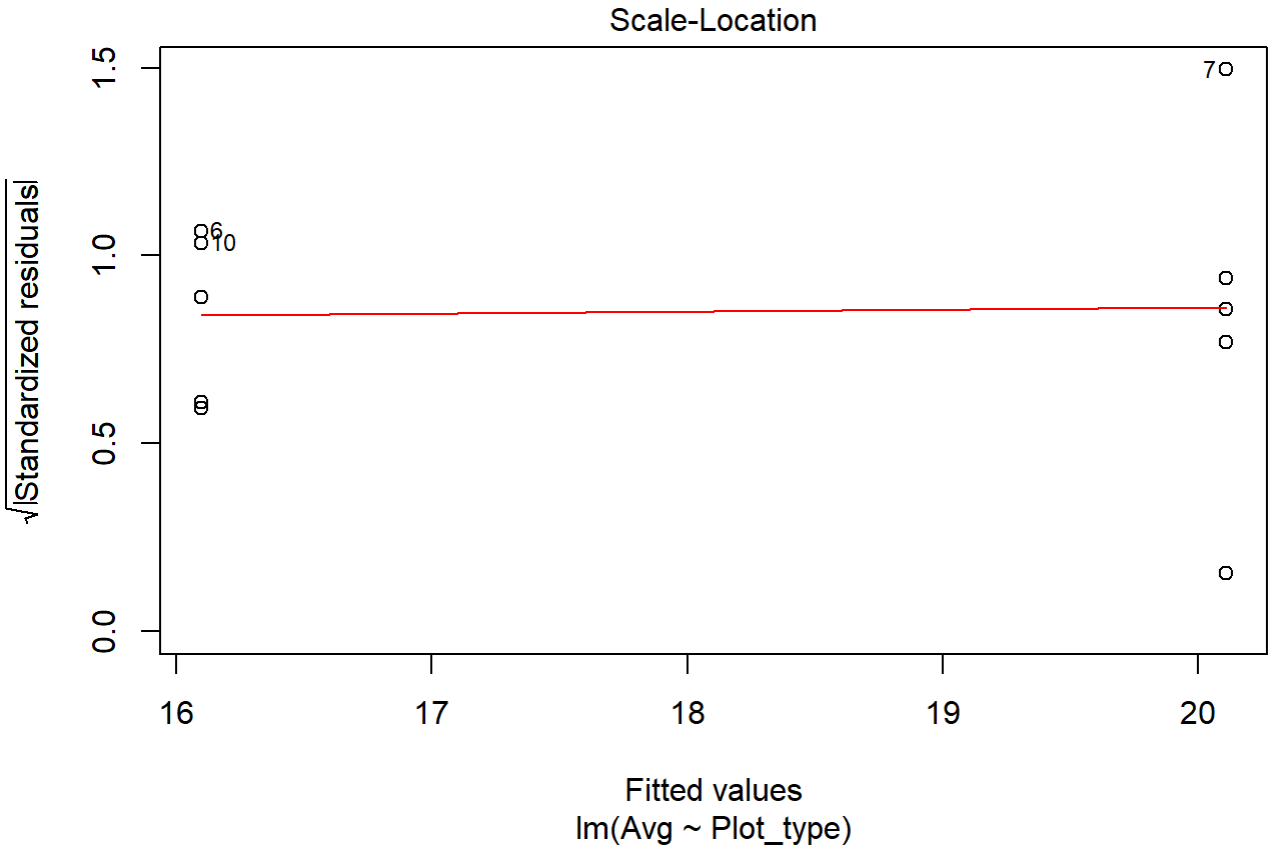
```
ggqqplot(residuals(mod))
```

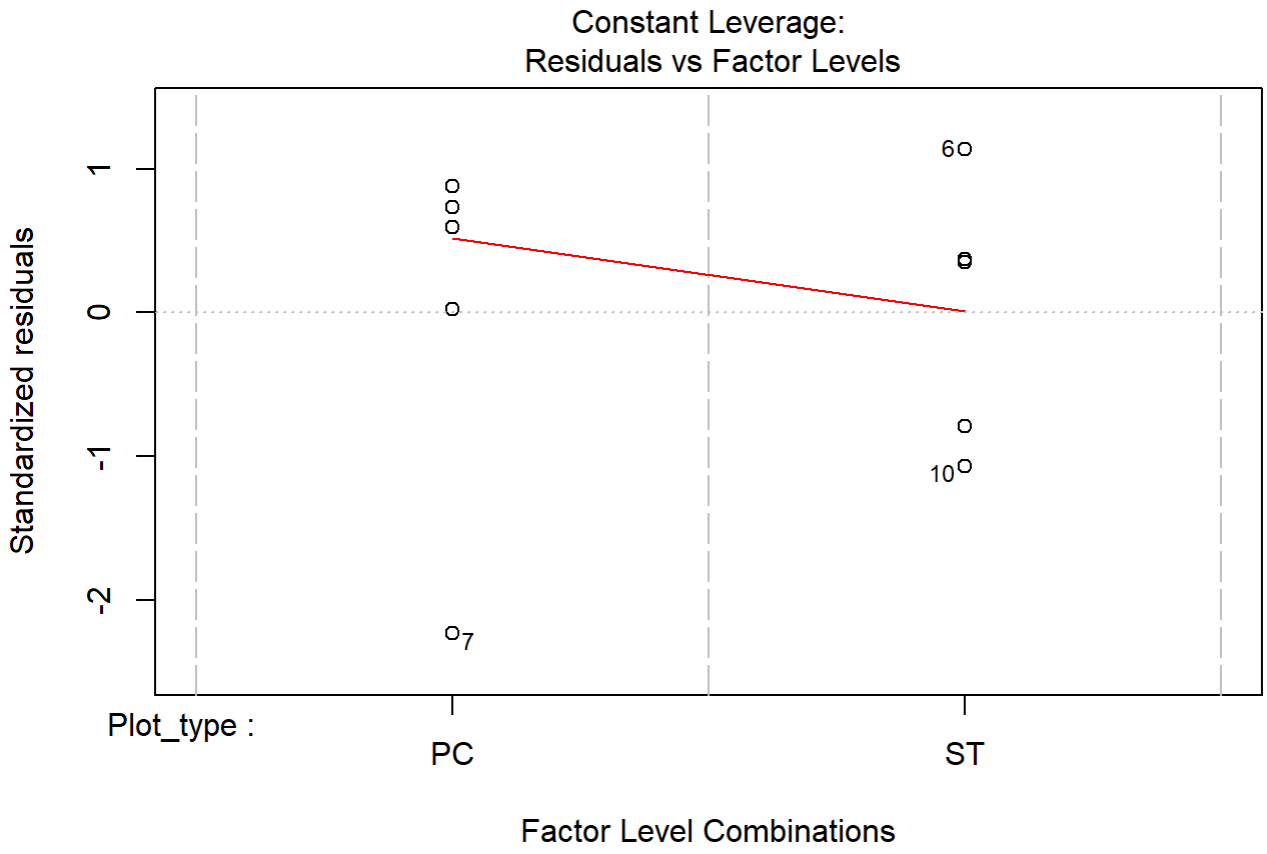



```
plot(mod)
```

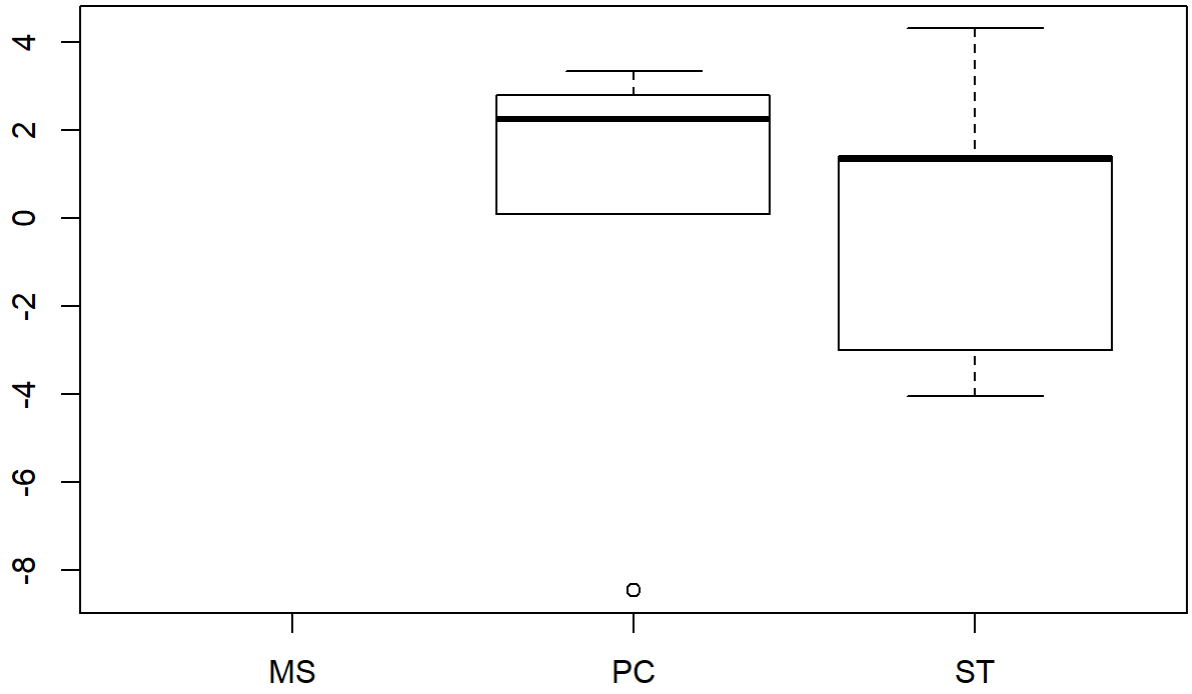

Residuals vs Fitted
Residuals
Fitted values
lm(Avg ~ Plot_type)
6
10
7
5
0
-5
-10
16
17
18
19
20


Normal Q-Q
Standardized residuals
Theoretical Quantiles
lm(Avg ~ Plot_type)
6
10
7
1
0
-1
-2
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5

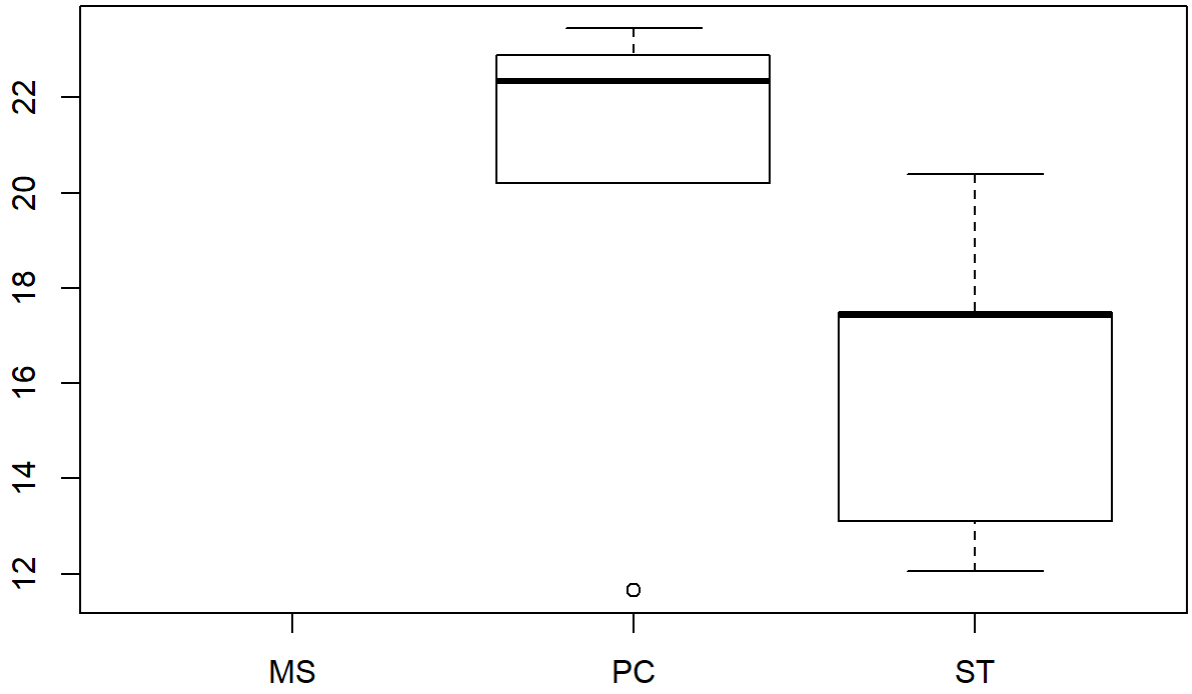

Scale-Location
√|Standardized residuals|
Fitted values
lm(Avg ~ Plot_type)
7
6
10
1.5
1.0
0.5
0.0
16
17
18
19
20




```
boxplot(residuals(mod) ~ TV12$Plot_type)
```




```
boxplot(TV12$Avg~ TV12$Plot_type)
```



14

```
TV14 <- filter(TV, Flight_hour == "14")

mod <-lm(Avg ~ Plot_type, data = TV14)

anova(mod)
```

```
## Analysis of Variance Table
##
## Response: Avg
##           Df  Sum Sq Mean Sq F value Pr(>F)
## Plot_type  1  20.736  20.736  0.7605 0.4086
## Residuals  8 218.125  27.266
```

```
em <-emmeans(mod, pairwise ~ Plot_type, adjust = "Tukey")
em
```

```
## $emmeans
##  Plot_type emmean   SE df lower.CL upper.CL
##  PC          24.4 2.34  8     19.0     29.8
##  ST          21.5 2.34  8     16.2     26.9
##
## Confidence level used: 0.95
```

```
##
## $contrasts
##  contrast estimate  SE df t.ratio p.value
##  PC - ST      2.88 3.3  8 0.872   0.4086
```

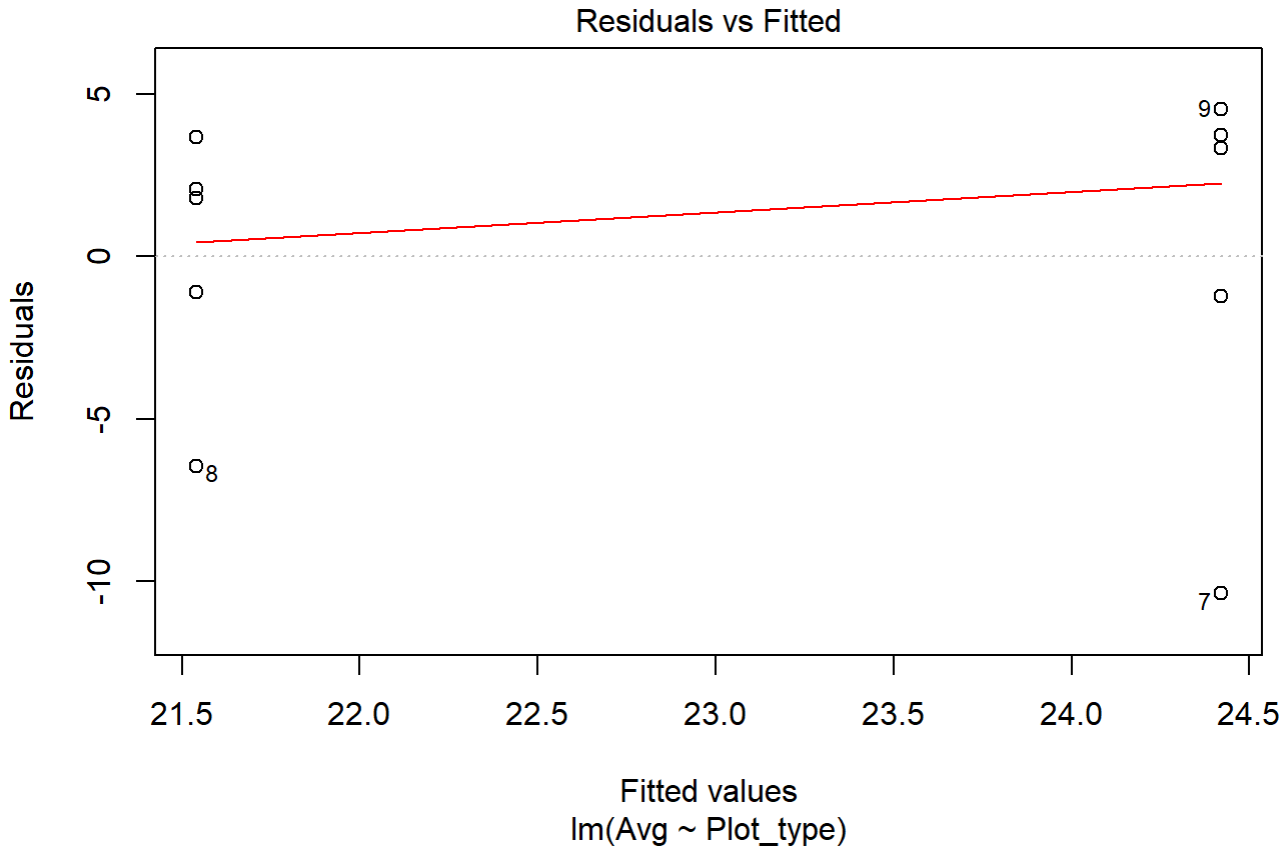
```
sumPESeptember[c(3:4),c(2:7)] <- summary(em)$emmeans

leveneTest(TV14$Avg ~ TV14$Plot_type)
```

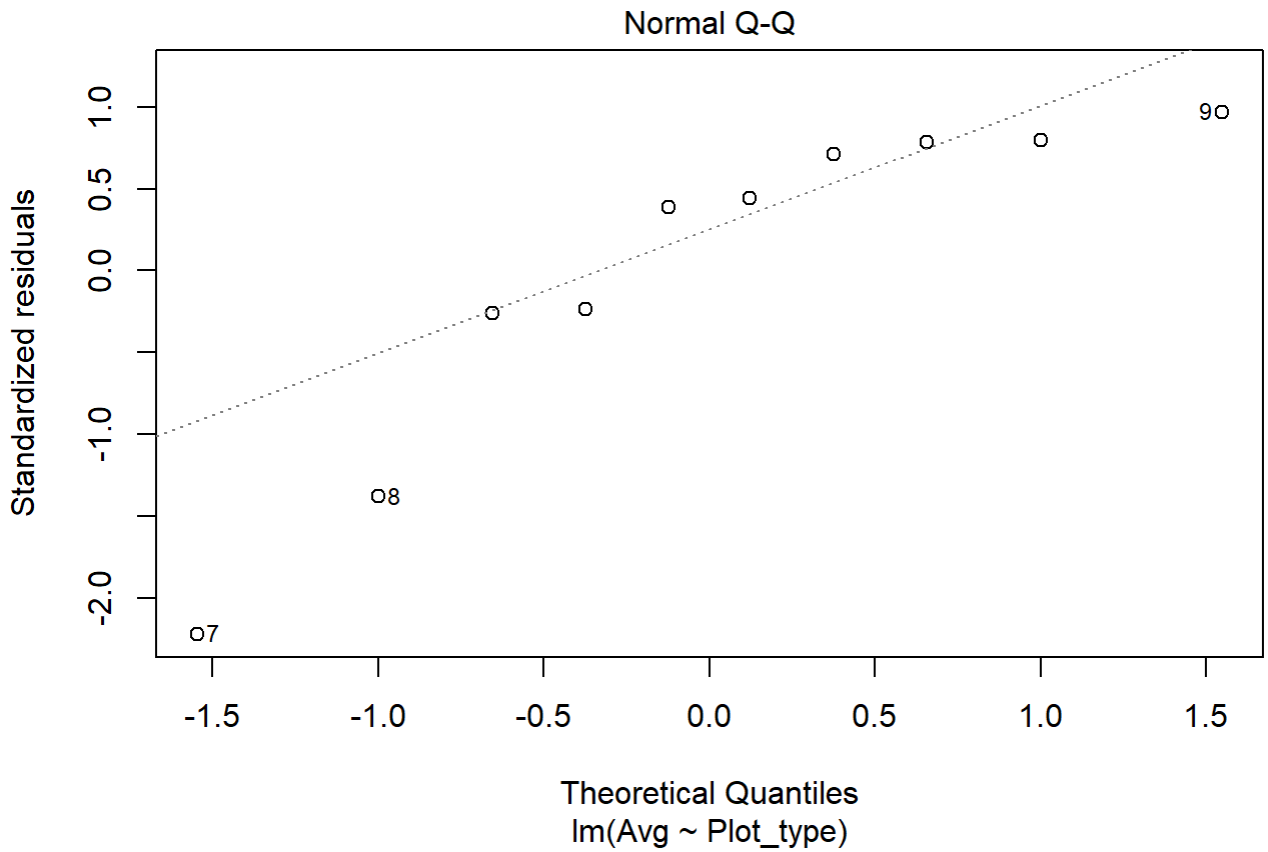
```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value Pr(>F)
## group  1   0.198 0.6682
##        8
```

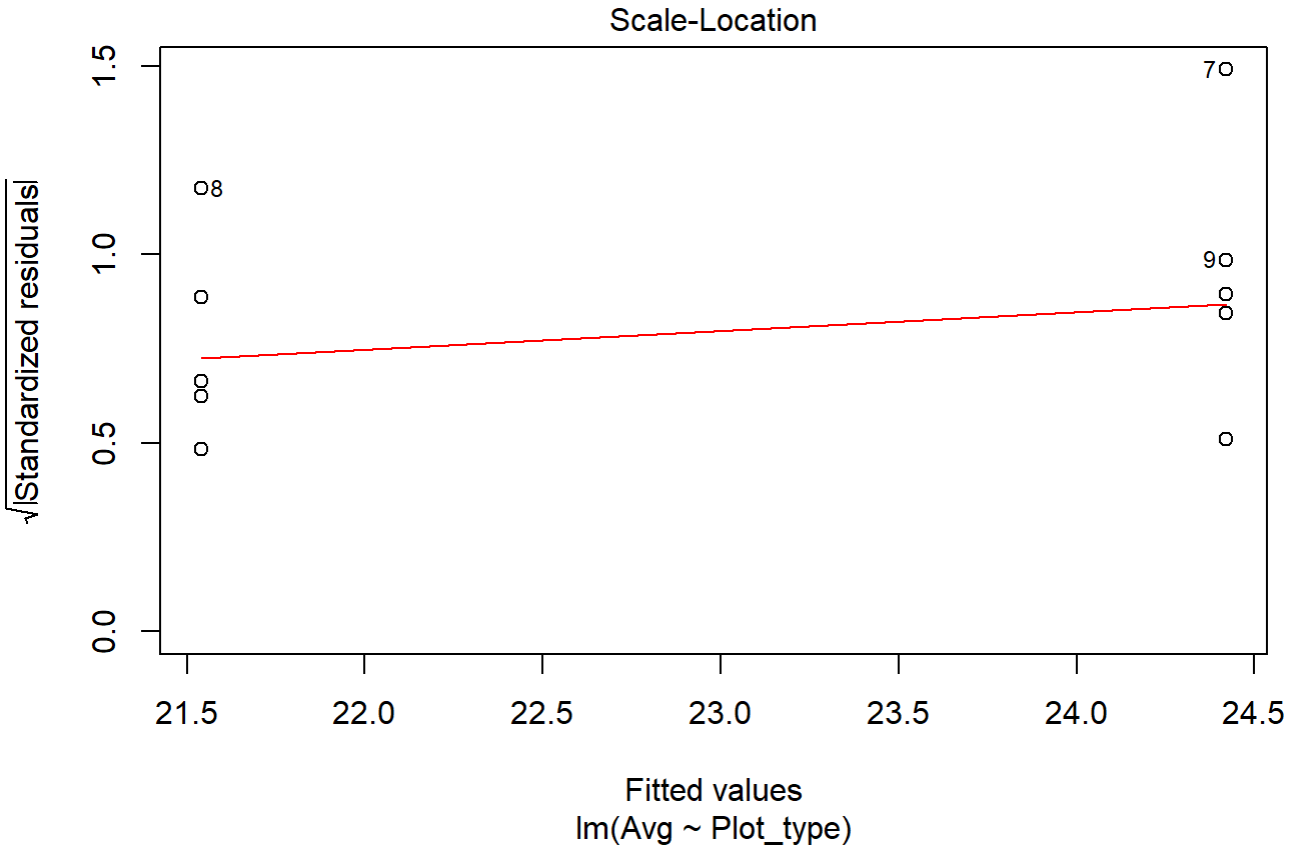
```
DT <- data.table(TV14)
DT[, .(W = shapiro.test(Avg)$statistic, P.value = shapiro.test(Avg)$p.value),
   by = .(Plot_type)]
```

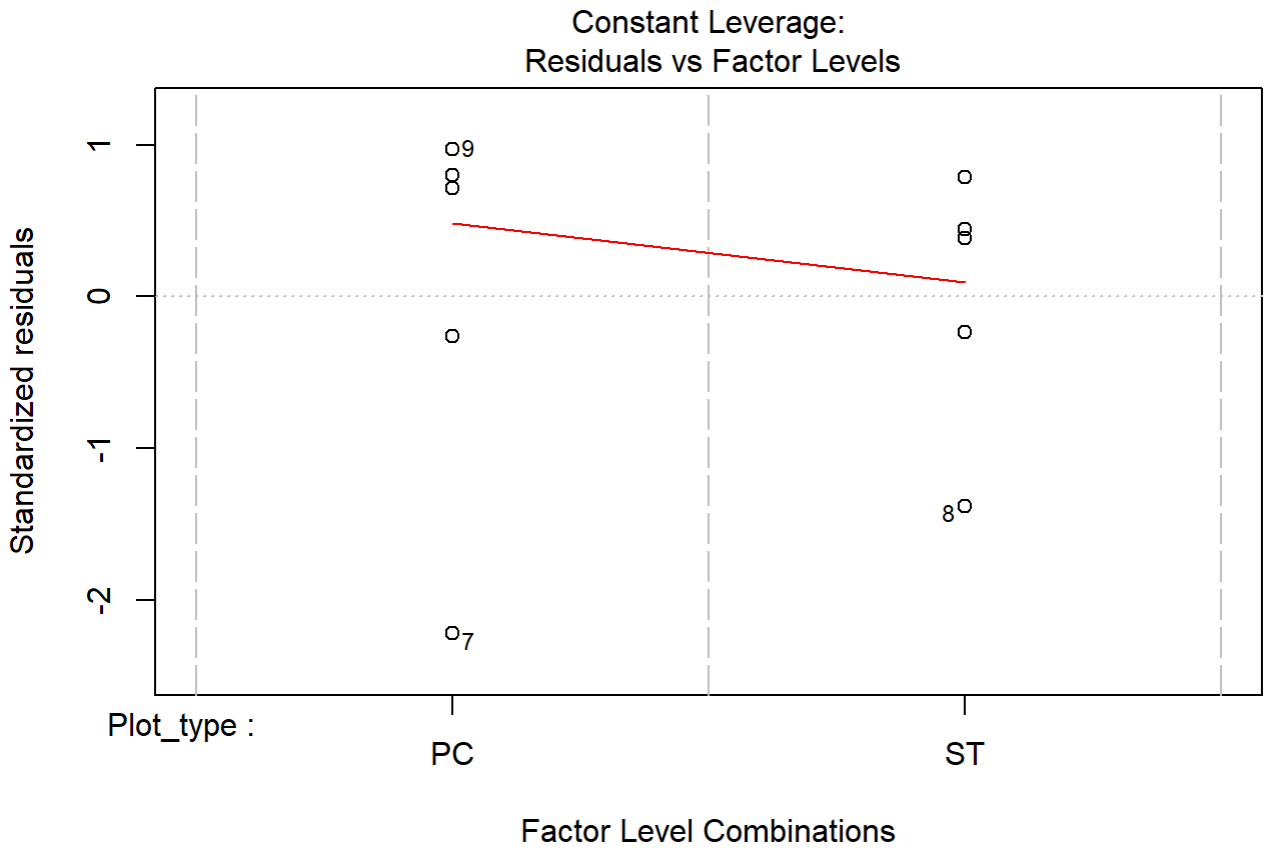
```
##    Plot_type         W   P.value
## 1:        PC 0.7969202 0.0764658
## 2:        ST 0.8784282 0.3022490
```

```
plot(mod)
```

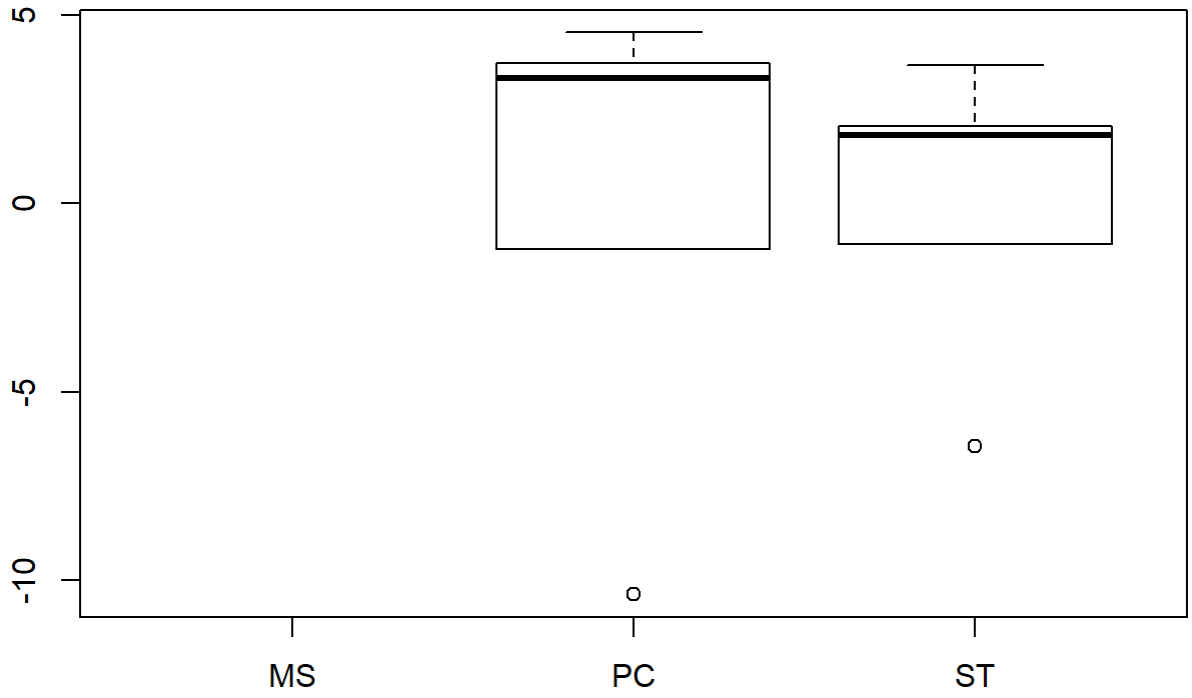



Normal Q-Q
Standardized residuals
1.0
0.5
0.0
-1.0
-2.0
9
8
7
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
Theoretical Quantiles
lm(Avg ~ Plot_type)

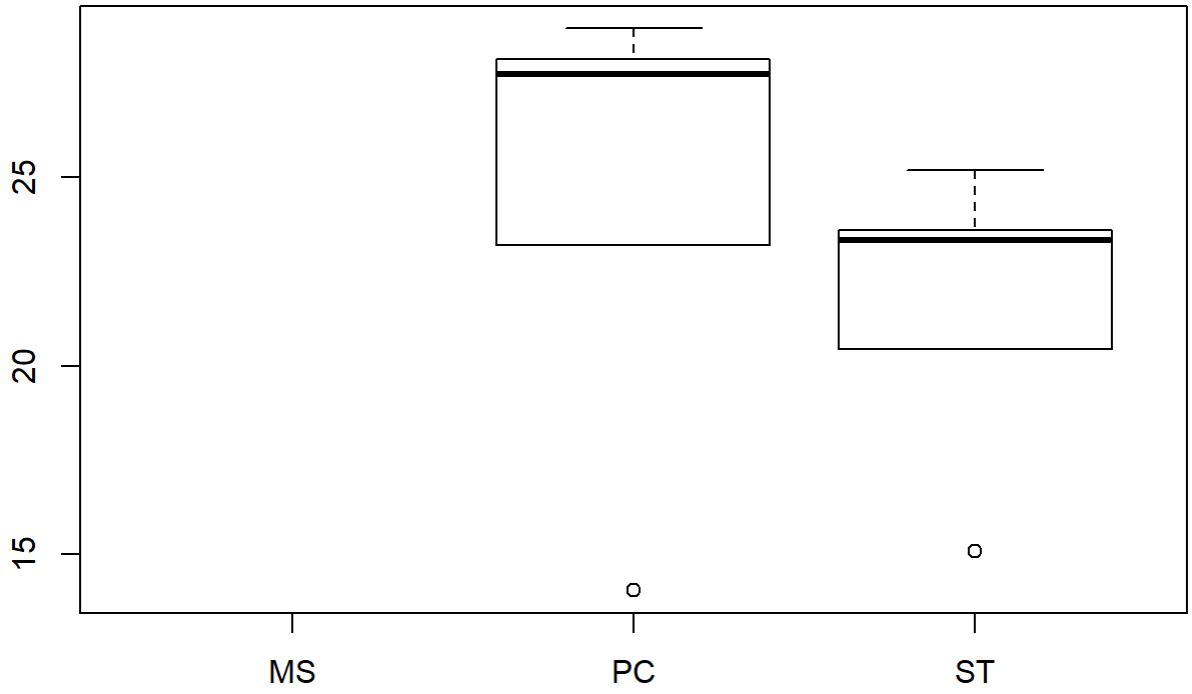

Scale-Location
√|Standardized residuals|
1.5
1.0
0.5
0.0
7
8
9
21.5
22.0
22.5
23.0
23.5
24.0
24.5
Fitted values
lm(Avg ~ Plot_type)




```
boxplot(residuals(mod) ~ TV14$Plot_type)
```




```
boxplot(TV14$Avg ~ TV14$Plot_type)
```



16

```
TV16 <- filter(TV, Flight_hour == "16")

mod <-lm(Avg ~ Plot_type, data = TV16)

anova(mod)
```

```
## Analysis of Variance Table
##
## Response: Avg
##           Df Sum Sq Mean Sq F value Pr(>F)
## Plot_type  1  15.50  15.500  0.9819 0.3508
## Residuals  8 126.29  15.786
```

```
em <-emmeans(mod, pairwise ~ Plot_type, adjust = "Tukey")
em
```

```
## $emmeans
##  Plot_type emmean   SE df lower.CL upper.CL
##  PC          23.1 1.78  8     19.0     27.2
##  ST          20.6 1.78  8     16.5     24.7
##
## Confidence level used: 0.95
```

```
##
## $contrasts
##  contrast estimate   SE df t.ratio p.value
##  PC - ST      2.49 2.51  8 0.991   0.3508
```

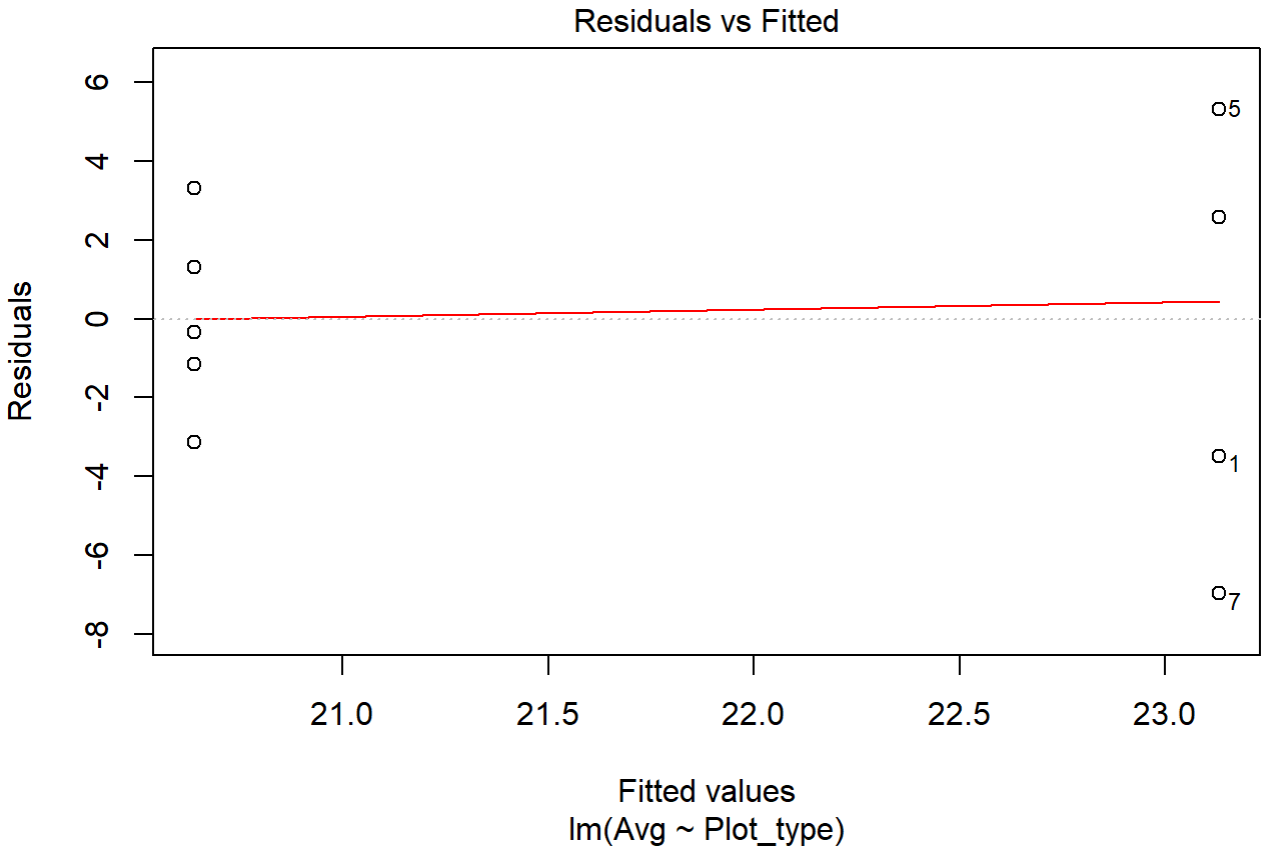
```
sumPESeptember[c(5:6),c(2:7)] <- summary(em)$emmeans

leveneTest(TV16$Avg ~ TV16$Plot_type)
```

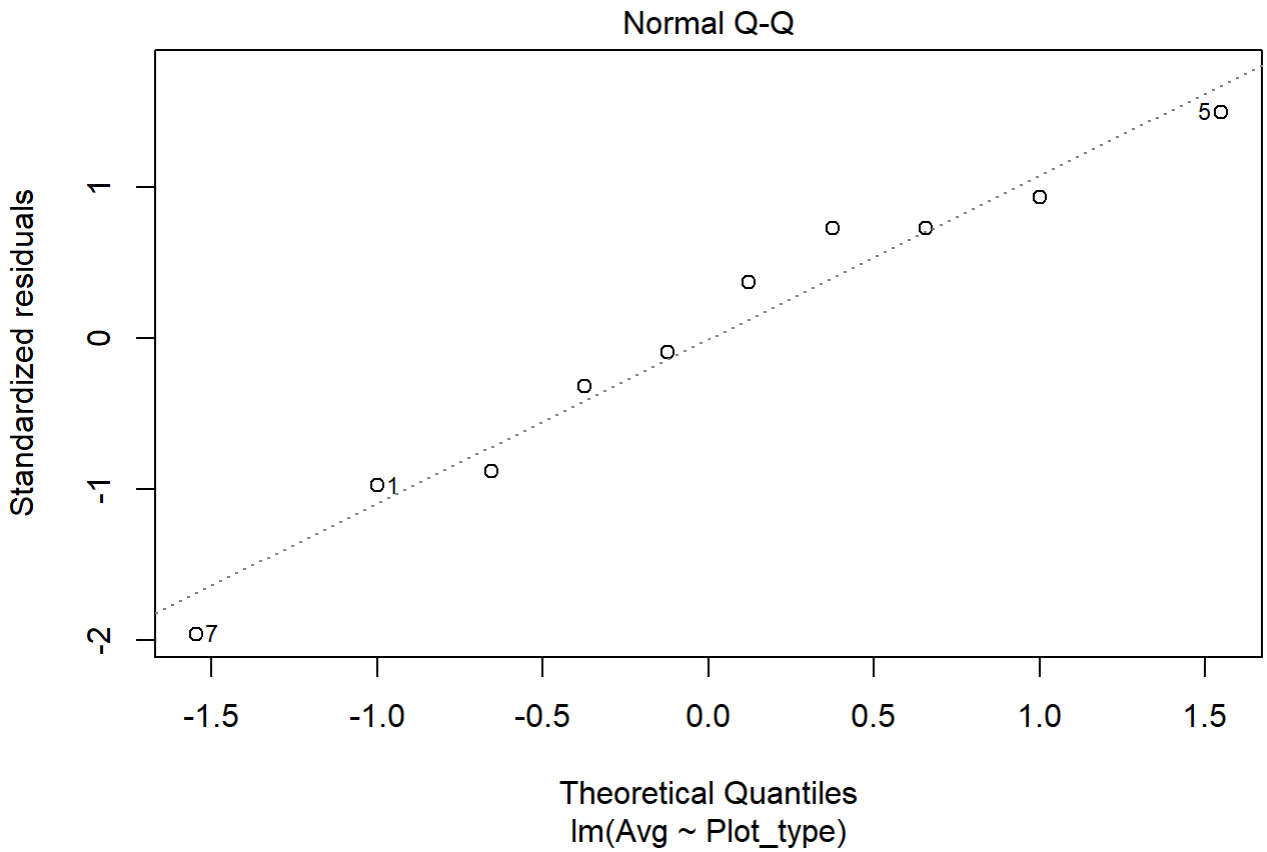
```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value Pr(>F)
## group  1  0.9314 0.3628
##        8
```

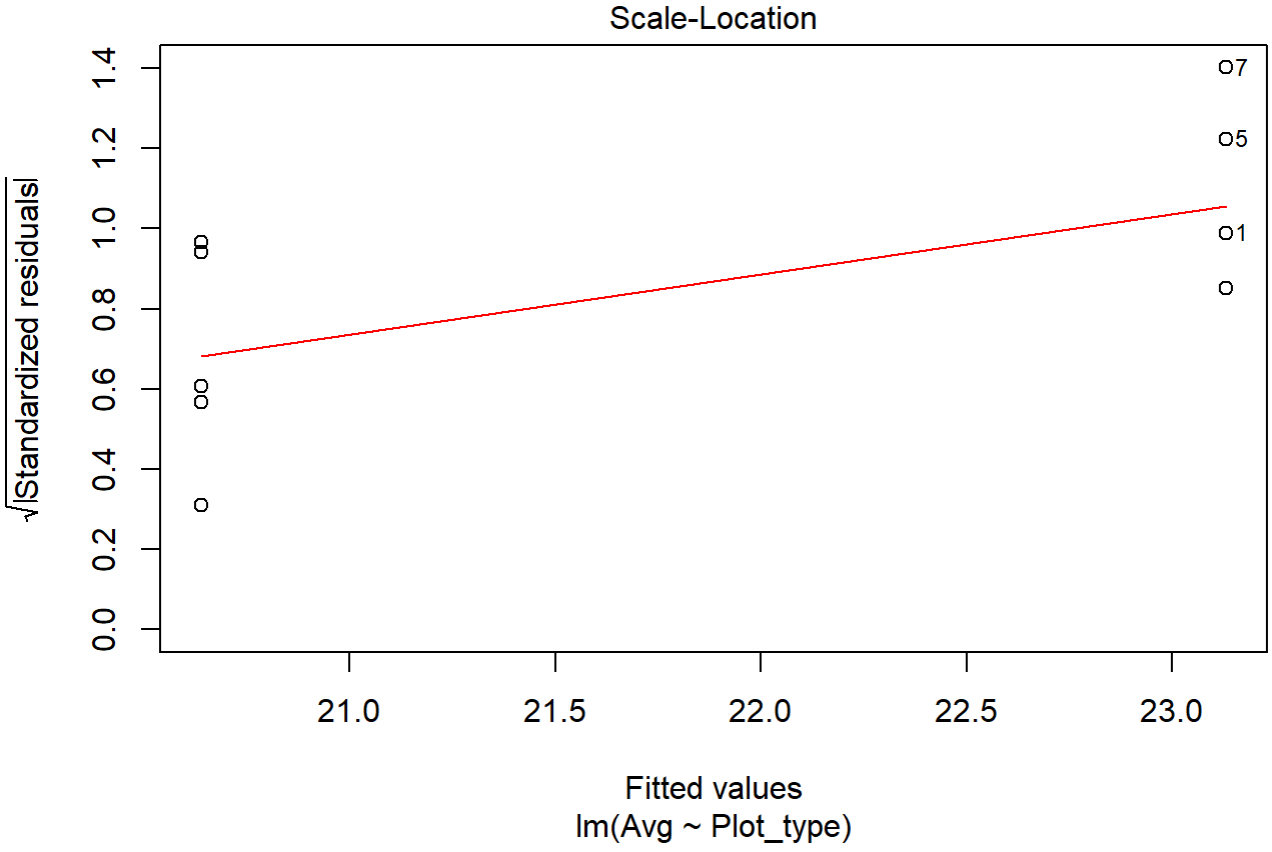
```
DT <- data.table(TV16)
DT[, .(W = shapiro.test(Avg)$statistic, P.value = shapiro.test(Avg)$p.value),
   by = .(Plot_type)]
```

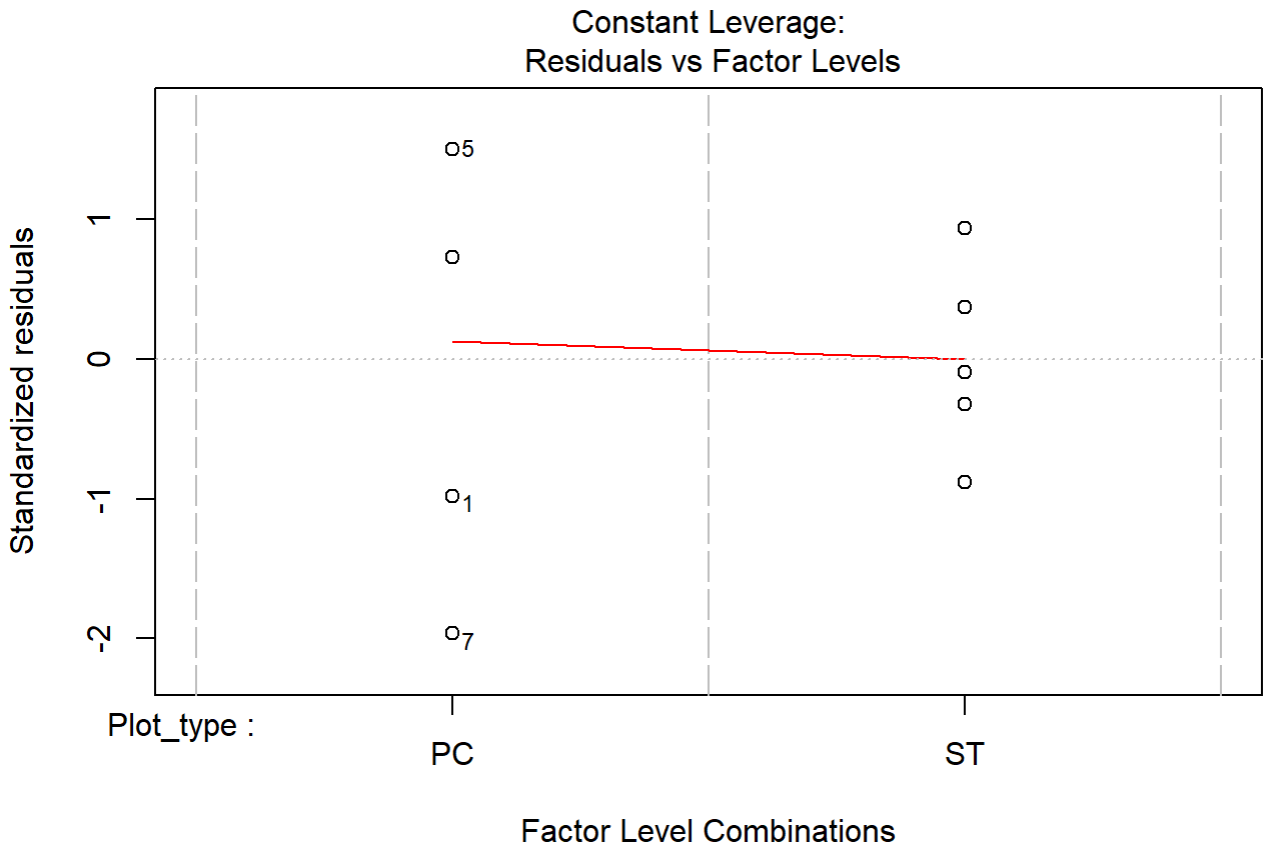
```
##    Plot_type         W   P.value
## 1:        PC 0.9071342 0.4505615
## 2:        ST 0.9937518 0.9910436
```

```
plot(mod)
```

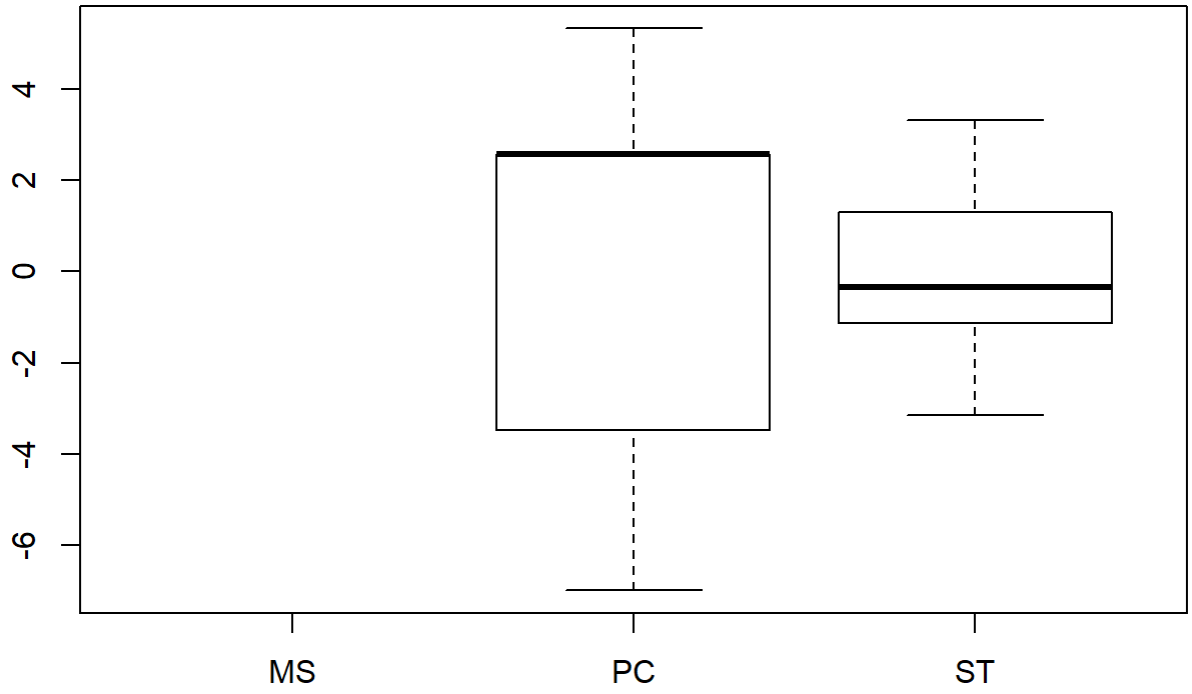



Normal Q-Q
Standardized residuals
Theoretical Quantiles
lm(Avg ~ Plot_type)
-2
-1
0
1
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
7
1
5

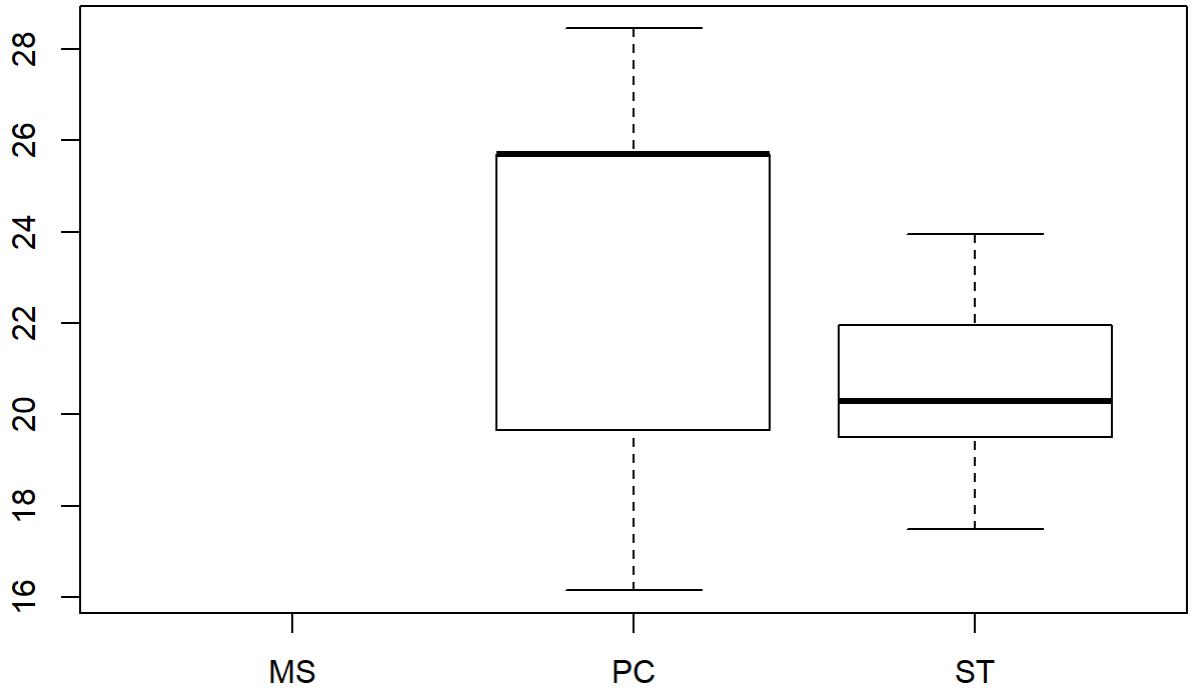

Scale-Location
√|Standardized residuals|
Fitted values
lm(Avg ~ Plot_type)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
21.0
21.5
22.0
22.5
23.0
7
5
1
8




```
boxplot(residuals(mod) ~ TV16$Plot_type)
```




```
boxplot(TV16$Avg~ TV16$Plot_type)
```



Graph over time - PE September

```
sumPESeptember[,'Plot_type']<-factor(sumPESeptember[,'Plot_type'])

tiff("GravelSeptember.tiff", width = 7, height = 5, units = 'in', res = 100)

ggplot(sumPESeptember, aes(x=Flight_hour, y=emmeans, colour=Plot_type)) +
  geom_errorbar(aes(ymin=lower.CL, ymax=Upper.cl), width=.3, position=position_dodge(width=0.2
)) +
  geom_point(position=pd, size=3, shape=21, fill="white") +
  geom_line(position=pd, linetype = "dashed") +
  xlab("Time of day (24-hr format)") +
  ylab(expression("EM Mean Surface Temperature  " ( degree*C))) +
  scale_colour_hue(name="Plot type",
                   breaks=c("1", "2"),
                   labels=c("Passive Control", "Topsoil Recipient"),
                   l=40) +
  expand_limits(y=0) +
  scale_y_continuous(breaks=c(0, 5, 10, 15, 20, 25, 30, 35, 40, 45)) +
  scale_x_continuous(breaks=c(12,14,16, 18,20)) +
  theme_bw() +
  theme(legend.position=c(0.8,0.2), legend.title = element_text(size = 14),
        legend.text = element_text(size = 12), text = element_text(size=14), axis.text = eleme
nt_text(color = "black", size=14)) +
  annotate(geom="label",x = 12.2,  y = 9,
           label = "p = 0.172 \n(2, 1)", fontface = "plain", col ="black", size = 4, fill = "w
```

```
hite") +
  annotate(geom="label",x = 14,  y = 13,
           label ="p = 0.408 \n (2, 1)", fontface = "plain", col ="black", size = 4, fill = "w
hite") +
  annotate(geom="label",x = 16,  y = 13,
           label = "p = 0.351 \n (2, 1)", fontface = "plain", col ="black", size = 4, fill = "
white")
```

```
## Warning: Removed 2 rows containing missing values (geom_point).
```

```
## Warning: Removed 2 row(s) containing missing values (geom_path).
```

```
dev.off()
```

```
## png
##   2
```

Gravel pit September temperature over time - all hours in LMER

```
mod <-lmer(Avg ~ Plot_type * Flight_hour + (1|Plot_id), data = TV)

anova(mod, ddf="Kenward-Roger")
```

```
## Type III Analysis of Variance Table with Kenward-Roger's method
##                       Sum Sq Mean Sq NumDF DenDF F value   Pr(>F)
## Plot_type              7.204   7.204     1    22  0.8187 0.375359
## Flight_hour           71.505  71.505     1    22  8.1261 0.009299 **
## Plot_type:Flight_hour  2.901   2.901     1    22  0.3296 0.571694
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
r.squaredGLMM(mod)
```

```
##            R2m       R2c
## [1,] 0.1875905 0.6760672
```

```
em <-emmeans(mod, pairwise ~ Plot_type, adjust = "Tukey")
```

```
## NOTE: Results may be misleading due to involvement in interactions
```

```
em
```

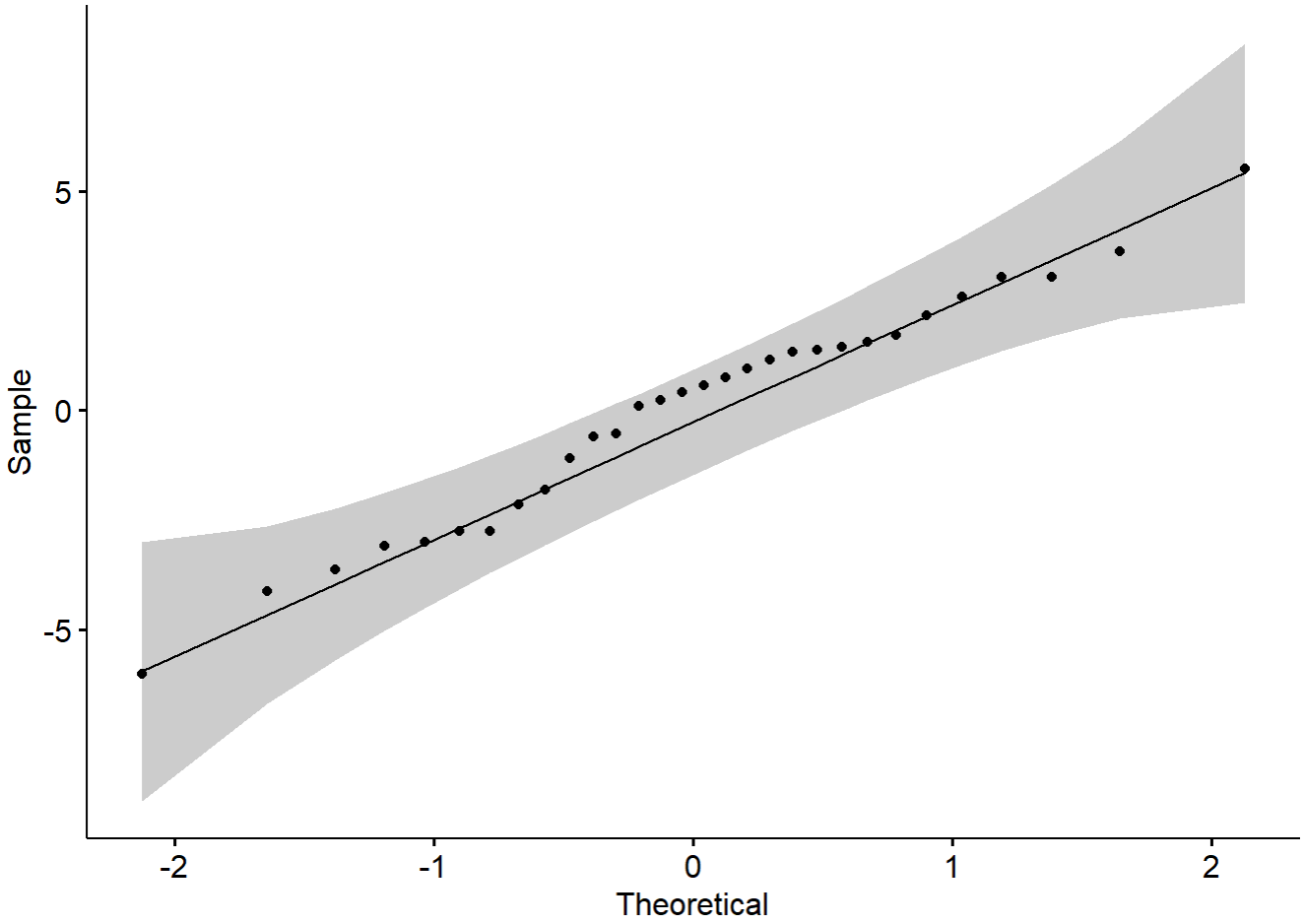
```
## $emmeans
##  Plot_type emmean  SE   df lower.CL upper.CL
##  PC          22.6 1.8 4.83     17.9     27.2
##  ST          19.4 1.8 4.83     14.7     24.1
```

```
##
## Degrees-of-freedom method: kenward-roger
## Confidence level used: 0.95
##
## $contrasts
##  contrast estimate   SE df t.ratio p.value
##  PC - ST      3.13 1.08 22 2.888   0.0085
```

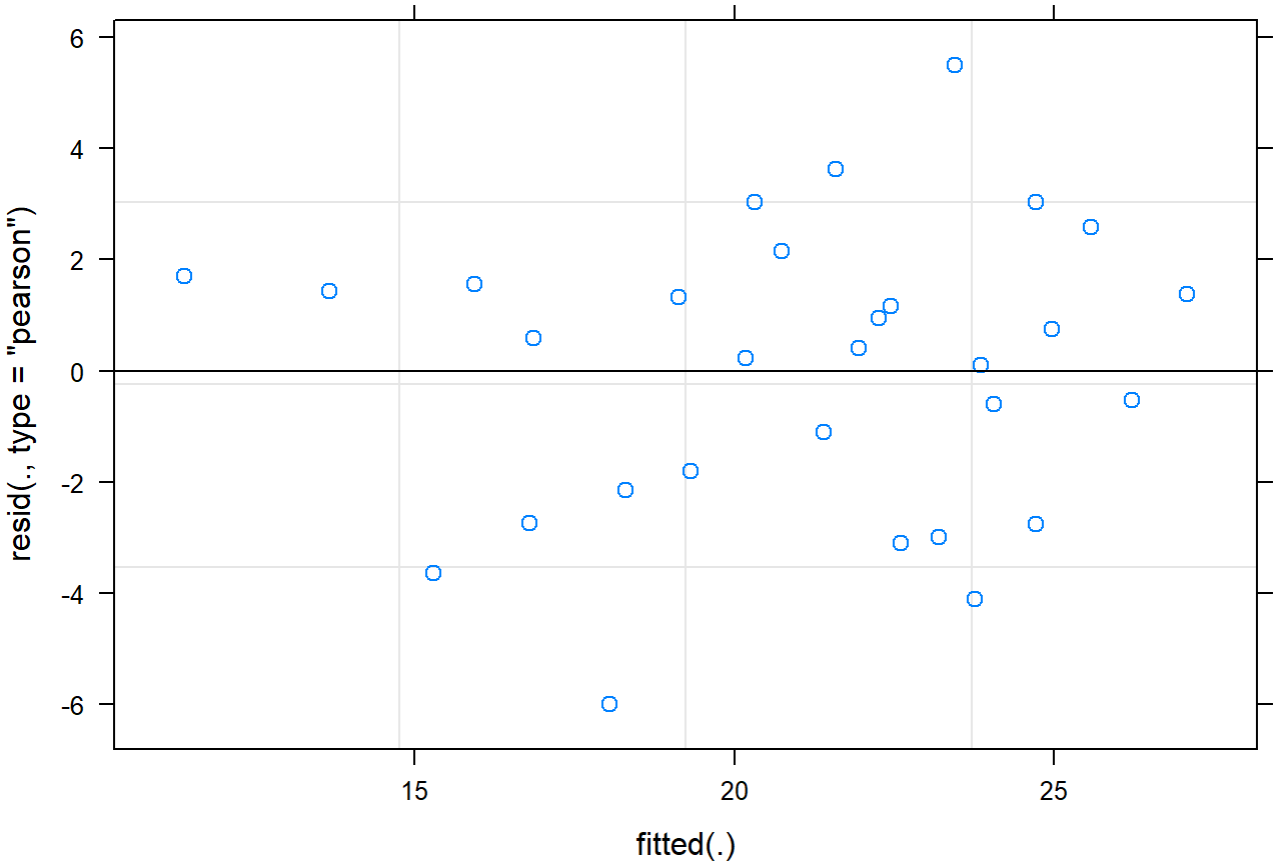
```
sumPESeptember[c(1:2),c(2:7)] <- summary(em)$emmeans
```

```
## Warning in `[<-.factor`(`*tmp*`, iseq, value = structure(1:2, .Label =
## c("PC", : invalid factor level, NA generated
```

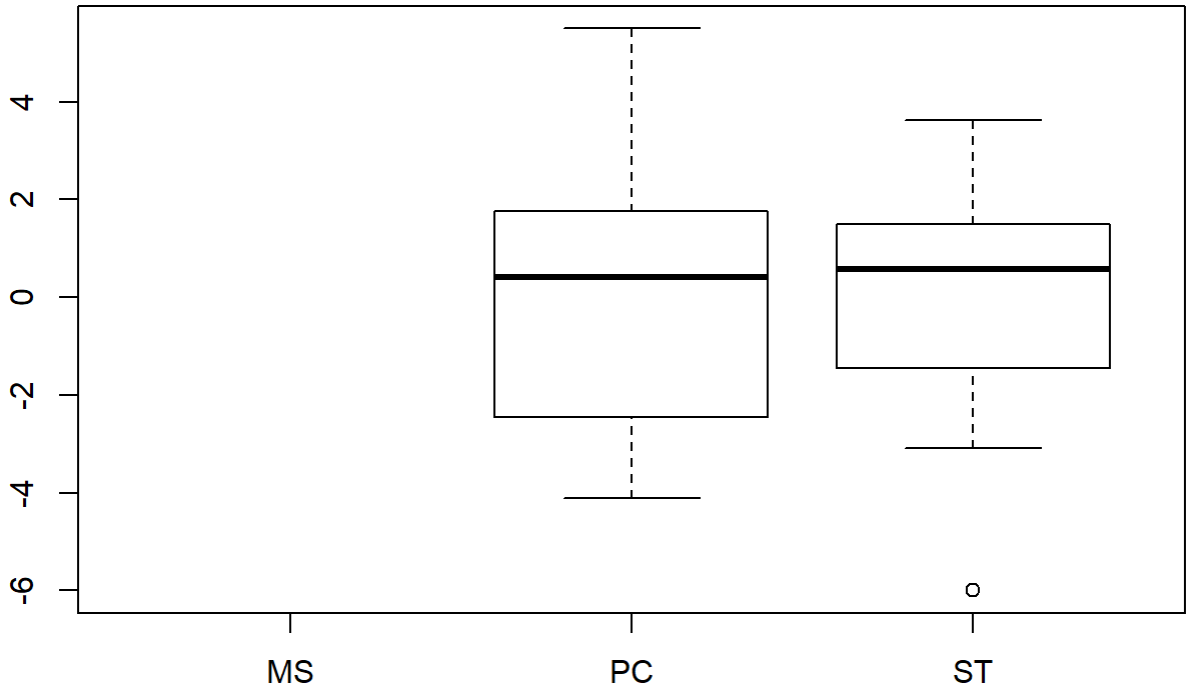
```
ggqqplot(residuals(mod))
```



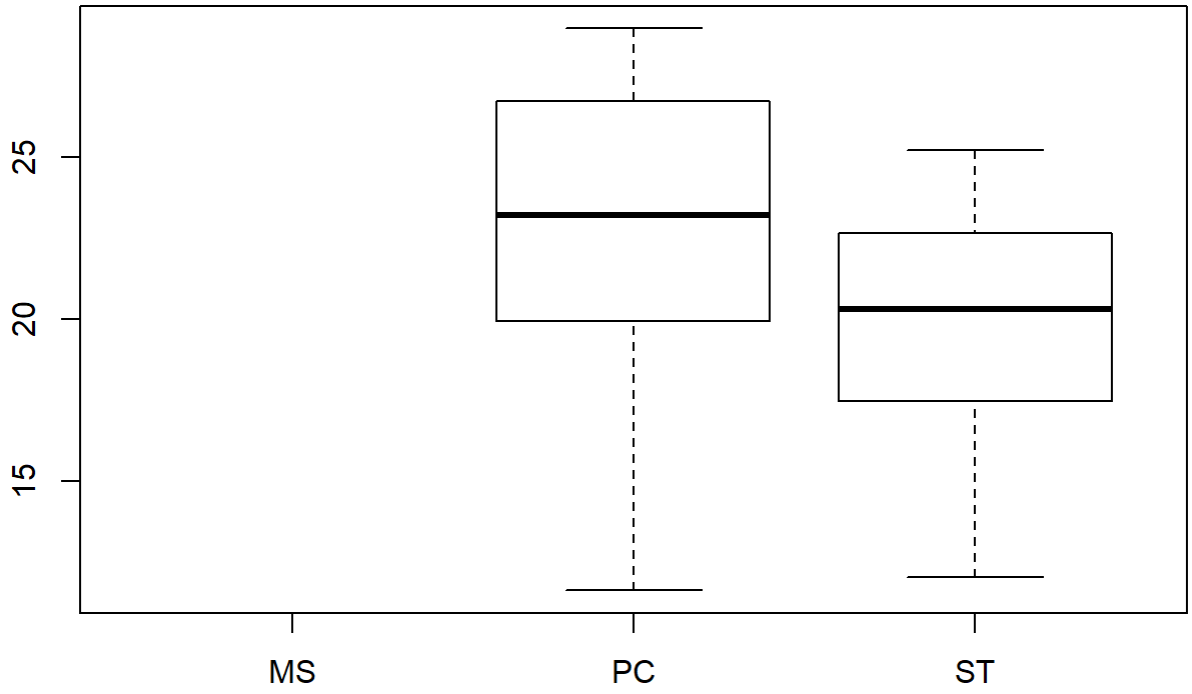

```
plot(mod)
```



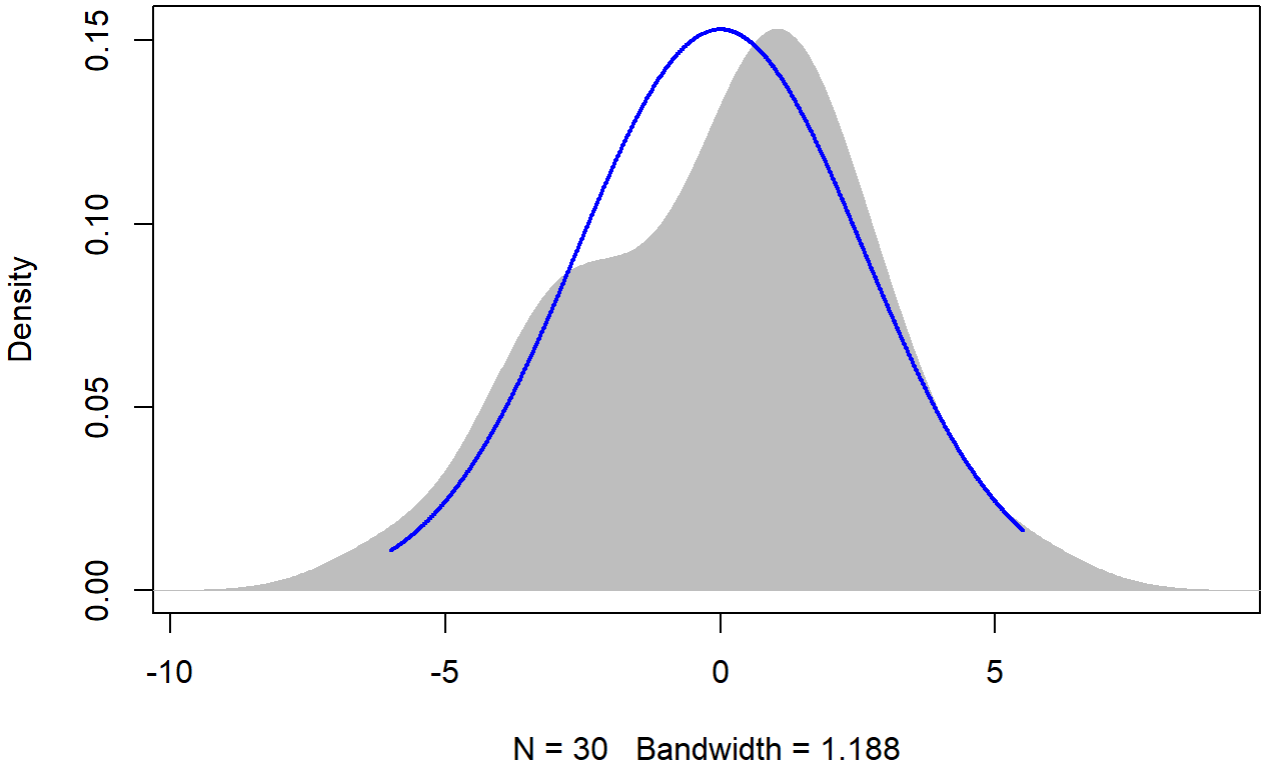

```
boxplot(residuals(mod) ~ TV$Plot_type)
```




```
boxplot(TV$Avg ~ TV$Plot_type)
```




```
plotNormalDensity(resid(mod))
```



4.3.1.2. 2016 Reforestation site

Reforestation 2016 - ecological attributes tables and tests

```
#ground cover - assumptions met

ex1 <- AllS_16 %>%
  group_by(Treatment) %>%
  summarise(mean(Ground.cover), sd(Ground.cover))
head(ex1)
```

```
## # A tibble: 2 x 3
##   Treatment `mean(Ground.cover)` `sd(Ground.cover)`
##   <fct>                    <dbl>              <dbl>
## 1 C                         0.5               0.187
## 2 ST                        0.79              0.143
```

```
mod <- lm(Ground.cover ~ Treatment, data = AllS_16)
anv <- aov(Ground.cover ~ Treatment, data = AllS_16)
emmeans(mod, pairwise ~ Treatment, adjust = "Tukey")
```

```
## $emmeans
##  Treatment emmean     SE df lower.CL upper.CL
##  C           0.50 0.0743  8    0.329    0.671
```

```
##  ST          0.79 0.0743  8    0.619    0.961
##
## Confidence level used: 0.95
##
## $contrasts
##  contrast estimate    SE df t.ratio p.value
##  C - ST      -0.29 0.105  8 -2.760  0.0247
```

```
shapiro.test(anv$residuals)
```

```
##
##  Shapiro-Wilk normality test
##
## data:  anv$residuals
## W = 0.91455, p-value = 0.3137
```

```
leveneTest((AllS_16$Ground.cover ~ AllS_16$Plot_type))
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value Pr(>F)
## group  1  0.0071 0.9348
##        8
```

```
outlierTest(mod)
```

```
## No Studentized residuals with Bonferonni p < 0.05
## Largest |rstudent|:
##    rstudent unadjusted p-value Bonferonni p
## 7 -2.890047           0.023315      0.23315
```

```
#NF Sp. richness - assumptions met
ex1 <- AllS_16 %>%
  group_by(Treatment) %>%
  summarise(mean(NF..sp..rich.), sd(NF..sp..rich.))
head(ex1)
```

```
## # A tibble: 2 x 3
##   Treatment `mean(NF..sp..rich.)` `sd(NF..sp..rich.)`
##   <fct>                     <dbl>               <dbl>
## 1 C                           1.8               0.447
## 2 ST                          9                 1.41
```

```
mod <- lm(NF..sp..rich. ~ Treatment, data = AllS_16)
anv <- aov(NF..sp..rich. ~ Treatment, data = AllS_16)
emmeans(mod, pairwise ~ Treatment, adjust = "Tukey")
```

```
## $emmeans
```

```
##  Treatment emmean    SE df lower.CL upper.CL
##  C            1.8 0.469  8    0.718     2.88
##  ST           9.0 0.469  8    7.918    10.08
##
## Confidence level used: 0.95
##
## $contrasts
##  contrast estimate    SE df t.ratio p.value
##  C - ST       -7.2 0.663  8 -10.854 <.0001
```

```
shapiro.test(anv$residuals)
```

```
##
##  Shapiro-Wilk normality test
##
## data:  anv$residuals
## W = 0.86507, p-value = 0.08753
```

```
leveneTest((AllS_16$NF..sp..rich. ~ AllS_16$Plot_type))
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value Pr(>F)
## group  1  1.4545 0.2623
##        8
```

```
outlierTest(mod)
```

```
## No Studentized residuals with Bonferonni p < 0.05
## Largest |rstudent|:
##   rstudent unadjusted p-value Bonferonni p
## 1 3.034885           0.018983      0.18983
```

```
#All Sp. richness - assumptions met
ex1 <- AllS_16 %>%
  group_by(Treatment) %>%
  summarise(mean(totSRich), sd(totSRich))
head(ex1)
```

```
## # A tibble: 2 x 3
##   Treatment `mean(totSRich)` `sd(totSRich)`
##   <fct>                <dbl>          <dbl>
## 1 C                     18.4           2.07
## 2 ST                    27.6           3.58
```

```
mod <- lm(totSRich ~ Treatment, data = AllS_16)
anv <- aov(totSRich ~ Treatment, data = AllS_16)
emmeans(mod, pairwise ~ Treatment, adjust = "Tukey")
```

```
## $emmeans
##  Treatment emmean   SE df lower.CL upper.CL
##  C           18.4 1.31  8     15.4     21.4
##  ST          27.6 1.31  8     24.6     30.6
##
## Confidence level used: 0.95
##
## $contrasts
##  contrast estimate   SE df t.ratio p.value
##  C - ST       -9.2 1.85  8 -4.975  0.0011
```

```
shapiro.test(anv$residuals)
```

```
##
##  Shapiro-Wilk normality test
##
## data:  anv$residuals
## W = 0.94405, p-value = 0.5989
```

```
leveneTest(AllS_16$totSRich ~ AllS_16$Plot_type)
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value Pr(>F)
## group  1     1.6 0.2415
##        8
```

```
outlierTest(mod)
```

```
## No Studentized residuals with Bonferonni p < 0.05
## Largest |rstudent|:
##    rstudent unadjusted p-value Bonferonni p
## 2 -2.100854           0.073778      0.73778
```

```
#All Sp. diversity - assumptions met
ex1 <- AllS_16 %>%
  group_by(Treatment) %>%
  summarise(mean(Total.diversity), sd(Total.diversity))
head(ex1)
```

```
## # A tibble: 2 x 3
##   Treatment `mean(Total.diversity)` `sd(Total.diversity)`
##   <fct>                       <dbl>                 <dbl>
## 1 C                            8.43                 0.780
## 2 ST                           9.40                 1.73
```

```
mod <- lm(Total.diversity ~ Treatment, data = AllS_16)
anv <- aov(Total.diversity ~ Treatment, data = AllS_16)
```

```
emmeans(mod, pairwise ~ Treatment, adjust = "Tukey")
```

```
## $emmeans
##  Treatment emmean  SE df lower.CL upper.CL
##  C           8.43 0.6  8     7.05     9.82
##  ST          9.40 0.6  8     8.01    10.78
##
## Confidence level used: 0.95
##
## $contrasts
##  contrast estimate    SE df t.ratio p.value
##  C - ST     -0.966 0.849  8 -1.138  0.2882
```

```
shapiro.test(anv$residuals)
```

```
##
##  Shapiro-Wilk normality test
##
## data:  anv$residuals
## W = 0.97671, p-value = 0.9452
```

```
leveneTest(AllS_16$Total.diversity ~ AllS_16$Plot_type)
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value Pr(>F)
## group  1  2.6912 0.1395
##        8
```

```
outlierTest(mod)
```

```
## No Studentized residuals with Bonferonni p < 0.05
## Largest |rstudent|:
##    rstudent unadjusted p-value Bonferonni p
## 2 -2.077964           0.076314      0.76314
```

```
#Tree genetic richness - divergence from normality - Kruskal-Wallis
ex1 <- AllS_16 %>%
  group_by(Treatment) %>%
  summarise(mean(TreeGenusRich), sd(TreeGenusRich))
head(ex1)
```

```
## # A tibble: 2 x 3
##   Treatment `mean(TreeGenusRich)` `sd(TreeGenusRich)`
##   <fct>                     <dbl>               <dbl>
## 1 C                             3               0.707
## 2 ST                            4               1
```

```
mod <- lm(TreeGenusRich ~ Treatment, data = AllS_16)
anv <- aov(TreeGenusRich ~ Treatment, data = AllS_16)
emmeans(mod, pairwise ~ Treatment, adjust = "Tukey")
```

```
## $emmeans
##  Treatment emmean    SE df lower.CL upper.CL
##  C              3 0.387  8     2.11     3.89
##  ST             4 0.387  8     3.11     4.89
##
## Confidence level used: 0.95
##
## $contrasts
##  contrast estimate    SE df t.ratio p.value
##  C - ST         -1 0.548  8 -1.826  0.1053
```

```
kruskal.test(TreeGenusRich ~ Treatment, data = AllS_16)
```

```
##
##  Kruskal-Wallis rank sum test
##
## data:  TreeGenusRich by Treatment
## Kruskal-Wallis chi-squared = 2.4671, df = 1, p-value = 0.1162
```

```
shapiro.test(anv$residuals)
```

```
##
##  Shapiro-Wilk normality test
##
## data:  anv$residuals
## W = 0.83184, p-value = 0.03521
```

```
leveneTest(AllS_16$TreeGenusRich ~ AllS_16$Plot_type)
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value Pr(>F)
## group  1     1.6 0.2415
##        8
```

```
outlierTest(mod)
```

```
## No Studentized residuals with Bonferonni p < 0.05
## Largest |rstudent|:
##   rstudent unadjusted p-value Bonferonni p
## 2 1.357242           0.21684           NA
```

```
#Tree height - assumptions met
ex1 <- AllS_16 %>%
```

```
  group_by(Treatment) %>%
  summarise(mean(Sum_height20), sd(Sum_height20))
head(ex1)
```

```
## # A tibble: 2 x 3
##   Treatment `mean(Sum_height20)` `sd(Sum_height20)`
##   <fct>                   <dbl>              <dbl>
## 1 C                       1592                191.
## 2 ST                      1482.               301.
```

```
mod <- lm(Sum_height20 ~ Treatment, data = AllS_16)
anv <- aov(Sum_height20 ~ Treatment, data = AllS_16)
emmeans(mod, pairwise ~ Treatment, adjust = "Tukey")
```

```
## $emmeans
##  Treatment emmean  SE df lower.CL upper.CL
##  C           1592 113  8     1332     1852
##  ST          1482 113  8     1222     1742
##
## Confidence level used: 0.95
##
## $contrasts
##  contrast estimate  SE df t.ratio p.value
##  C - ST        110 159  8 0.691   0.5091
```

```
shapiro.test(anv$residuals)
```

```
##
##  Shapiro-Wilk normality test
##
## data:  anv$residuals
## W = 0.96054, p-value = 0.7921
```

```
leveneTest(AllS_16$Sum_height20 ~ AllS_16$Plot_type)
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value Pr(>F)
## group  1  0.4042 0.5427
##        8
```

```
outlierTest(mod)
```

```
## No Studentized residuals with Bonferonni p < 0.05
## Largest |rstudent|:
##    rstudent unadjusted p-value Bonferonni p
## 1 -2.678357           0.031614      0.31614
```

```
#Tree diameter - assumptions met
ex1 <- AllS_16 %>%
  group_by(Treatment) %>%
  summarise(mean(Sum_diam), sd(Sum_diam))
head(ex1)
```

```
## # A tibble: 2 x 3
##   Treatment `mean(Sum_diam)` `sd(Sum_diam)`
##   <fct>                <dbl>          <dbl>
## 1 C                     219.           40.5
## 2 ST                    236.           50.3
```

```
mod <- lm(Sum_diam ~ Treatment, data = AllS_16)
anv <- aov(Sum_diam ~ Treatment, data = AllS_16)
emmeans(mod, pairwise ~ Treatment, adjust = "Tukey")
```

```
## $emmeans
##  Treatment emmean   SE df lower.CL upper.CL
##  C            219 20.4  8      172      266
##  ST           236 20.4  8      189      283
##
## Confidence level used: 0.95
##
## $contrasts
##  contrast estimate   SE df t.ratio p.value
##  C - ST      -16.8 28.9  8 -0.582  0.5767
```

```
shapiro.test(anv$residuals)
```

```
##
##  Shapiro-Wilk normality test
##
## data:  anv$residuals
## W = 0.98348, p-value = 0.981
```

```
leveneTest(AllS_16$Sum_diam ~ AllS_16$Plot_type)
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value Pr(>F)
## group  1  0.0078 0.9318
##        8
```

```
outlierTest(mod)
```

```
## No Studentized residuals with Bonferonni p < 0.05
## Largest |rstudent|:
##    rstudent unadjusted p-value Bonferonni p
## 1 -2.024769           0.082547      0.82547
```

Temp over time Reforestation site - July

```
TV <-read.csv("ThermVegAvg.csv")
sumYA2016July <- read.csv("f_hours.csv")

TV <- filter(TV, Field == "YA2016", Month == "July")
```

12

```
TV12 <- filter(TV, Flight_hour == "12")

mod <-lmer(Avg ~ Plot_type * Date + (1|Plot_id), data = TV12)

mod2 <-lm(Avg ~ Plot_type * Date, data = TV12)

r.squaredGLMM(mod)
```

```
##            R2m      R2c
## [1,] 0.4955822 0.950949
```

```
anova(mod, ddf="Kenward-Roger")
```

```
## Type III Analysis of Variance Table with Kenward-Roger's method
##                 Sum Sq Mean Sq NumDF DenDF F value  Pr(>F)
## Plot_type      0.72551 0.72551     1     8  9.6253 0.01461 *
## Date           0.12013 0.12013     1     8  1.5937 0.24235
## Plot_type:Date 0.15313 0.15313     1     8  2.0315 0.19189
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
em <-emmeans(mod, pairwise ~ Plot_type, adjust = "Tukey")
```

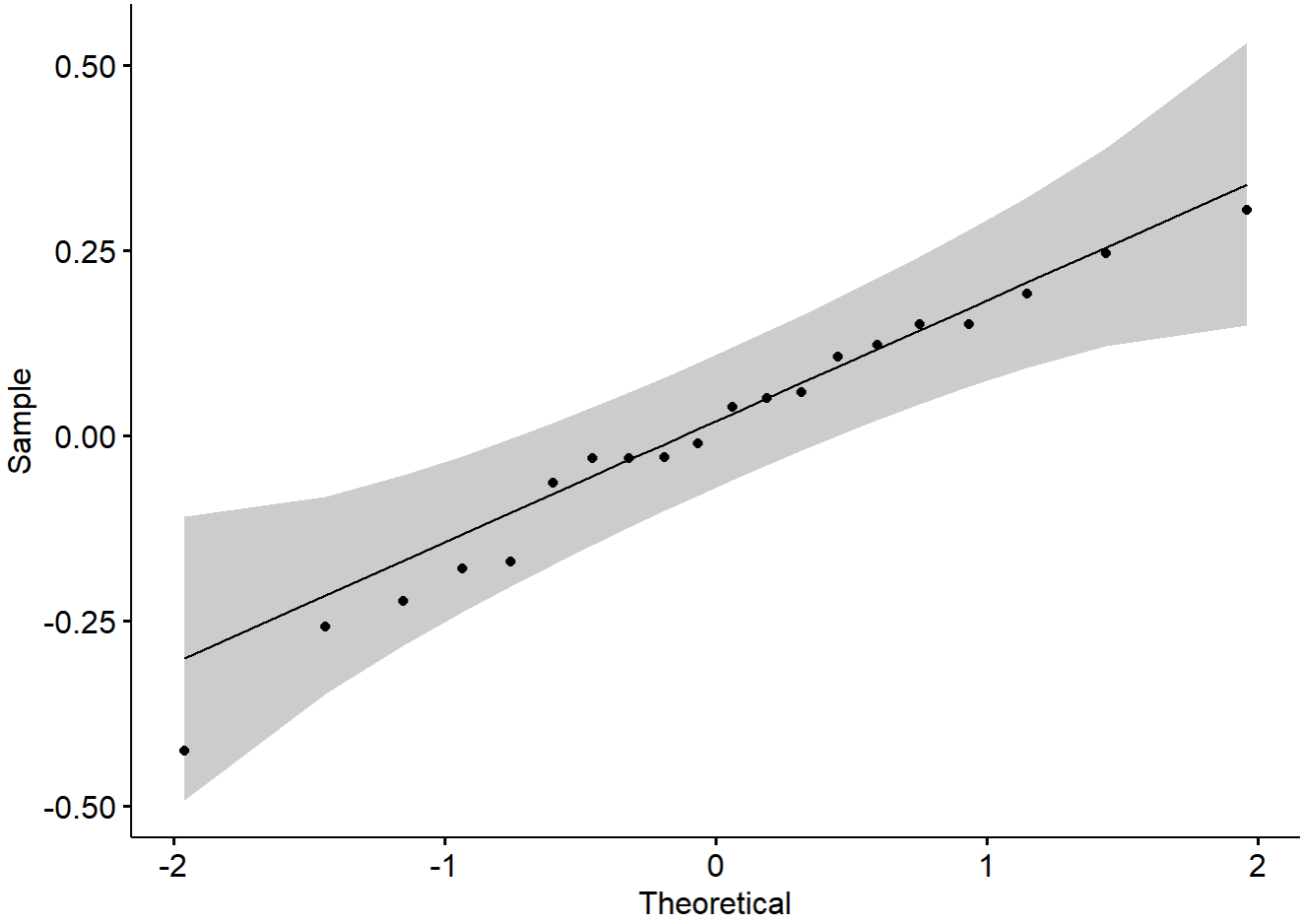
```
## NOTE: Results may be misleading due to involvement in interactions
```

```
em
```

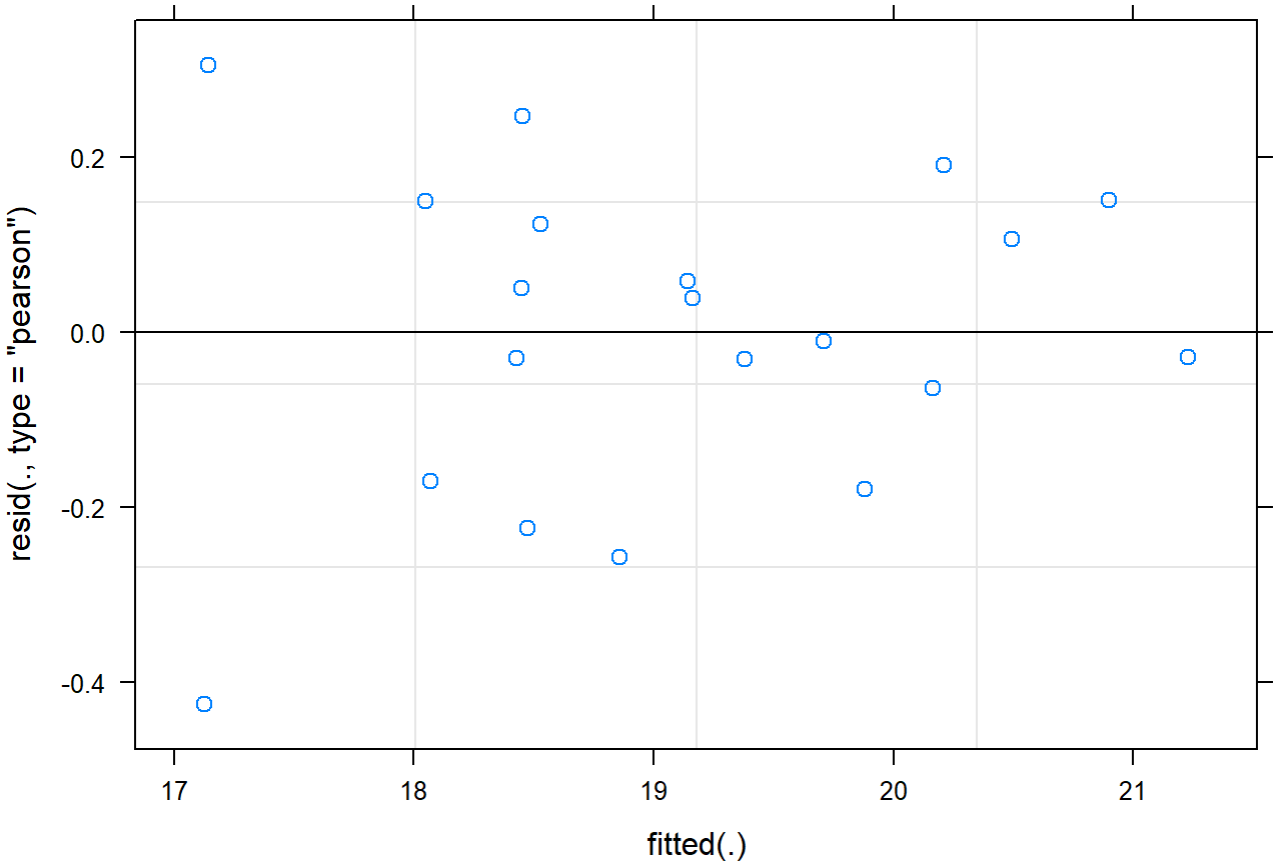
```
## $emmeans
##  Plot_type emmean    SE df lower.CL upper.CL
##  PC          19.9 0.384  8     19.0     20.8
##  ST          18.2 0.384  8     17.4     19.1
##
## Results are averaged over the levels of: Date
## Degrees-of-freedom method: kenward-roger
## Confidence level used: 0.95
##
## $contrasts
##  contrast estimate    SE df t.ratio p.value
##  PC - ST      1.68 0.543  8 3.102   0.0146
```

```
##
## Results are averaged over the levels of: Date
```

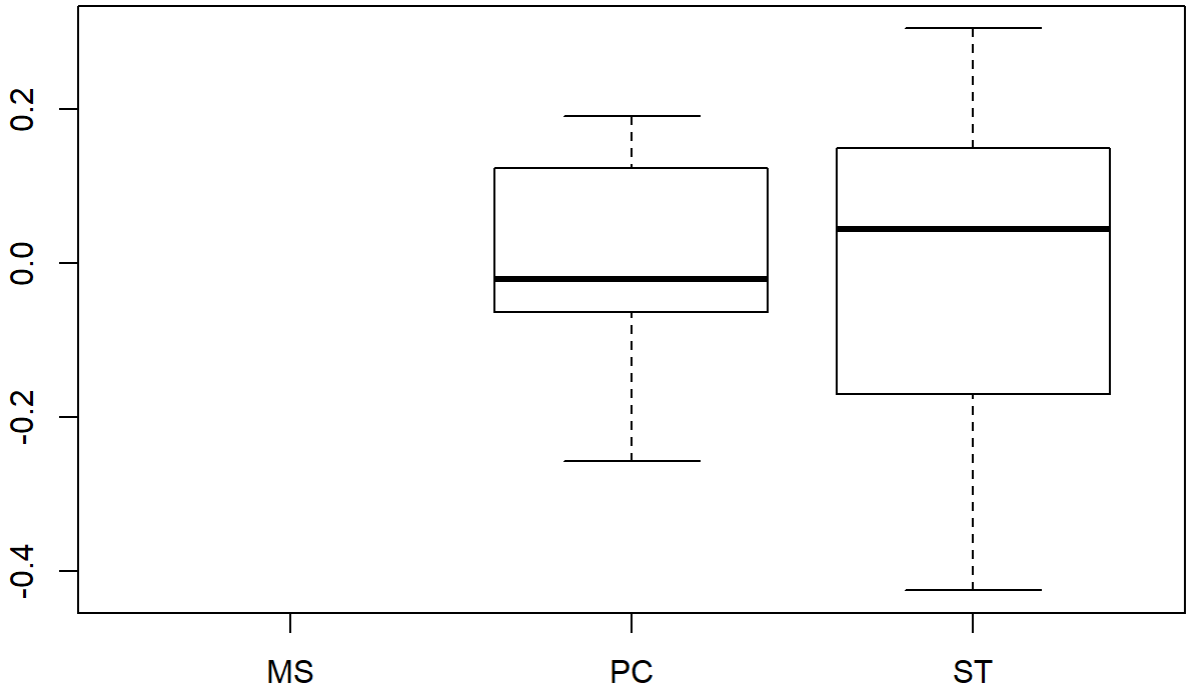
```
sumYA2016July[c(1:2),c(2:7)] <- summary(em)$emmeans

ggqqplot(residuals(mod))
```



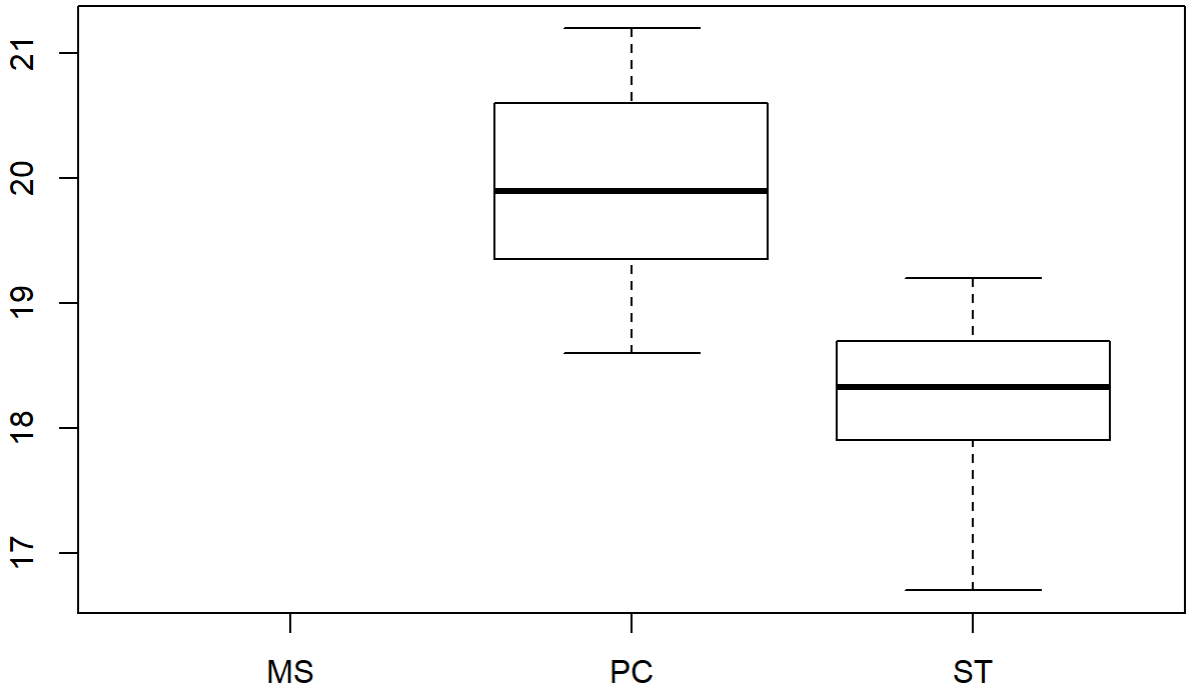

```
plot(mod)
```



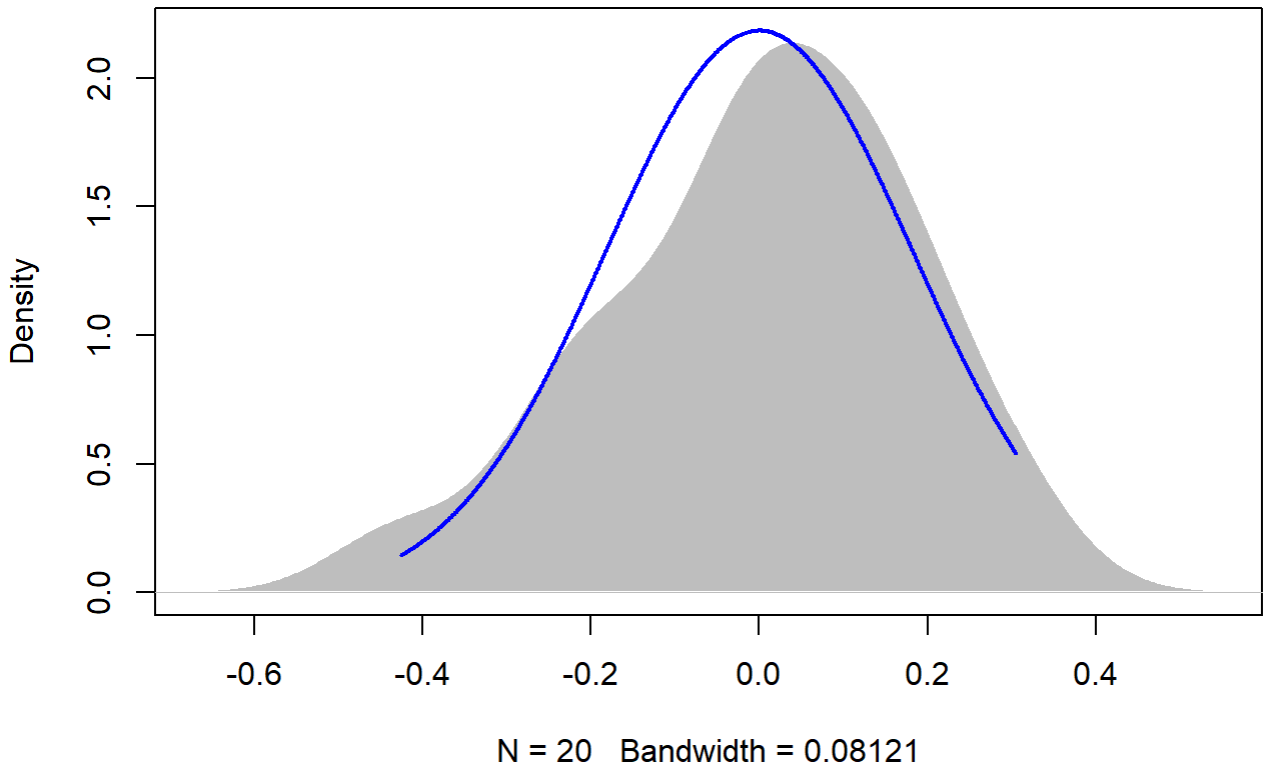

```
boxplot(residuals(mod) ~ TV12$Plot_type)
```




```
boxplot(TV12$Avg~ TV12$Plot_type)
```




```
plotNormalDensity(resid(mod))
```



14

```
TV14 <- filter(TV, Flight_hour == "14")

mod <-lmer(Avg ~ Plot_type * Date + (1|Plot_id), data = TV14)

anova(mod, ddf="Kenward-Roger")
```

```
## Type III Analysis of Variance Table with Kenward-Roger's method
##                Sum Sq Mean Sq NumDF DenDF  F value    Pr(>F)
## Plot_type      10.997  10.997     1     8  33.6290 0.0004056 ***
## Date           78.557  39.279     2    16 120.1105 2.312e-10 ***
## Plot_type:Date  1.332   0.666     2    16   2.0368 0.1629105
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
r.squaredGLMM(mod)
```

```
##            R2m       R2c
## [1,] 0.8651195 0.9351503
```

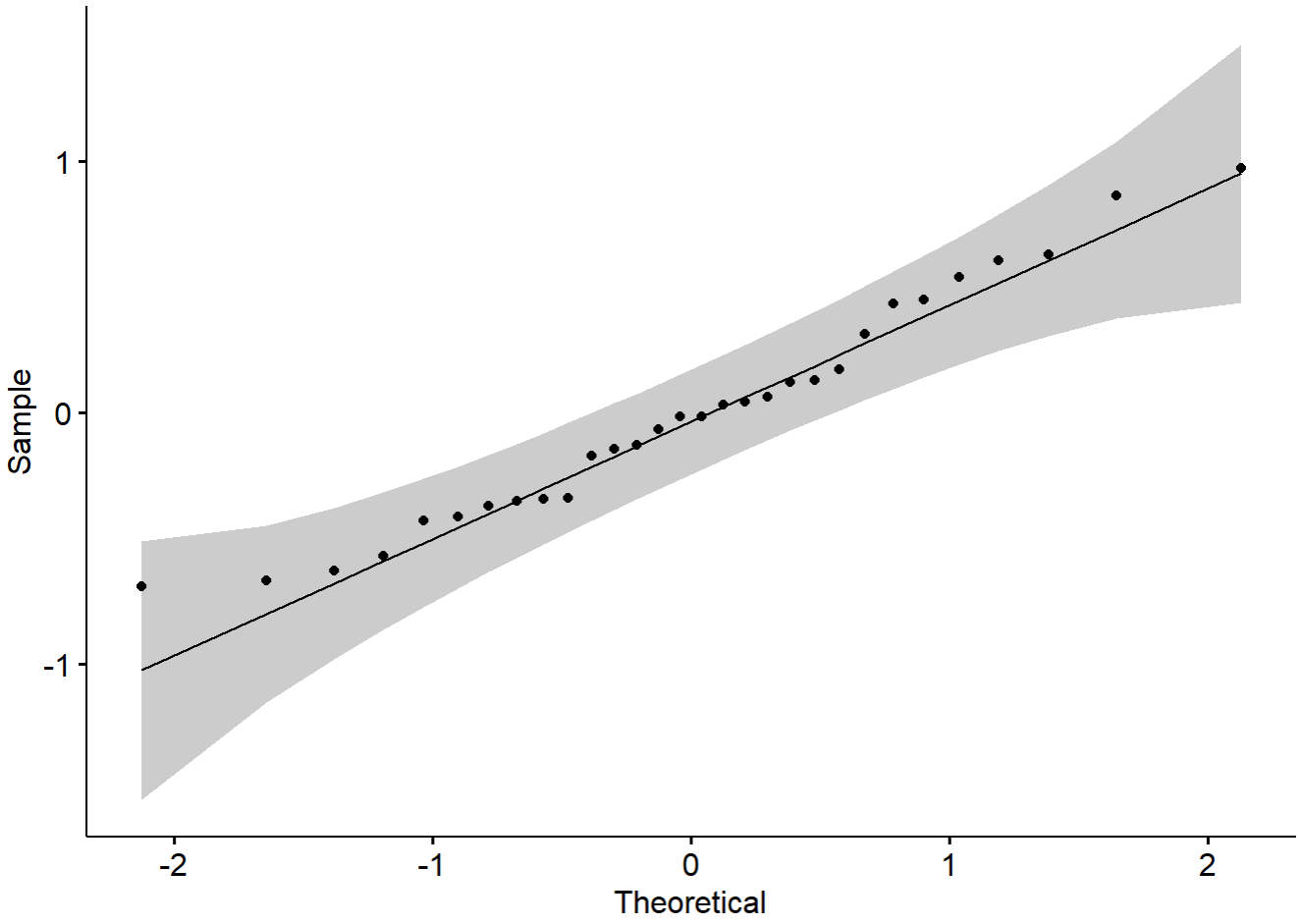
```
em <-emmeans(mod, pairwise ~ Plot_type, adjust = "Tukey")
```

```
## NOTE: Results may be misleading due to involvement in interactions
```

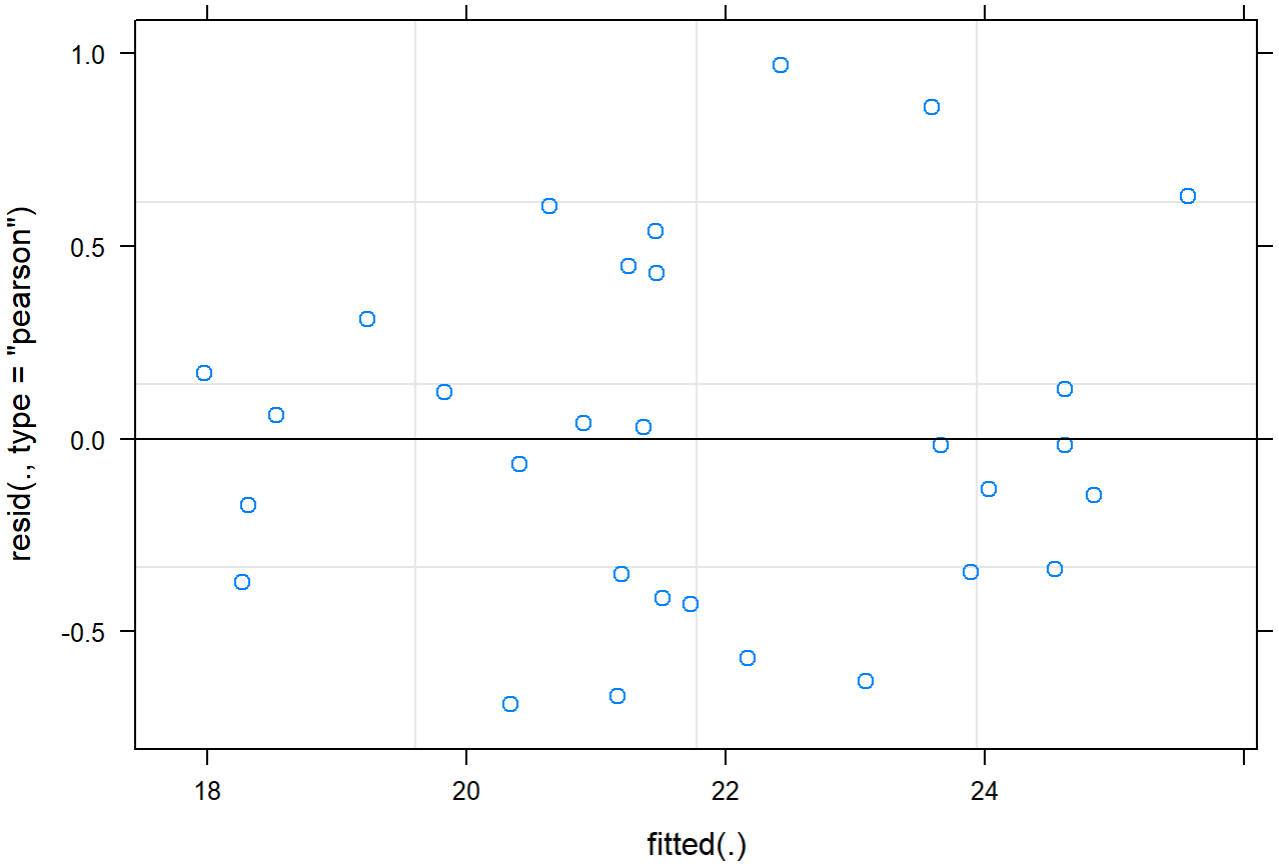
```
em
```

```
## $emmeans
##  Plot_type emmean    SE df lower.CL upper.CL
##  PC          23.0 0.304  8     22.3     23.7
##  ST          20.5 0.304  8     19.8     21.2
##
## Results are averaged over the levels of: Date
## Degrees-of-freedom method: kenward-roger
## Confidence level used: 0.95
##
## $contrasts
##  contrast estimate   SE df t.ratio p.value
##  PC - ST      2.49 0.43  8 5.799   0.0004
##
## Results are averaged over the levels of: Date
```

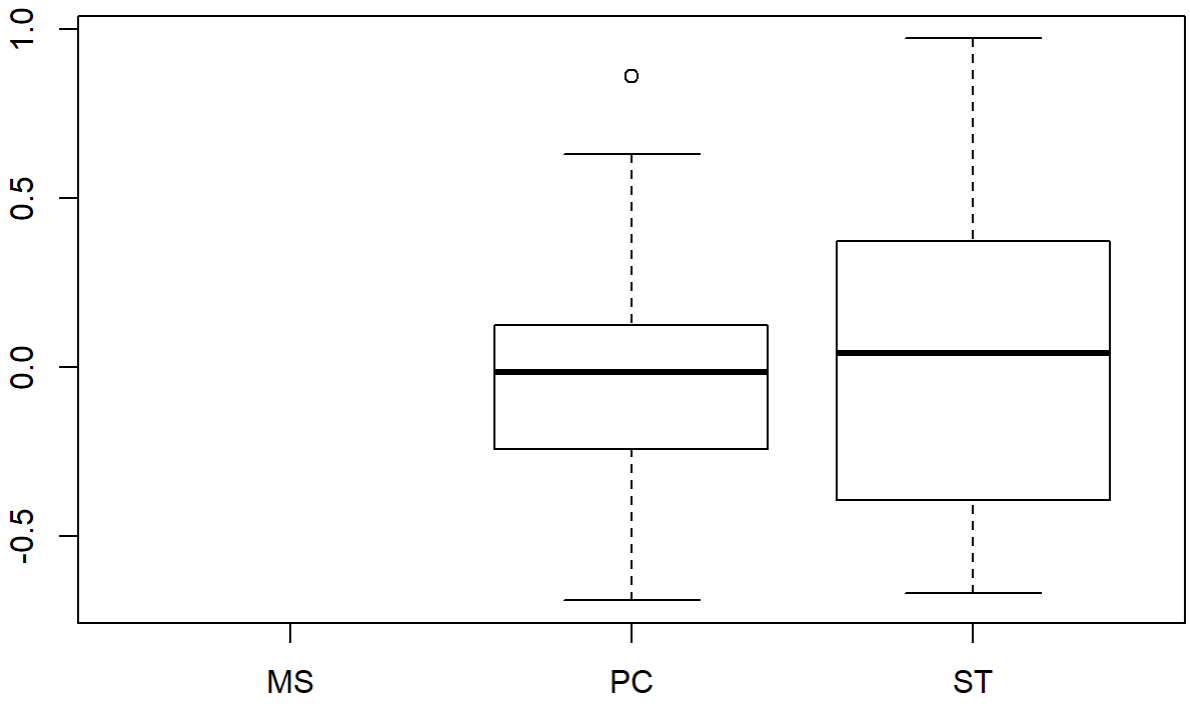
```
sumYA2016July[c(3:4),c(2:7)] <- summary(em)$emmeans

ggqqplot(residuals(mod))
```



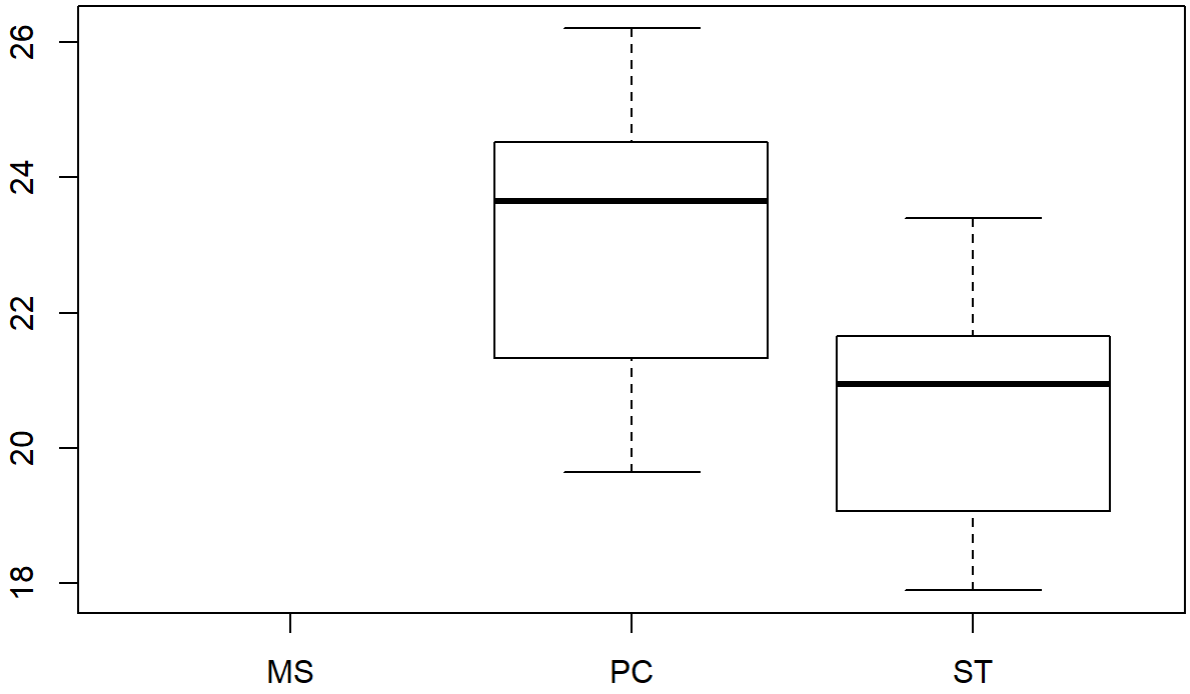

```
plot(mod)
```



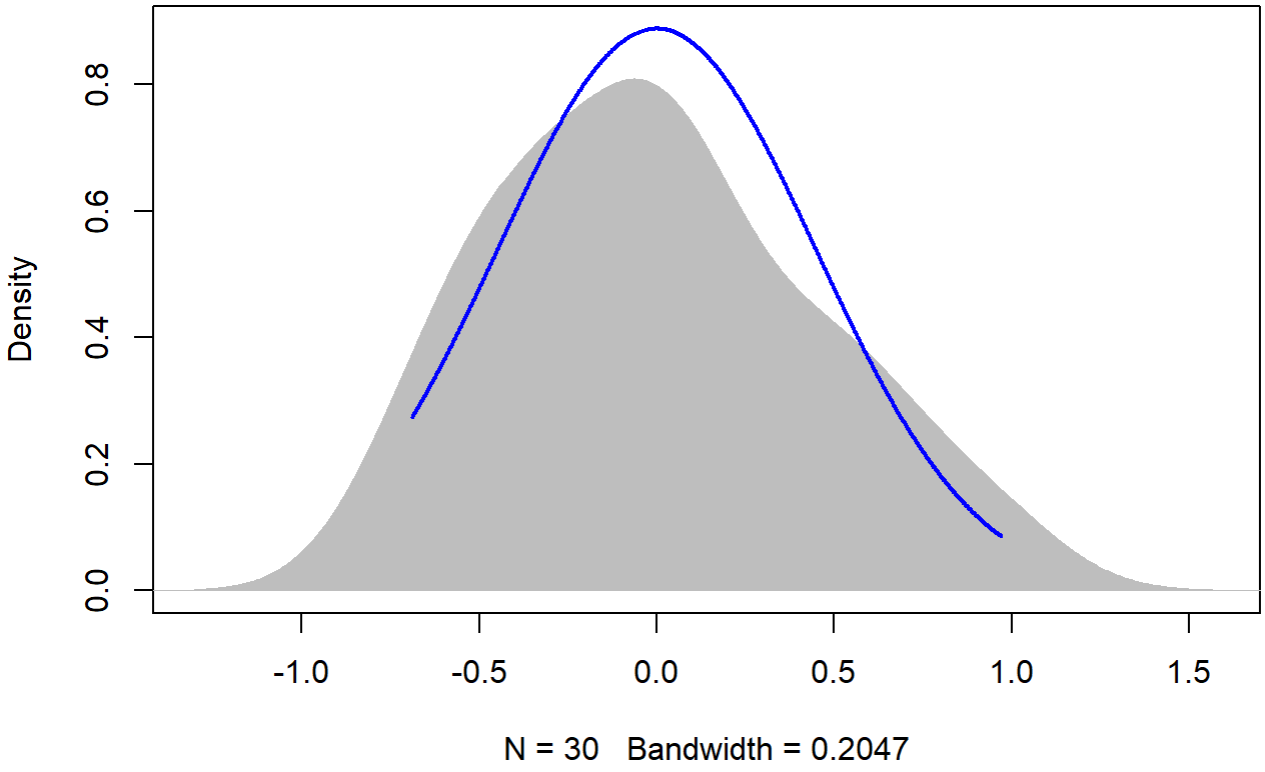

```
boxplot(residuals(mod) ~ TV14$Plot_type)
```




```
boxplot(TV14$Avg~ TV14$Plot_type)
```




```
plotNormalDensity(resid(mod))
```



16

```
TV16 <- filter(TV, Flight_hour == "16")

mod <-lmer(Avg ~ Plot_type * Date + (1|Plot_id), data = TV16)

r.squaredGLMM(mod)
```

```
##            R2m       R2c
## [1,] 0.6986633 0.8215557
```

```
anova(mod, ddf="Kenward-Roger")
```

```
## Type III Analysis of Variance Table with Kenward-Roger's method
##                Sum Sq Mean Sq NumDF DenDF F value    Pr(>F)
## Plot_type       8.862  8.8615     1     8 14.0154  0.005675 **
## Date           44.298 22.1491     2    16 35.0310 1.427e-06 ***
## Plot_type:Date  0.322  0.1611     2    16  0.2548  0.778180
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

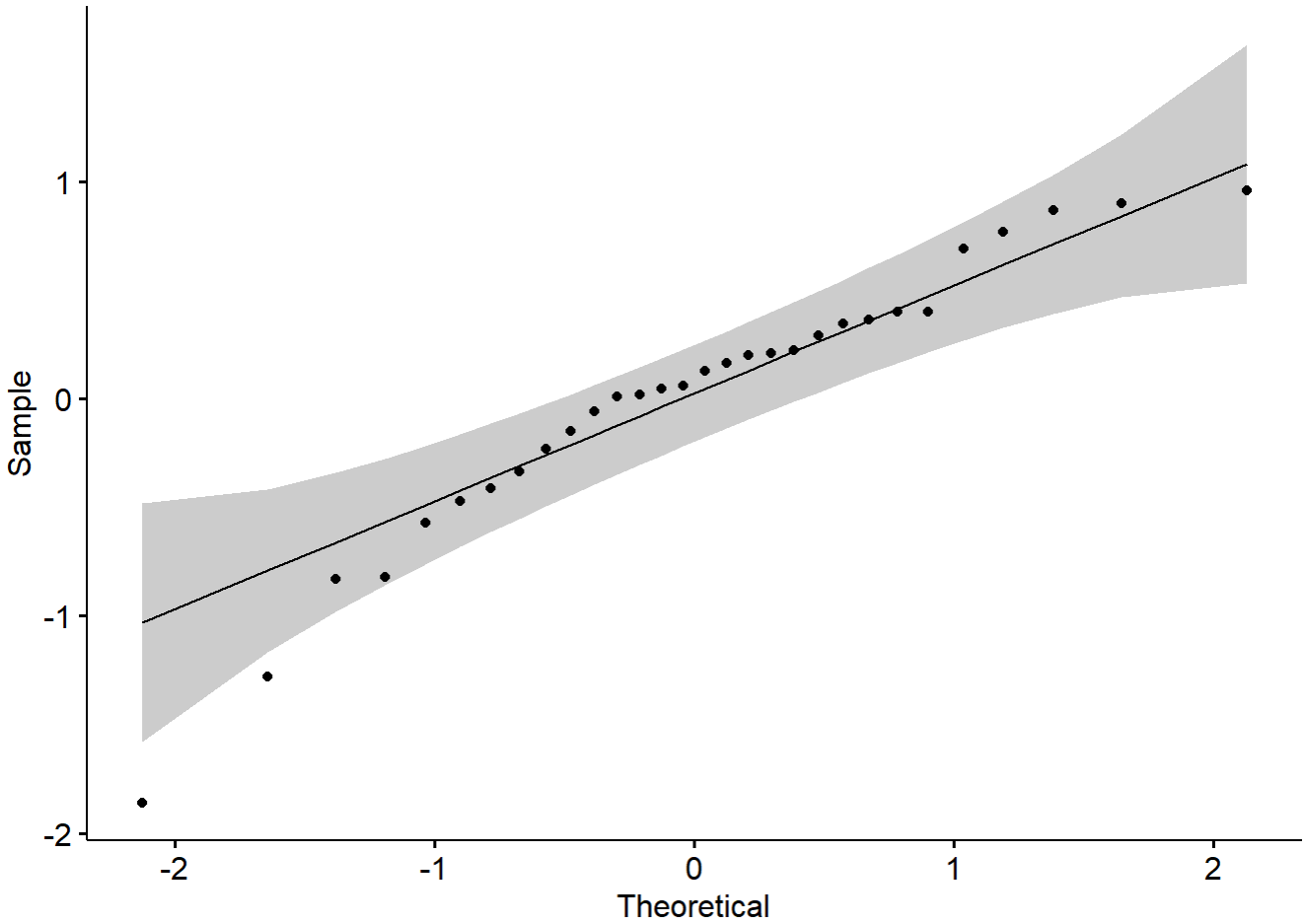
```
em <-emmeans(mod, pairwise ~ Plot_type, adjust = "Tukey")
```

```
## NOTE: Results may be misleading due to involvement in interactions
```

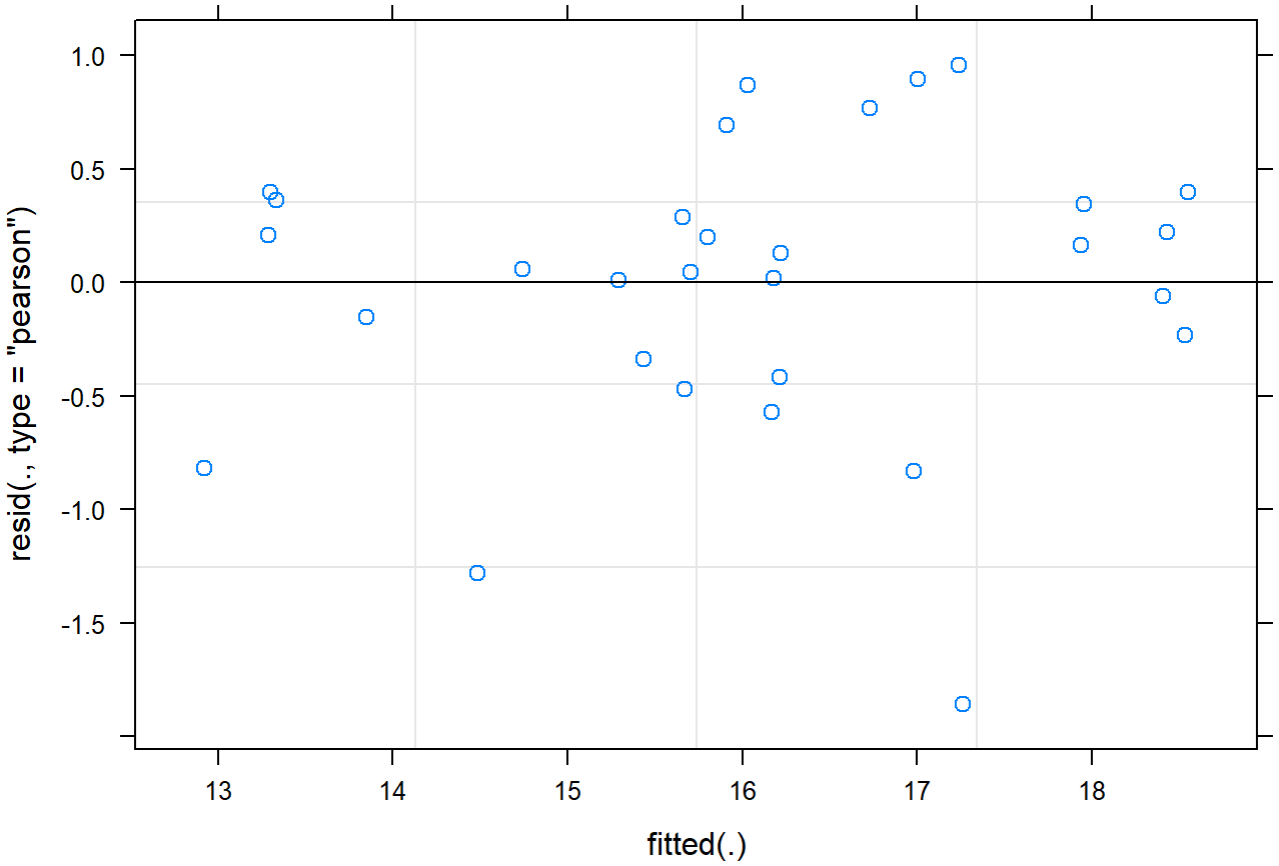
```
em
```

```
## $emmeans
##  Plot_type emmean    SE df lower.CL upper.CL
##  PC          17.0 0.359  8     16.2     17.8
##  ST          15.1 0.359  8     14.3     15.9
##
## Results are averaged over the levels of: Date
## Degrees-of-freedom method: kenward-roger
## Confidence level used: 0.95
##
## $contrasts
##  contrast estimate    SE df t.ratio p.value
##  PC - ST       1.9 0.508  8 3.744   0.0057
##
## Results are averaged over the levels of: Date
```

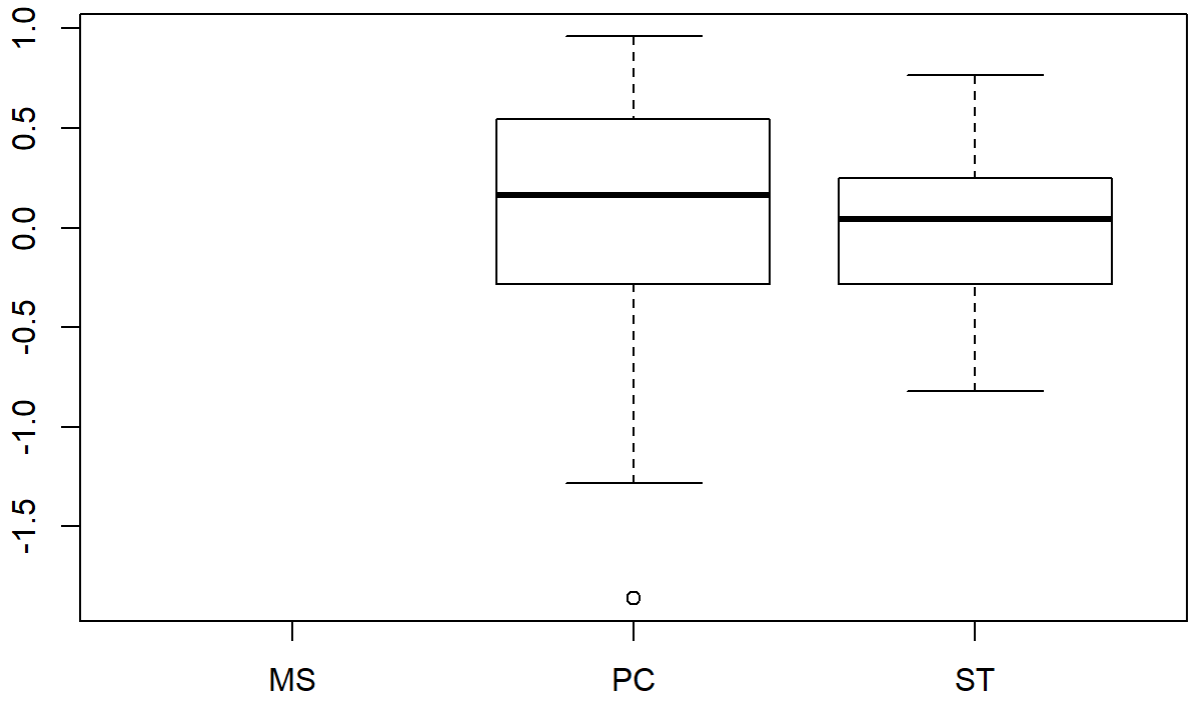
```
sumYA2016July[c(5:6),c(2:7)] <- summary(em)$emmeans

ggqqplot(residuals(mod))
```



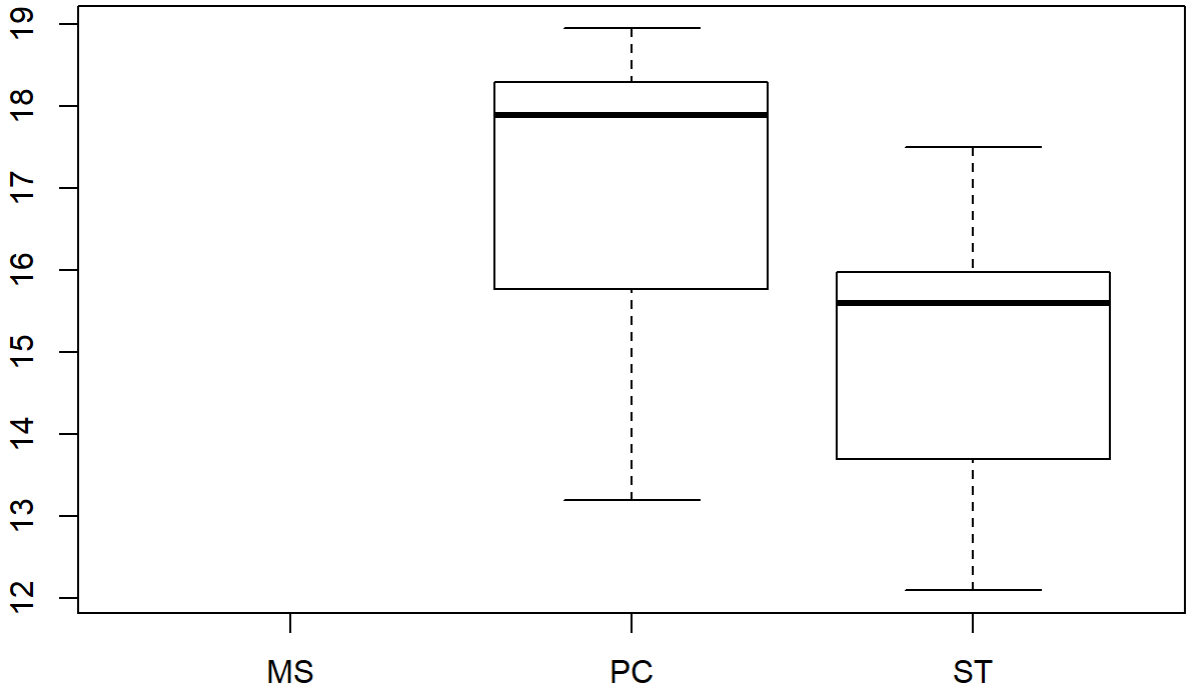

```
plot(mod)
```



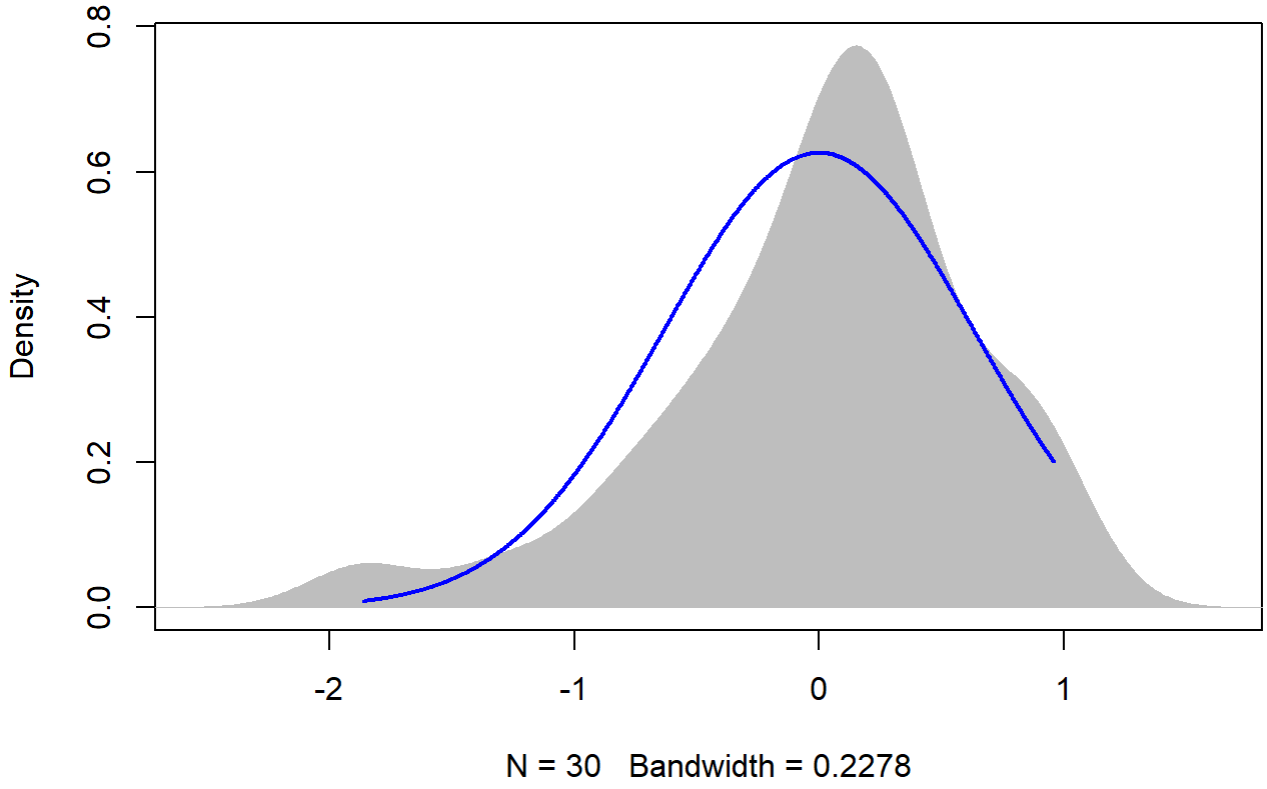

```
boxplot(residuals(mod) ~ TV16$Plot_type)
```




```
boxplot(TV16$Avg~ TV16$Plot_type)
```




```
plotNormalDensity(resid(mod))
```



20

```
TV20 <- filter(TV, Flight_hour == "20")

mod <-lmer(Avg ~ Plot_type * Date + (1|Plot_id), data = TV20)

anova(mod, ddf="Kenward-Roger")
```

```
## Type III Analysis of Variance Table with Kenward-Roger's method
##                 Sum Sq Mean Sq NumDF DenDF   F value Pr(>F)
## Plot_type        0.020   0.020     1     8    0.5029 0.4984
## Date           191.998  95.999     2    16 2385.0723 <2e-16 ***
## Plot_type:Date   0.036   0.018     2    16    0.4493 0.6459
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
em <-emmeans(mod, pairwise ~ Plot_type, adjust = "Tukey")
```

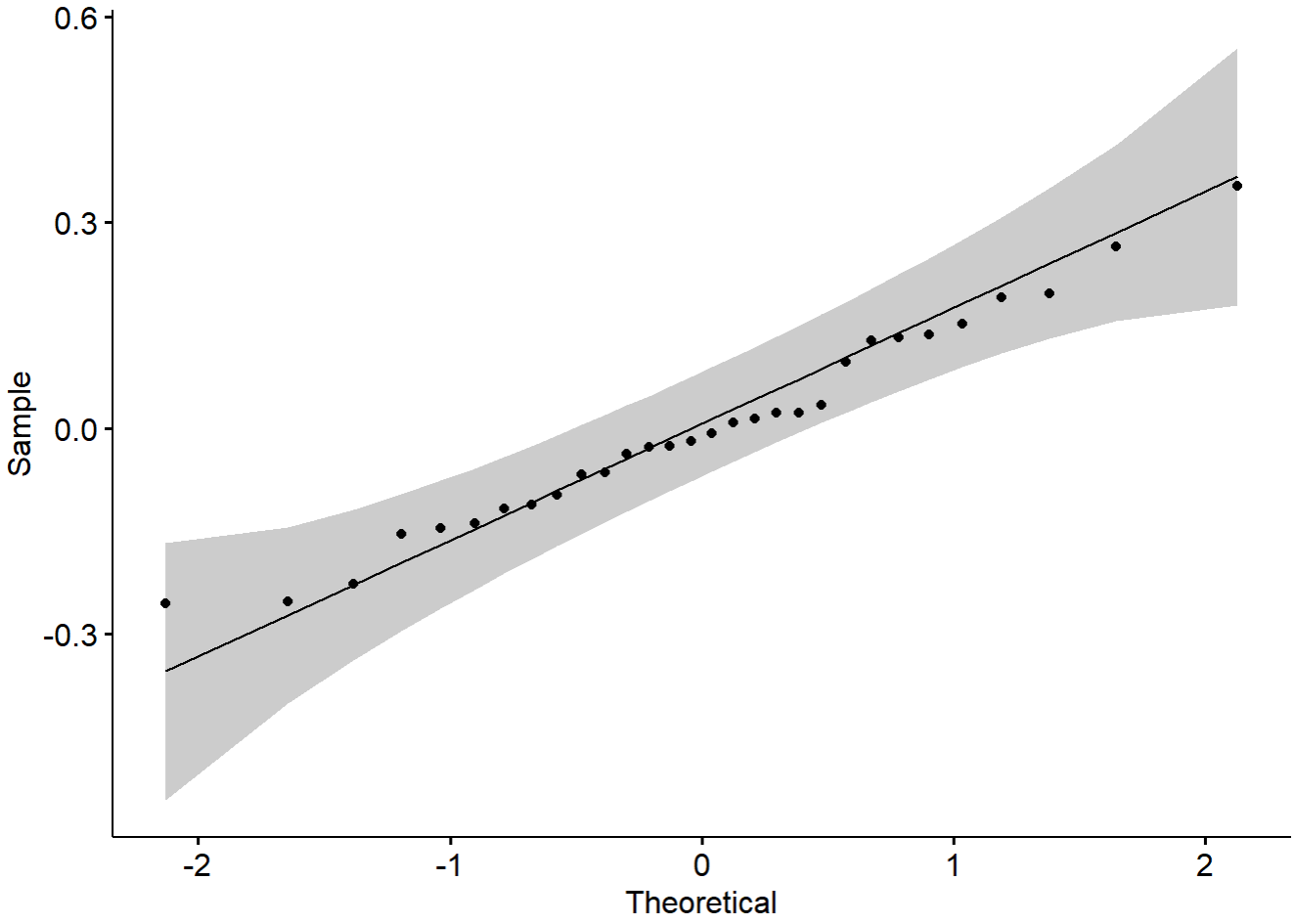
```
## NOTE: Results may be misleading due to involvement in interactions
```

```
em
```

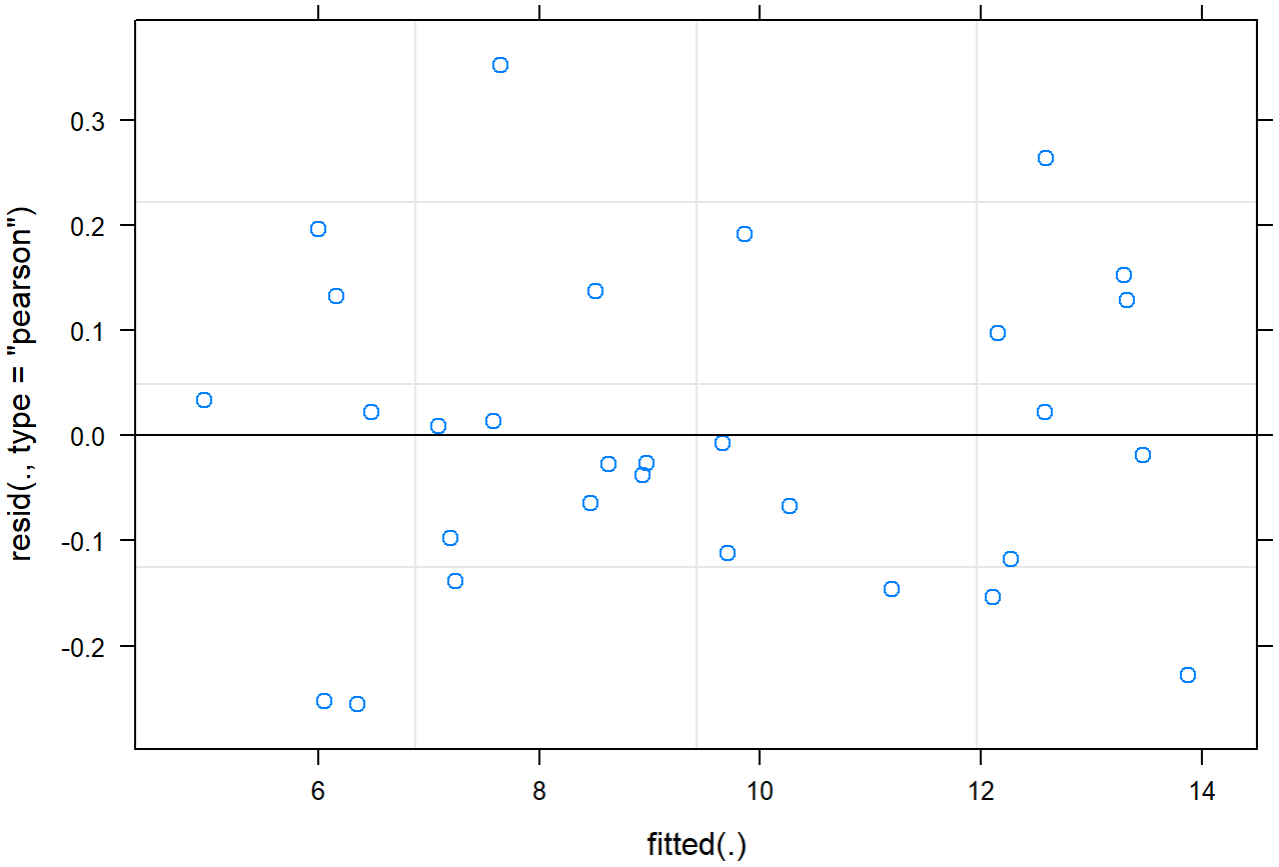
```
## $emmeans
```

```
##  Plot_type emmean    SE df lower.CL upper.CL
##  PC          9.61 0.376  8     8.74     10.5
##  ST          9.23 0.376  8     8.37     10.1
##
## Results are averaged over the levels of: Date
## Degrees-of-freedom method: kenward-roger
## Confidence level used: 0.95
##
## $contrasts
##  contrast estimate    SE df t.ratio p.value
##  PC - ST     0.377 0.531  8 0.709   0.4984
##
## Results are averaged over the levels of: Date
```

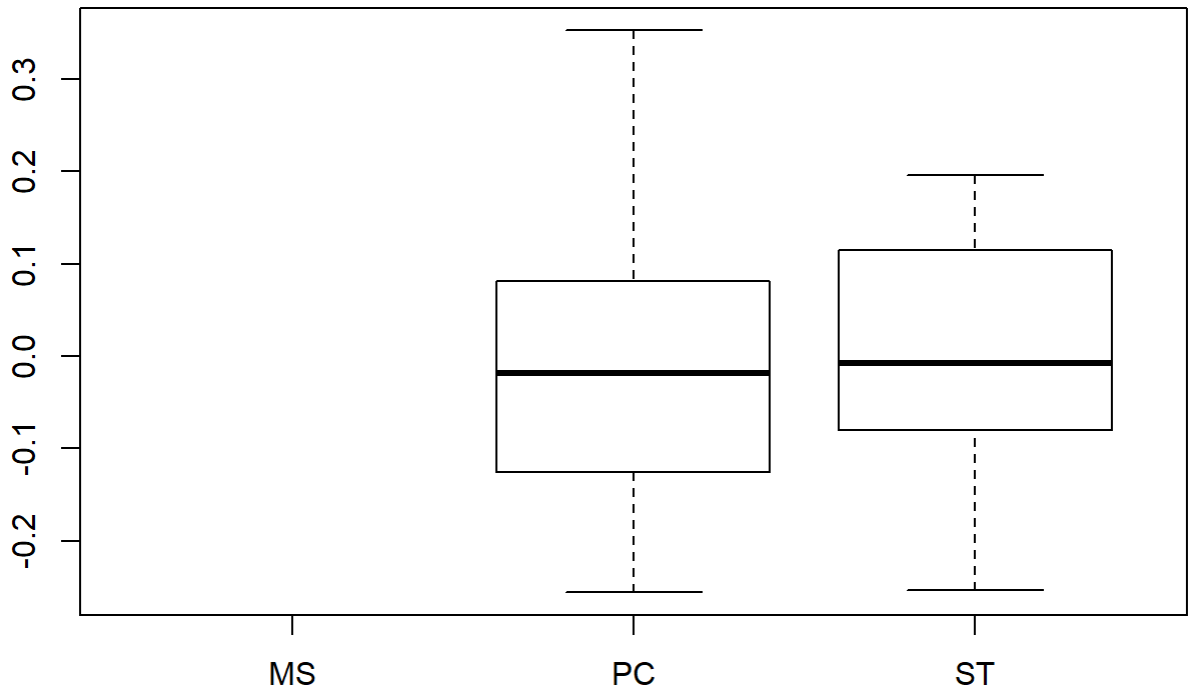
```
sumYA2016July[c(7:8),c(2:7)] <- summary(em)$emmeans

ggqqplot(residuals(mod))
```



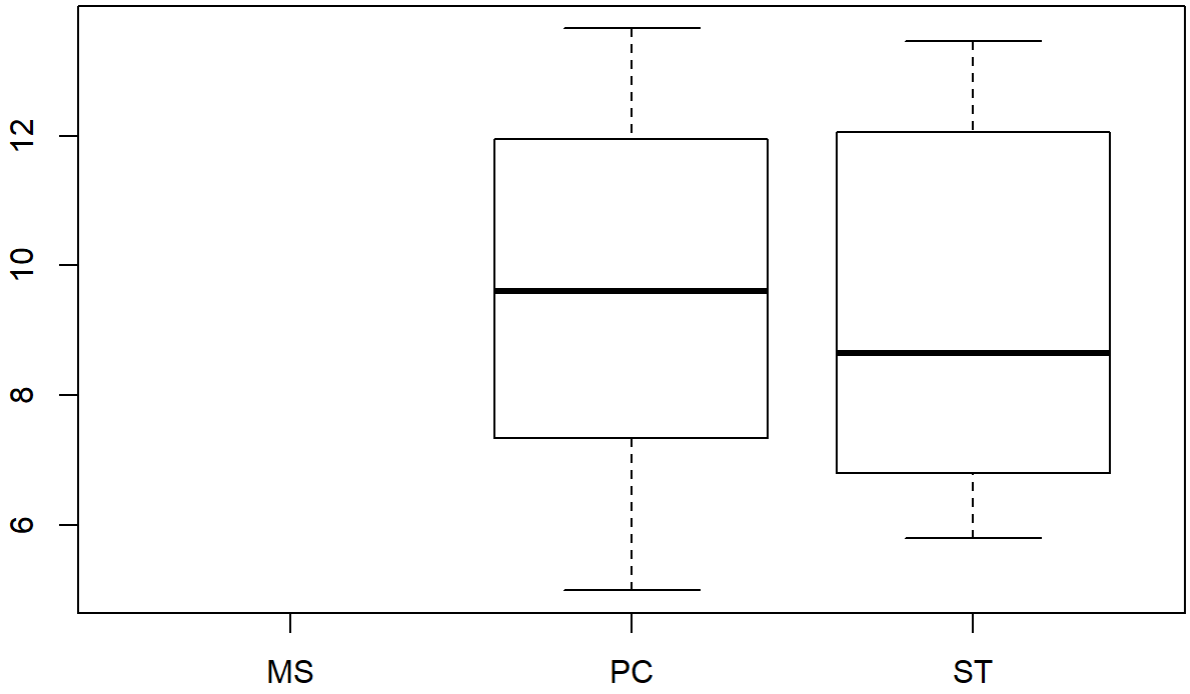

```
plot(mod)
```



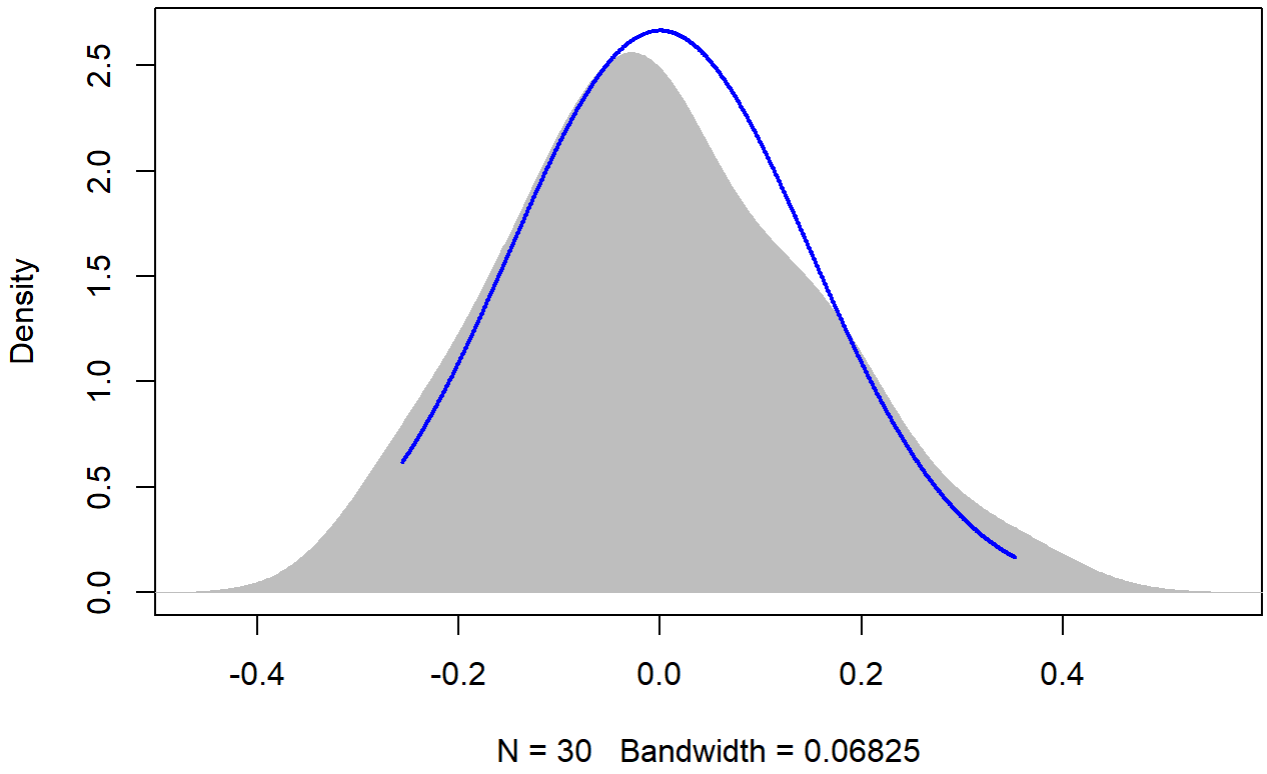

```
boxplot(residuals(mod) ~ TV20$Plot_type)
```




```
boxplot(TV20$Avg~ TV20$Plot_type)
```




```
plotNormalDensity(resid(mod))
```



Graph over time - 2016 Reforestation site July

```
sumYA2016July[,'Plot_type']<-factor(sumYA2016July[,'Plot_type'])

tiff("YA2016July.tiff", width = 7, height = 5, units = 'in', res = 100)

ggplot(sumYA2016July, aes(x=Flight_hour, y=emmeans, colour=Plot_type)) +
  geom_errorbar(aes(ymin=lower.CL, ymax=Upper.cl), width=.3, position=position_dodge(width=0.3
)) +
  geom_point(position=pd, size=3, shape=21, fill="white") +
  geom_line(position=pd, linetype = "dashed") +
  xlab("Time of day (24-hr format)") +
  ylab(expression("EM Mean Surface Temperature  " ( degree*C))) +
  scale_colour_hue(name="Plot type",
                   breaks=c("1", "2"),
                   labels=c("Passive Control", "Topsoil Recipient"),
                   l=40) +
  expand_limits(y=0) +
  scale_y_continuous(breaks=c(0, 5, 10, 15, 20, 25, 30, 35, 40, 45)) +
  scale_x_continuous(breaks=c(12,14,16,18,20)) +
  theme_bw() +
  theme(legend.position=c(0.8,0.8), legend.title = element_text(size = 14),
        legend.text = element_text(size = 12), text = element_text(size=14), axis.text = eleme
nt_text(color = "black", size=14)) +
  annotate(geom="label",x = 12.3,  y = 15,
         label = "p = 0.008\nmR^2 = 0.70\n (4, 2)", fontface = "plain", col ="black", size = 4
```

```
, fill = "white") +
  annotate(geom="label",x = 14,  y = 16.4,
           label ="p < 0.001\nmR^2 = 0.87\n (5, 3)", fontface = "plain", col ="black", size =
4, fill = "white") +
  annotate(geom="label",x = 16,  y = 11.7,
           label = "p = 0.006\nmR^2 = 0.70\n(5, 3)", fontface = "plain", col ="black", size =
4, fill = "white") +
  annotate(geom="label",x = 19.8,  y = 6.4,
           label = "p = 0.498\n(5, 3)", fontface = "plain", col ="black", size = 4, fill = "wh
ite")

dev.off()
```

```
## png
##   2
```

Temp over time 2016 Reforestation site - September

```
TV <-read.csv("ThermVegAvg.csv")
sumYA2016September <- read.csv("f_hours.csv")

TV <- filter(TV, Field == "YA2016", Month == "September")
```

12 (Issues with residuals - heavy outlier - forest shade on plot YA25 - 9/9)

```
TV12 <- filter(TV, Flight_hour == "12")
outlierTest(lm(Avg ~ Plot_type, data = TV12))
```

```
## No Studentized residuals with Bonferonni p < 0.05
## Largest |rstudent|:
##     rstudent unadjusted p-value Bonferonni p
## 25 -2.190969           0.037263           NA
```

```
TV12 <- TV12[-15,]

mod <-lmer(Avg ~ Plot_type * Date + (1|Plot_id), data = TV12)

anova(mod, ddf="Kenward-Roger")
```

```
## Type III Analysis of Variance Table with Kenward-Roger's method
##                 Sum Sq Mean Sq NumDF   DenDF  F value    Pr(>F)
## Plot_type        1.380   1.380     1  7.9991   2.7602    0.1352
## Date           115.699  57.849     2 15.0419 115.7186 7.345e-10 ***
## Plot_type:Date   1.257   0.629     2 15.0419   1.2576    0.3126
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

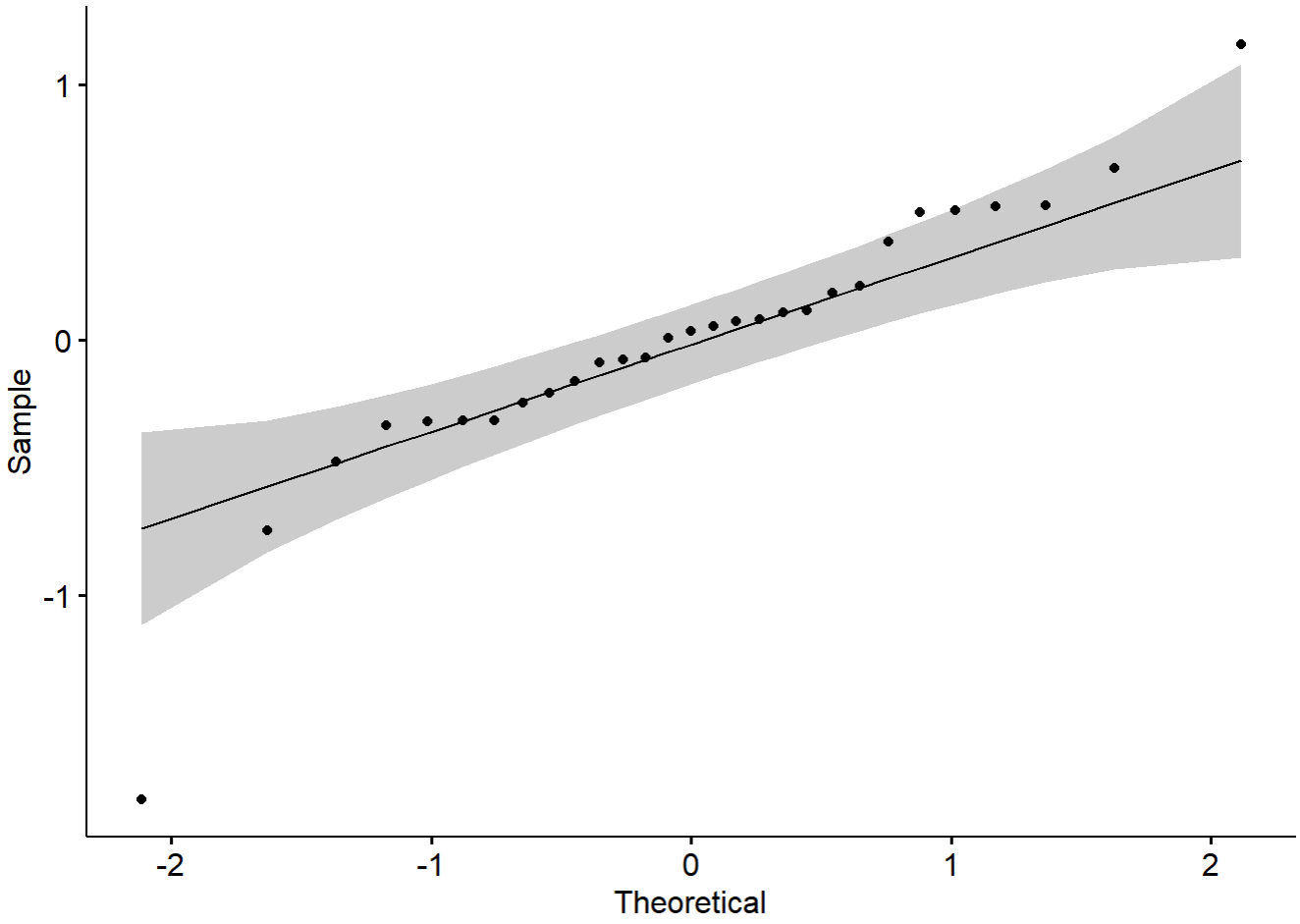
```
em <-emmeans(mod, pairwise ~ Plot_type, adjust = "Tukey")
```

```
## NOTE: Results may be misleading due to involvement in interactions
```

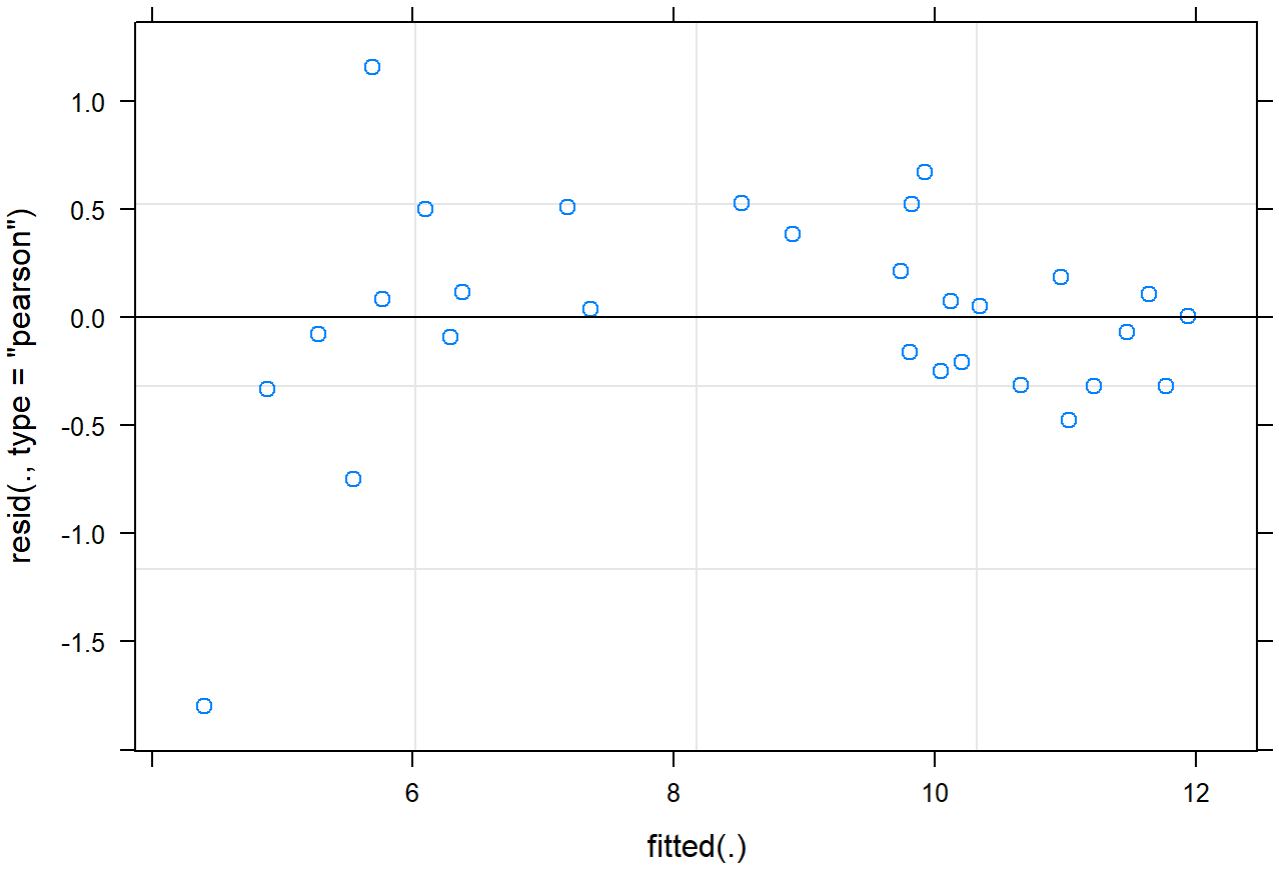
```
em
```

```
## $emmeans
##  Plot_type emmean    SE   df lower.CL upper.CL
##  PC          9.40 0.801 7.95     7.55    11.25
##  ST          7.52 0.804 8.05     5.67     9.37
##
## Results are averaged over the levels of: Date
## Degrees-of-freedom method: kenward-roger
## Confidence level used: 0.95
##
## $contrasts
##  contrast estimate   SE df t.ratio p.value
##  PC - ST      1.89 1.14  8 1.661   0.1352
##
## Results are averaged over the levels of: Date
```

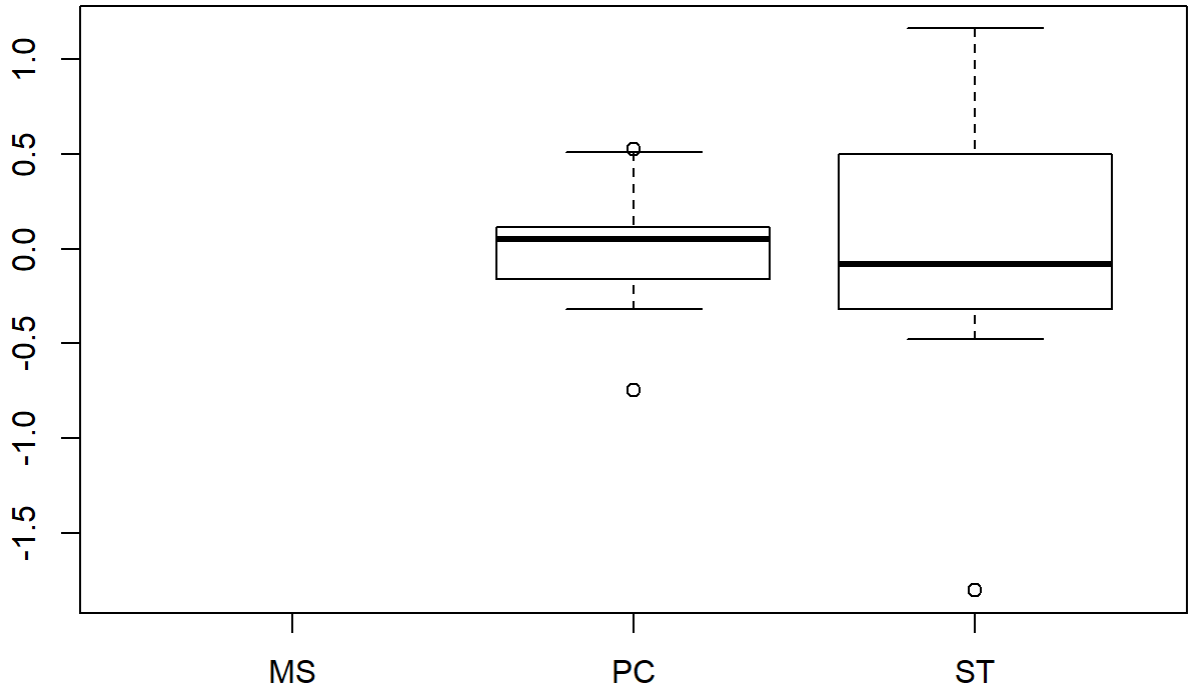
```
sumYA2016September[c(1:2),c(2:7)] <- summary(em)$emmeans


ggqqplot(residuals(mod))
```



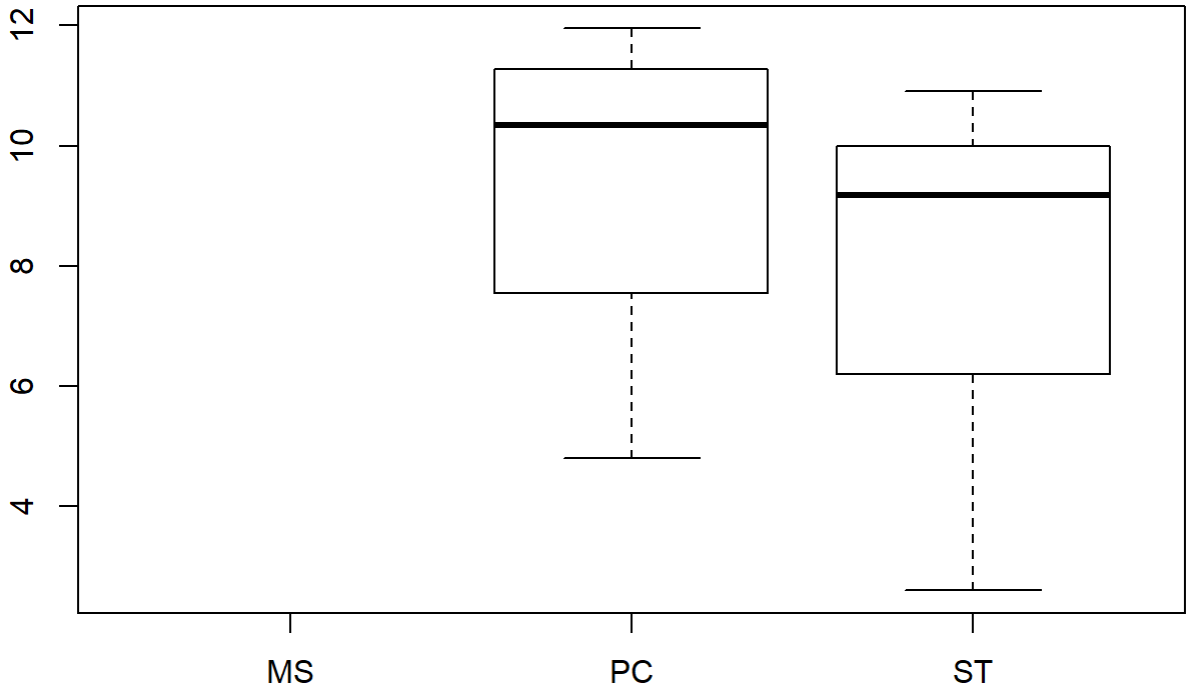
```
plot(mod)
```



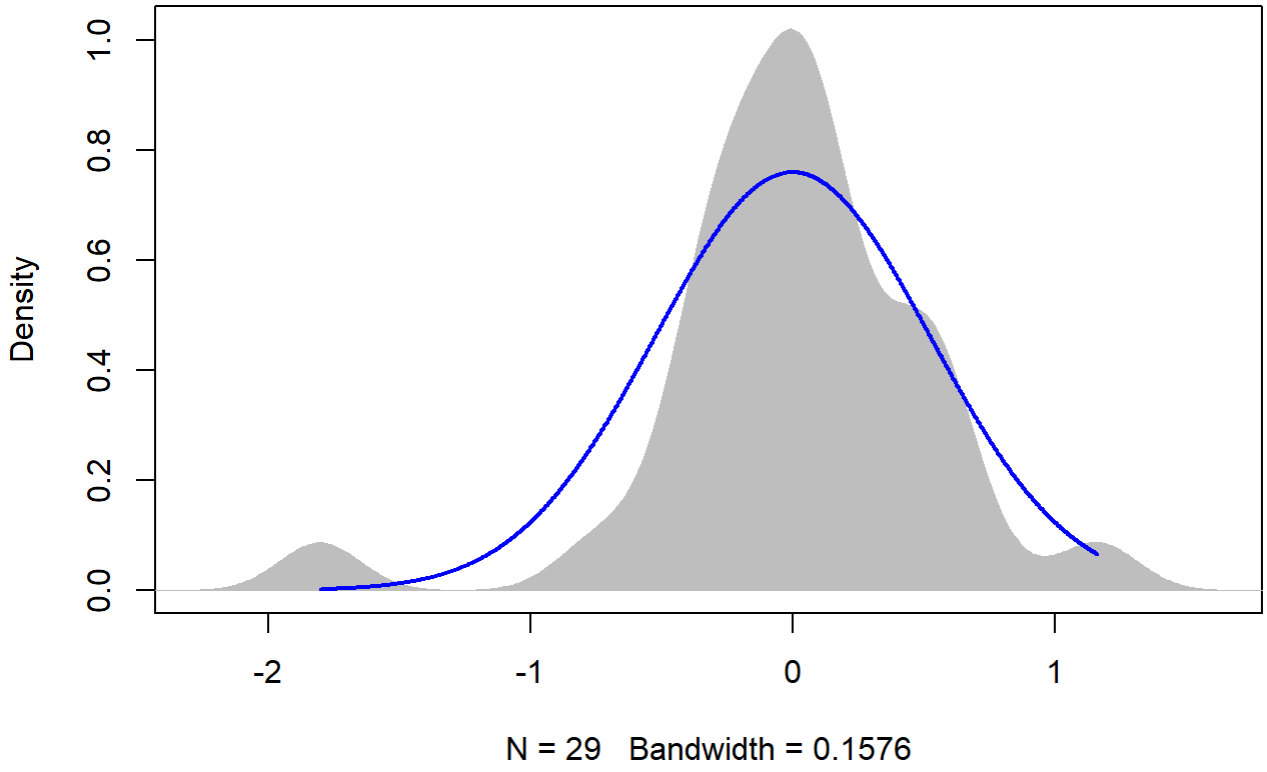

```
boxplot(residuals(mod) ~ TV12$Plot_type)
```




```
boxplot(TV12$Avg~ TV12$Plot_type)
```




```
plotNormalDensity(resid(mod))
```



14

```
TV14 <- filter(TV, Flight_hour == "14")

mod <-lmer(Avg ~ Plot_type * Date + (1|Plot_id), data = TV14)

r.squaredGLMM(mod)
```

```
##            R2m       R2c
## [1,] 0.7595818 0.8503376
```

```
anova(mod, ddf="Kenward-Roger")
```

```
## Type III Analysis of Variance Table with Kenward-Roger's method
##                Sum Sq Mean Sq NumDF DenDF F value   Pr(>F)
## Plot_type       9.039   9.039     1     8 11.3868 0.009722 **
## Date           90.860  45.430     2    16 57.2272 5.12e-08 ***
## Plot_type:Date  0.498   0.249     2    16  0.3138 0.735086
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

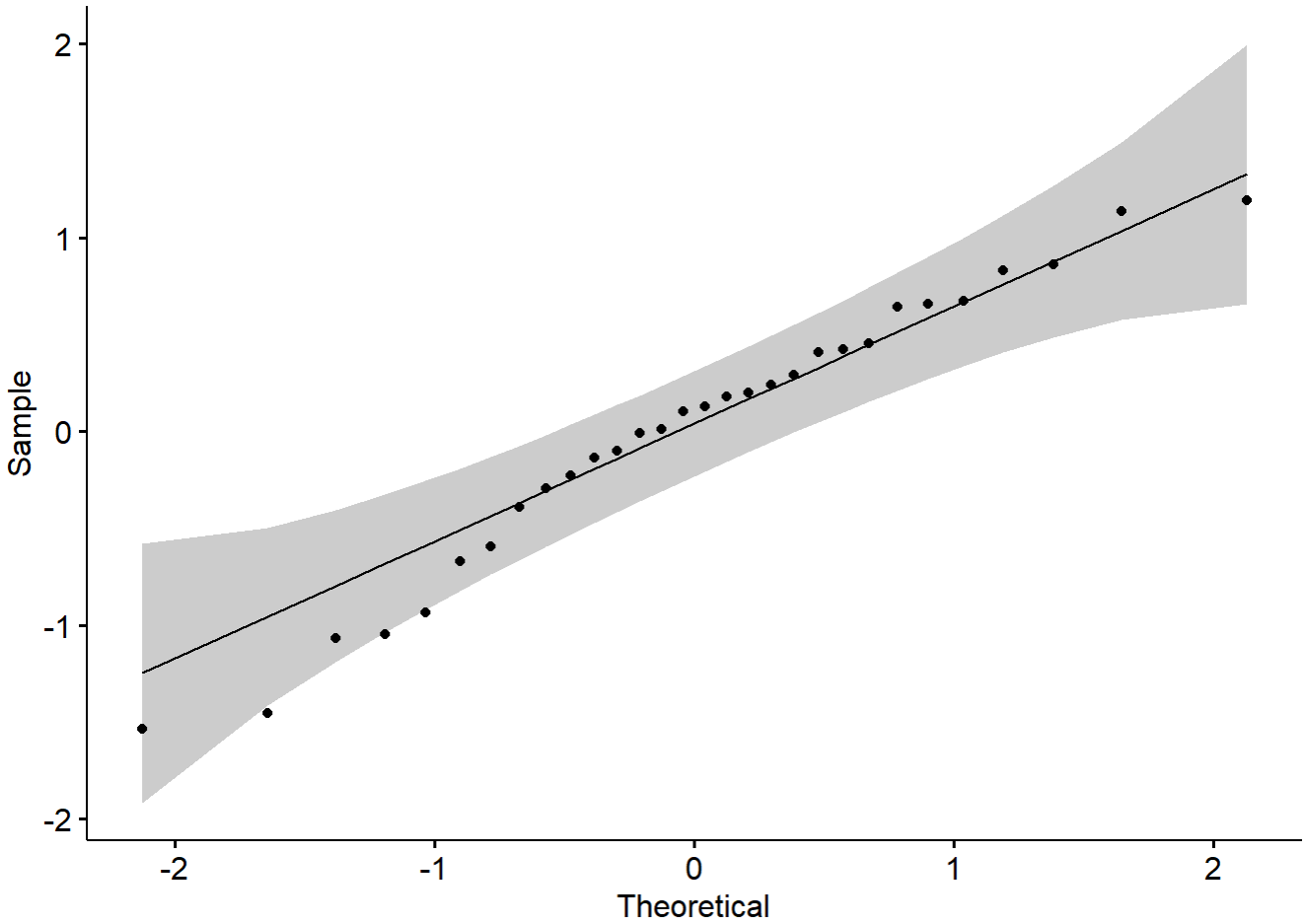
```
em <-emmeans(mod, pairwise ~ Plot_type, adjust = "Tukey")
```

```
## NOTE: Results may be misleading due to involvement in interactions
```

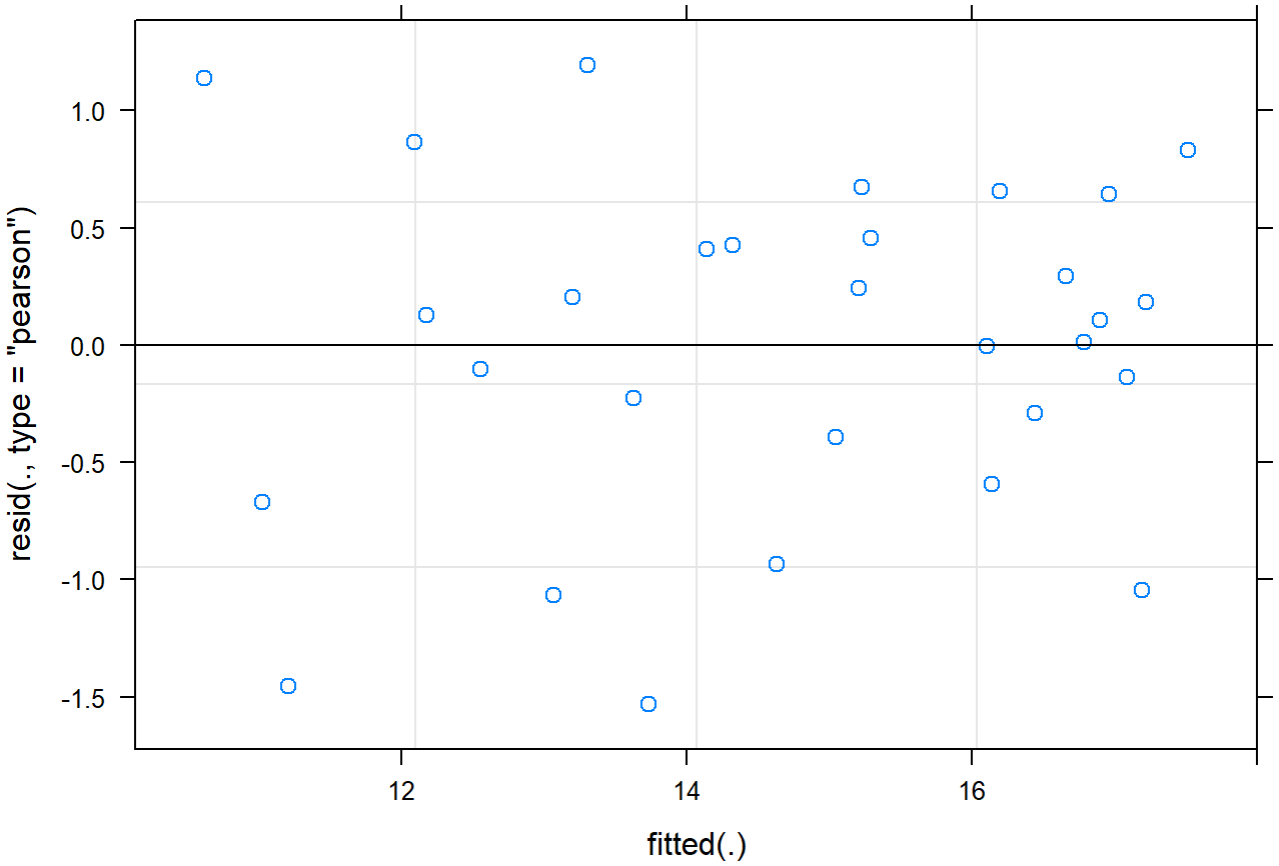
```
em
```

```
## $emmeans
##  Plot_type emmean    SE df lower.CL upper.CL
##  PC          15.6 0.386  8     14.8     16.5
##  ST          13.8 0.386  8     12.9     14.7
##
## Results are averaged over the levels of: Date
## Degrees-of-freedom method: kenward-roger
## Confidence level used: 0.95
##
## $contrasts
##  contrast estimate    SE df t.ratio p.value
##  PC - ST      1.84 0.546  8 3.374   0.0097
##
## Results are averaged over the levels of: Date
```

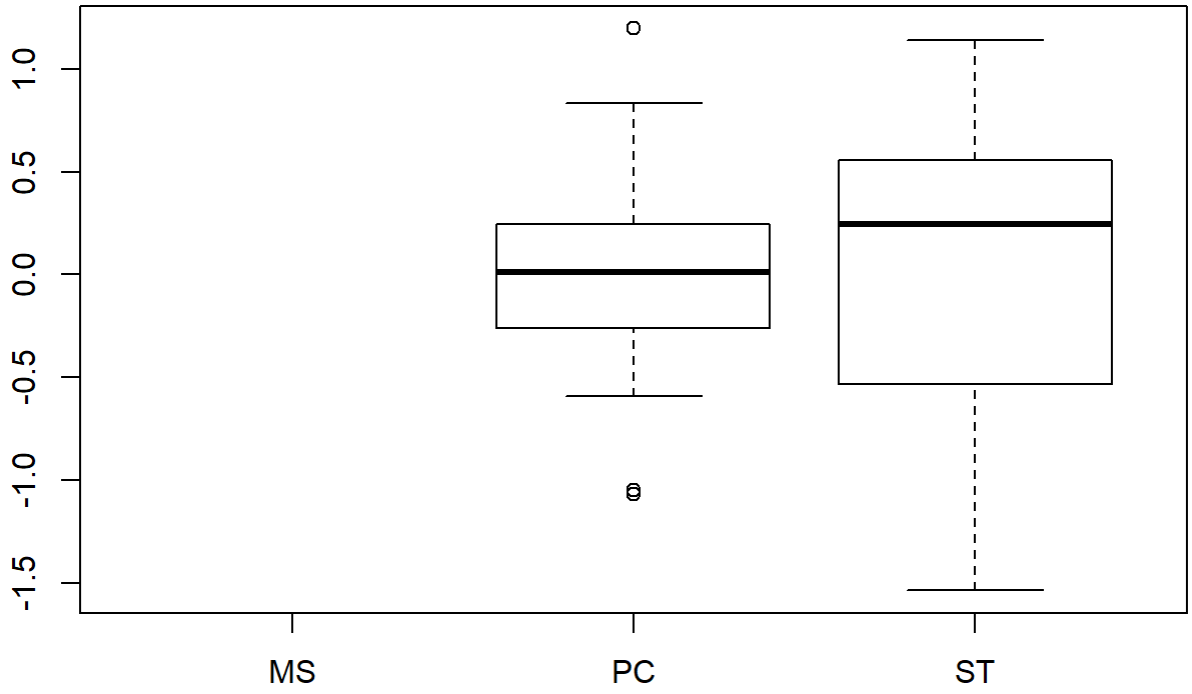
```
sumYA2016September[c(3:4),c(2:7)] <- summary(em)$emmeans

ggqqplot(residuals(mod))
```



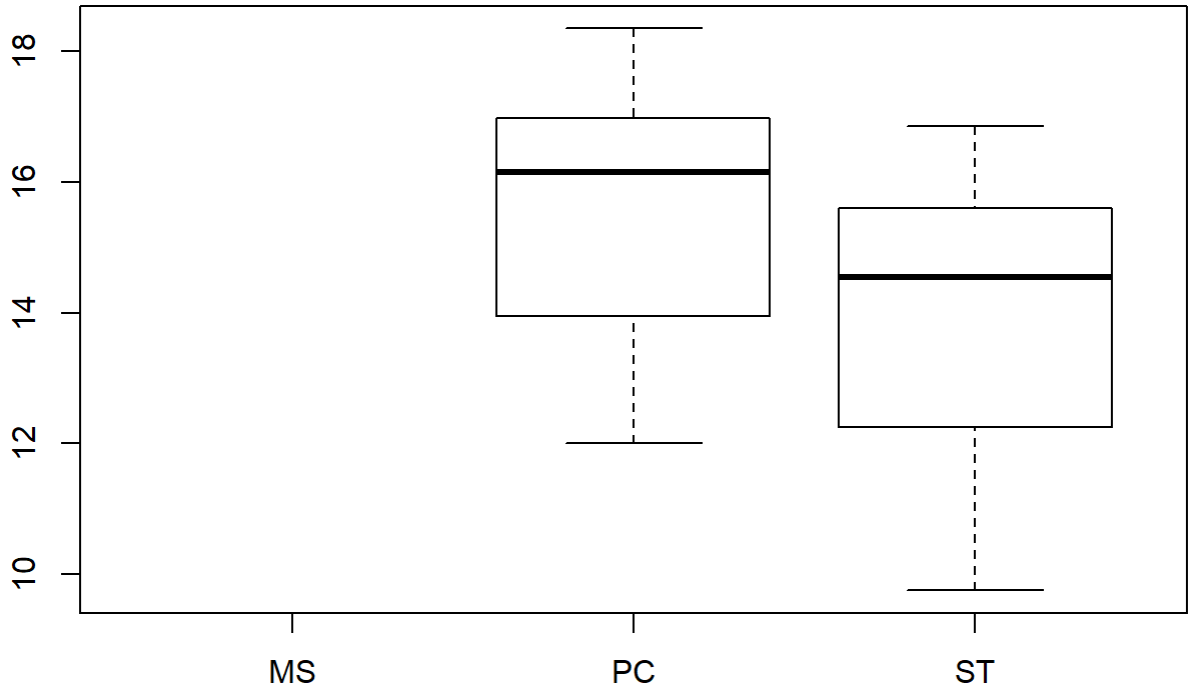

```
plot(mod)
```



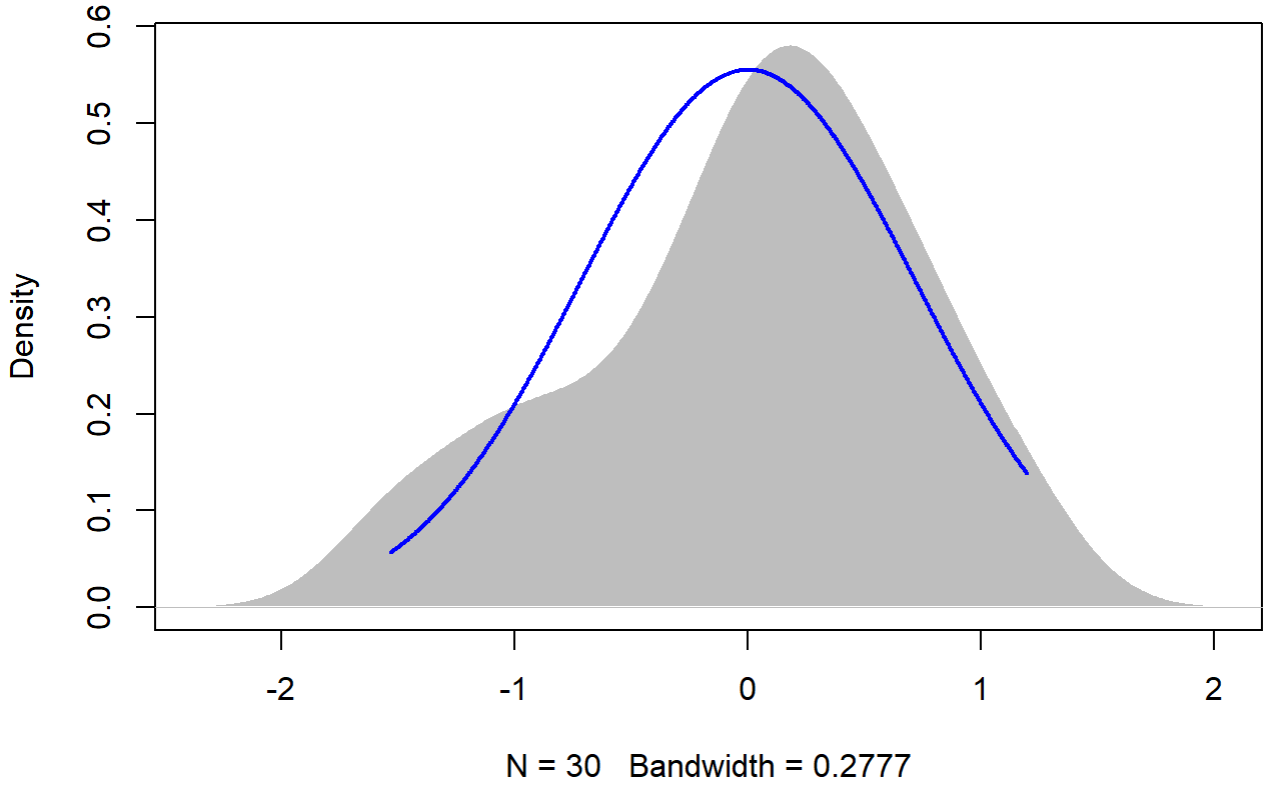

```
boxplot(residuals(mod) ~ TV14$Plot_type)
```




```
boxplot(TV14$Avg~ TV14$Plot_type)
```




```
plotNormalDensity(resid(mod))
```



16

```
TV16 <- filter(TV, Flight_hour == "16")

mod <-lmer(Avg ~ Plot_type * Date + (1|Plot_id), data = TV16)

r.squaredGLMM(mod)
```

```
##            R2m       R2c
## [1,] 0.9329827 0.9555781
```

```
anova(mod, ddf="Kenward-Roger")
```

```
## Type III Analysis of Variance Table with Kenward-Roger's method
##                 Sum Sq Mean Sq NumDF DenDF  F value    Pr(>F)
## Plot_type        6.387   6.387     1     8  13.8911  0.005812 **
## Date           262.754 131.377     2    16 285.7316 3.028e-13 ***
## Plot_type:Date   1.163   0.581     2    16   1.2643  0.309175
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

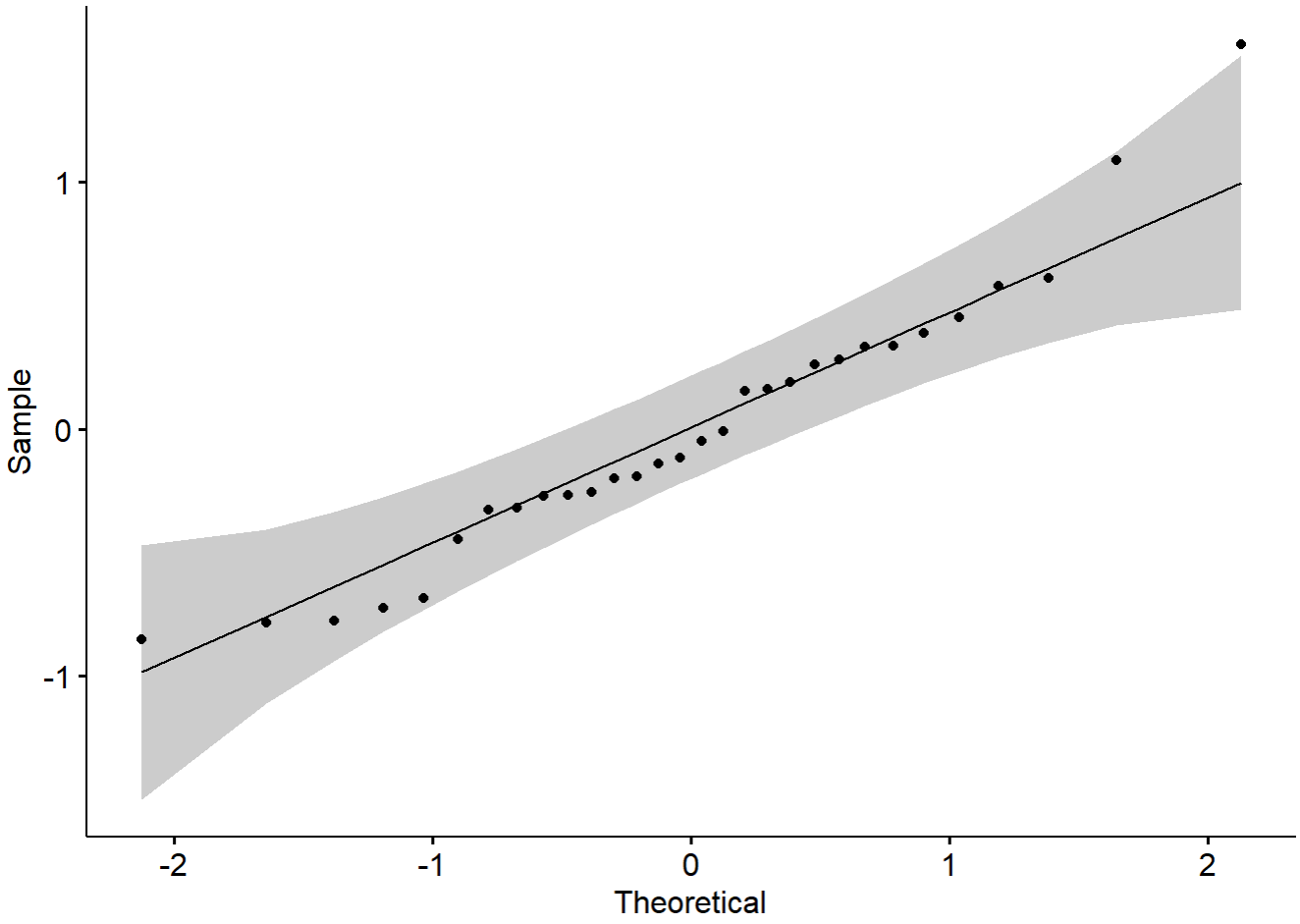
```
em <-emmeans(mod, pairwise ~ Plot_type, adjust = "Tukey")
```

```
## NOTE: Results may be misleading due to involvement in interactions
```

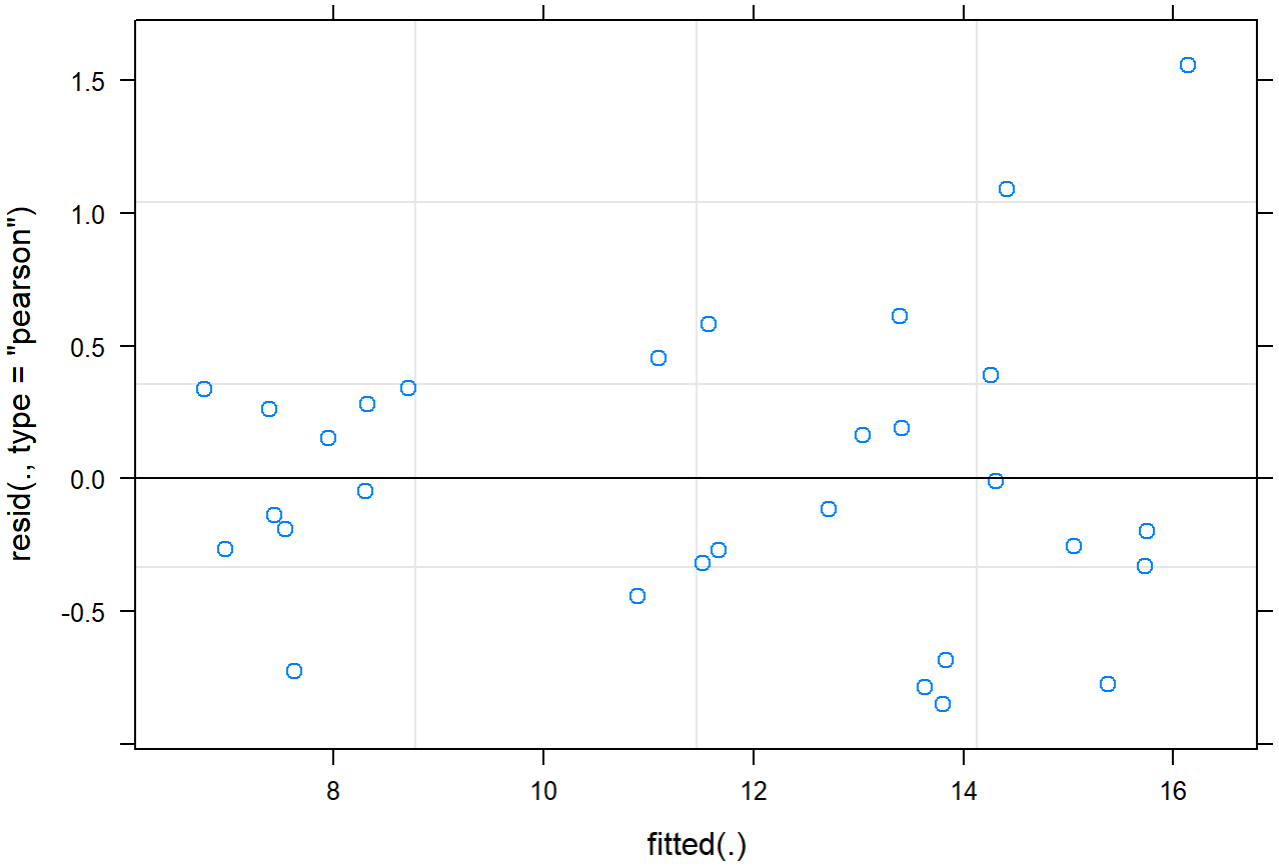
```
em
```

```
## $emmeans
##  Plot_type emmean    SE df lower.CL upper.CL
##  PC          12.4 0.278  8     11.7     13.0
##  ST          10.9 0.278  8     10.2     11.5
##
## Results are averaged over the levels of: Date
## Degrees-of-freedom method: kenward-roger
## Confidence level used: 0.95
##
## $contrasts
##  contrast estimate    SE df t.ratio p.value
##  PC - ST      1.47 0.394  8 3.727   0.0058
##
## Results are averaged over the levels of: Date
```

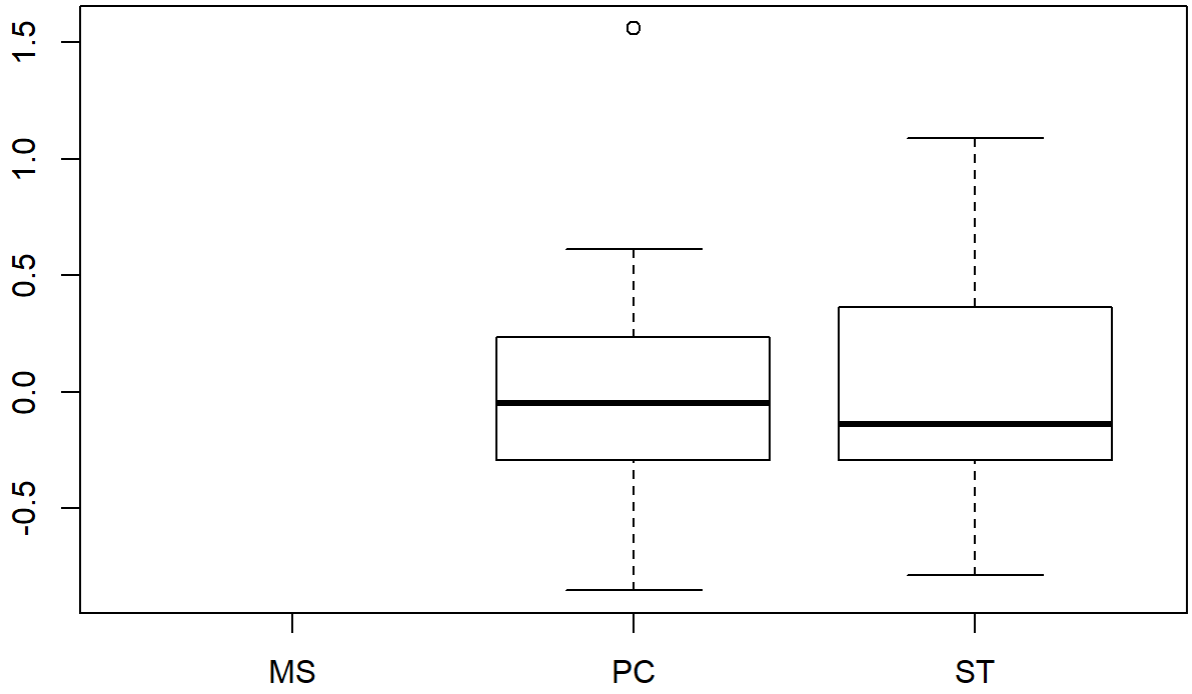
```
sumYA2016September[c(5:6),c(2:7)] <- summary(em)$emmeans

ggqqplot(residuals(mod))
```



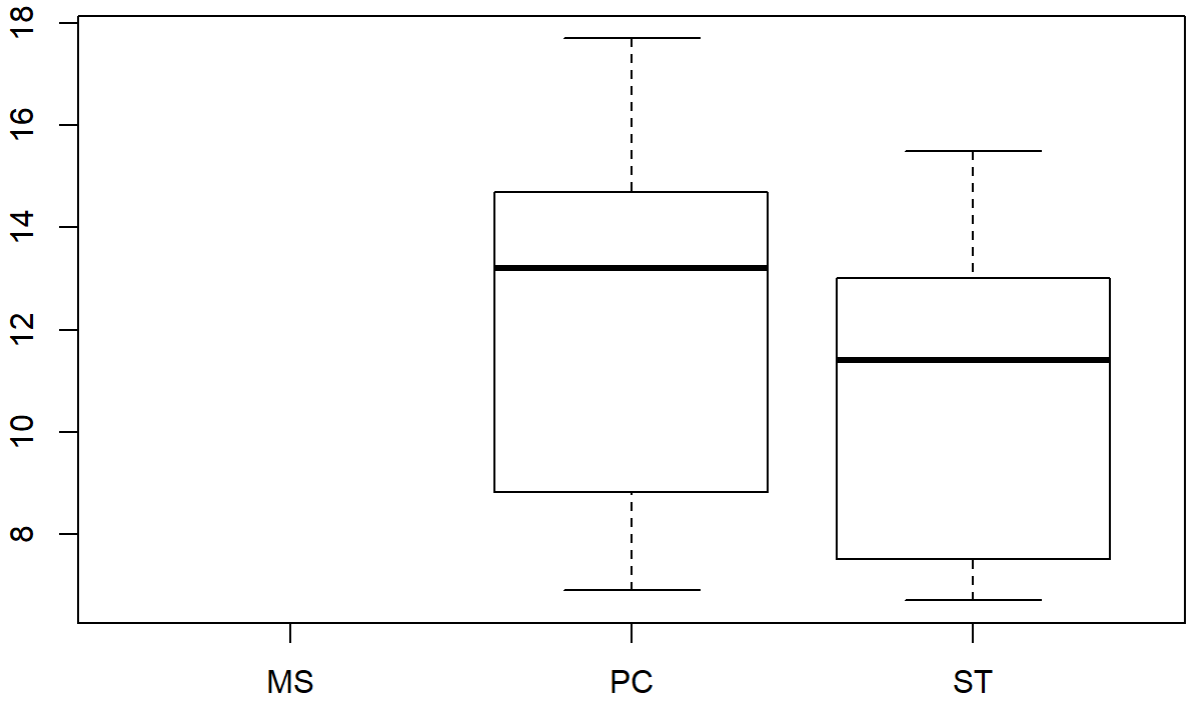

```
plot(mod)
```



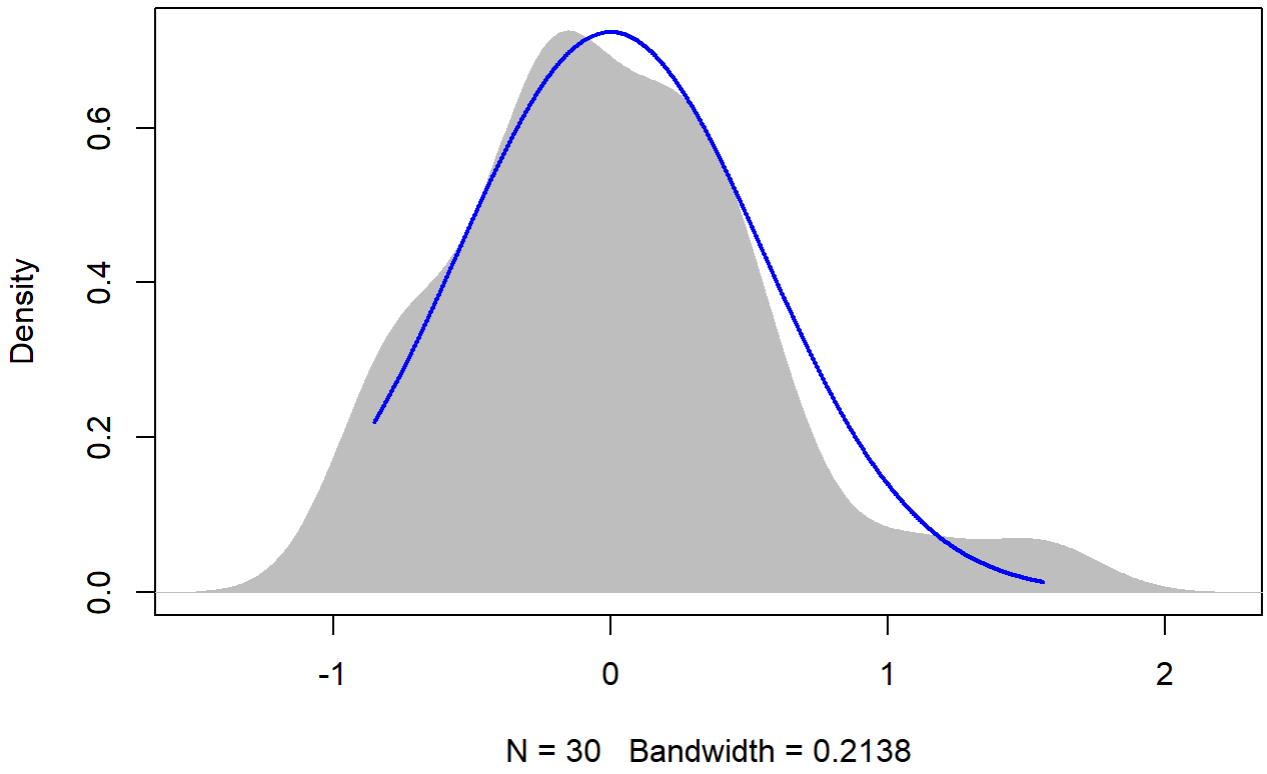

```
boxplot(residuals(mod) ~ TV16$Plot_type)
```




```
boxplot(TV16$Avg~ TV16$Plot_type)
```




```
plotNormalDensity(resid(mod))
```



20

```
sumYA2016September[c(7:8),c(2:7)] <- NA
```

Graph over time - 2016 Reforestation September

```
sumYA2016September[,'Plot_type']<-factor(sumYA2016September[,'Plot_type'])

tiff("YA2016September.tiff", width = 7, height = 5, units = 'in', res = 100)

ggplot(sumYA2016September, aes(x=Flight_hour, y=emmeans, colour=Plot_type)) +
  geom_errorbar(aes(ymin=lower.CL, ymax=Upper.cl), width=.3, position=position_dodge(width=0.3
)) +
  geom_point(position=pd, size=3, shape=21, fill="white") +
  geom_line(position=pd, linetype = "dashed") +
  xlab("Time of day (24-hr format)") +
  ylab(expression("EM Mean Surface Temperature  " ( degree*C))) +
  scale_colour_hue(name="Plot type",
                   breaks=c("1", "2"),
                   labels=c("Passive Control", "Topsoil Recipient"),
                   l=40) +
  expand_limits(y=0) +
  scale_y_continuous(breaks=c(0, 5, 10, 15, 20, 25, 30, 35, 40, 45)) +
  scale_x_continuous(breaks=c(12,14,16,18,20)) +
  theme_bw() +
  theme(legend.position=c(0.8,0.2), legend.title = element_text(size = 14),
```

```
        legend.text = element_text(size = 12), text = element_text(size=14), axis.text = eleme
nt_text(color = "black", size=14)) +
  annotate(geom="label",x = 12.2,  y = 4.8,
           label = "p = 0.088\n(6, 3)", fontface = "plain", col ="black", size = 4, fill = "wh
ite") +
  annotate(geom="label",x = 14.2,  y = 10.5,
           label ="p = 0.010\nmR^2 = 0.76\n(6, 3)", fontface = "plain", col ="black", size = 4
, fill = "white") +
  annotate(geom="label",x = 16,  y = 8.3,
           label = "p = 0.006\nmR^2 = 0.93\n(6, 3)", fontface = "plain", col ="black", size =
4, fill = "white")
```

```
## Warning: Removed 2 rows containing missing values (geom_point).
```

```
## Warning: Removed 2 row(s) containing missing values (geom_path).
```

```
dev.off()
```

```
## png
##   2
```

4.3.1.3

Reforestation 2015 - Ecological attributes difference table and tests

```
#ground cover - unequal variance - KW

ex1 <- AllS_15 %>%
  group_by(Plot_type) %>%
  summarise(mean(Ground.cover), sd(Ground.cover))
head(ex1)
```

```
## # A tibble: 3 x 3
##   Plot_type `mean(Ground.cover)` `sd(Ground.cover)`
##   <fct>                    <dbl>              <dbl>
## 1 MS                       0.96             0.00707
## 2 PC                       0.866            0.140
## 3 ST                       0.942            0.0402
```

```
mod <- lm(Ground.cover ~ Plot_type, data = AllS_15)
anv <- aov(Ground.cover ~ Plot_type, data = AllS_15)
summary(anv)
```

```
##             Df  Sum Sq Mean Sq F value Pr(>F)
## Plot_type    2 0.02489 0.01245   1.753  0.215
## Residuals   12 0.08520 0.00710
```

```
emmeans(mod, pairwise ~ Plot_type, adjust = "Tukey")
```

```
## $emmeans
##  Plot_type emmean     SE df lower.CL upper.CL
##  MS         0.960 0.0377 12    0.878    1.042
##  PC         0.866 0.0377 12    0.784    0.948
##  ST         0.942 0.0377 12    0.860    1.024
##
## Confidence level used: 0.95
##
## $contrasts
##  contrast estimate     SE df t.ratio p.value
##  MS - PC     0.094 0.0533 12  1.764  0.2229
##  MS - ST     0.018 0.0533 12  0.338  0.9394
##  PC - ST    -0.076 0.0533 12 -1.426  0.3591
##
## P value adjustment: tukey method for comparing a family of 3 estimates
```

```
kruskal.test(Ground.cover ~ Plot_type, data = AllS_15)
```

```
##
##  Kruskal-Wallis rank sum test
##
## data:  Ground.cover by Plot_type
## Kruskal-Wallis chi-squared = 0.37164, df = 2, p-value = 0.8304
```

```
shapiro.test(anv$residuals)
```

```
##
##  Shapiro-Wilk normality test
##
## data:  anv$residuals
## W = 0.92825, p-value = 0.2569
```

```
leveneTest((AllS_15$Ground.cover ~ AllS_15$Plot_type))
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value Pr(>F)
## group  2  4.0904 0.0442 *
##       12
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
outlierTest(mod)
```

```
## No Studentized residuals with Bonferonni p < 0.05
## Largest |rstudent|:
##    rstudent unadjusted p-value Bonferonni p
## 4 -2.732247             0.0195       0.2925
```

```
#NF Sp. richness - assumptions met
ex1 <- AllS_15 %>%
  group_by(Plot_type) %>%
  summarise(mean(NF..sp..rich.), sd(NF..sp..rich.))
head(ex1)
```

```
## # A tibble: 3 x 3
##   Plot_type `mean(NF..sp..rich.)` `sd(NF..sp..rich.)`
##   <fct>                   <dbl>              <dbl>
## 1 MS                        2.6               3.21
## 2 PC                        1.8               1.10
## 3 ST                        5.8               3.03
```

```
mod <- lm(NF..sp..rich. ~ Plot_type, data = AllS_15)
anv <- aov(NF..sp..rich. ~ Plot_type, data = AllS_15)
summary(anv)
```

```
##             Df Sum Sq Mean Sq F value Pr(>F)
## Plot_type    2   44.8    22.4   3.246 0.0747 .
## Residuals   12   82.8     6.9
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
emmeans(mod, pairwise ~ Plot_type, adjust = "Tukey")
```

```
## $emmeans
##  Plot_type emmean   SE df lower.CL upper.CL
##  MS           2.6 1.17 12   0.0405     5.16
##  PC           1.8 1.17 12  -0.7595     4.36
##  ST           5.8 1.17 12   3.2405     8.36
##
## Confidence level used: 0.95
##
## $contrasts
##  contrast estimate   SE df t.ratio p.value
##  MS - PC       0.8 1.66 12  0.482  0.8812
##  MS - ST      -3.2 1.66 12 -1.926  0.1737
##  PC - ST      -4.0 1.66 12 -2.408  0.0786
##
## P value adjustment: tukey method for comparing a family of 3 estimates
```

```
shapiro.test(anv$residuals)
```

```
##
##  Shapiro-Wilk normality test
##
## data:  anv$residuals
```

```
## W = 0.93306, p-value = 0.303
```

```
leveneTest((AllS_15$NF..sp..rich. ~ AllS_15$Plot_type))
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value Pr(>F)
## group  2  0.6667 0.5314
##       12
```

```
outlierTest(mod)
```

```
## No Studentized residuals with Bonferonni p < 0.05
## Largest |rstudent|:
##   rstudent unadjusted p-value Bonferonni p
## 1 2.941171            0.01342      0.20129
```

```
#All Sp. richness - assumptions met
ex1 <- AllS_15 %>%
  group_by(Plot_type) %>%
  summarise(mean(totSRich), sd(totSRich))
head(ex1)
```

```
## # A tibble: 3 x 3
##   Plot_type `mean(totSRich)` `sd(totSRich)`
##   <fct>                <dbl>          <dbl>
## 1 MS                    20.2           6.26
## 2 PC                    21.4           2.07
## 3 ST                    27.6           6.11
```

```
mod <- lm(totSRich ~ Plot_type, data = AllS_15)
anv <- aov(totSRich ~ Plot_type, data = AllS_15)
summary(anv)
```

```
##             Df Sum Sq Mean Sq F value Pr(>F)
## Plot_type    2  157.7   78.87   2.928 0.0921 .
## Residuals   12  323.2   26.93
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
emmeans(mod, pairwise ~ Plot_type, adjust = "Tukey")
```

```
## $emmeans
##  Plot_type emmean   SE df lower.CL upper.CL
##  MS          20.2 2.32 12     15.1     25.3
##  PC          21.4 2.32 12     16.3     26.5
##  ST          27.6 2.32 12     22.5     32.7
##
```

```
## Confidence level used: 0.95
##
## $contrasts
##  contrast estimate   SE df t.ratio p.value
##  MS - PC      -1.2 3.28 12 -0.366  0.9294
##  MS - ST      -7.4 3.28 12 -2.255  0.1019
##  PC - ST      -6.2 3.28 12 -1.889  0.1841
##
## P value adjustment: tukey method for comparing a family of 3 estimates
```

```
shapiro.test(anv$residuals)
```

```
##
##  Shapiro-Wilk normality test
##
## data:  anv$residuals
## W = 0.92456, p-value = 0.226
```

```
leveneTest(AllS_15$totSRich ~ AllS_15$Plot_type)
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value Pr(>F)
## group  2  0.5688 0.5807
##       12
```

```
outlierTest(mod)
```

```
## No Studentized residuals with Bonferonni p < 0.05
## Largest |rstudent|:
##   rstudent unadjusted p-value Bonferonni p
## 1 3.006757           0.011935      0.17902
```

```
#All Sp. diversity - assumptions met
ex1 <- AllS_15 %>%
  group_by(Plot_type) %>%
  summarise(mean(Total.diversity), sd(Total.diversity))
head(ex1)
```

```
## # A tibble: 3 x 3
##   Plot_type `mean(Total.diversity)` `sd(Total.diversity)`
##   <fct>                       <dbl>                 <dbl>
## 1 MS                           8.19                  3.82
## 2 PC                          10.2                   1.51
## 3 ST                          11.0                   3.48
```

```
mod <- lm(Total.diversity ~ Plot_type, data = AllS_15)
anv <- aov(Total.diversity ~ Plot_type, data = AllS_15)
summary(anv)
```

```
##             Df Sum Sq Mean Sq F value Pr(>F)
## Plot_type    2  21.19  10.593   1.095  0.366
## Residuals   12 116.07   9.672
```

```
emmeans(mod, pairwise ~ Plot_type, adjust = "Tukey")
```

```
## $emmeans
##  Plot_type emmean   SE df lower.CL upper.CL
##  MS          8.19 1.39 12     5.16     11.2
##  PC         10.22 1.39 12     7.19     13.2
##  ST         11.02 1.39 12     7.99     14.0
##
## Confidence level used: 0.95
##
## $contrasts
##  contrast estimate   SE df t.ratio p.value
##  MS - PC     -2.02 1.97 12 -1.029  0.5736
##  MS - ST     -2.82 1.97 12 -1.436  0.3546
##  PC - ST     -0.80 1.97 12 -0.407  0.9135
##
## P value adjustment: tukey method for comparing a family of 3 estimates
```

```
shapiro.test(anv$residuals)
```

```
##
##  Shapiro-Wilk normality test
##
## data:  anv$residuals
## W = 0.98197, p-value = 0.9812
```

```
leveneTest(AllS_15$Total.diversity ~ AllS_15$Plot_type)
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value Pr(>F)
## group  2  0.5497  0.591
##       12
```

```
outlierTest(mod)
```

```
## No Studentized residuals with Bonferonni p < 0.05
## Largest |rstudent|:
##   rstudent unadjusted p-value Bonferonni p
## 1 2.776932           0.018002      0.27004
```

```
#Tree genetic richness - assumptions met
ex1 <- AllS_15 %>%
```

```
  group_by(Plot_type) %>%
  summarise(mean(TreeGenusRich), sd(TreeGenusRich))
head(ex1)
```

```
## # A tibble: 3 x 3
##   Plot_type `mean(TreeGenusRich)` `sd(TreeGenusRich)`
##   <fct>                     <dbl>              <dbl>
## 1 MS                          3.4              0.894
## 2 PC                          2.6              0.548
## 3 ST                          2.8              0.837
```

```
mod <- lm(TreeGenusRich ~ Plot_type, data = AllS_15)
anv <- aov(TreeGenusRich ~ Plot_type, data = AllS_15)
summary(anv)
```

```
##             Df Sum Sq Mean Sq F value Pr(>F)
## Plot_type    2  1.733  0.8667   1.444  0.274
## Residuals   12  7.200  0.6000
```

```
emmeans(mod, pairwise ~ Plot_type, adjust = "Tukey")
```

```
## $emmeans
##  Plot_type emmean    SE df lower.CL upper.CL
##  MS           3.4 0.346 12     2.65     4.15
##  PC           2.6 0.346 12     1.85     3.35
##  ST           2.8 0.346 12     2.05     3.55
##
## Confidence level used: 0.95
##
## $contrasts
##  contrast estimate   SE df t.ratio p.value
##  MS - PC       0.8 0.49 12  1.633  0.2701
##  MS - ST       0.6 0.49 12  1.225  0.4619
##  PC - ST      -0.2 0.49 12 -0.408  0.9129
##
## P value adjustment: tukey method for comparing a family of 3 estimates
```

```
shapiro.test(anv$residuals)
```

```
##
##  Shapiro-Wilk normality test
##
## data:  anv$residuals
## W = 0.93235, p-value = 0.2957
```

```
leveneTest(AllS_15$TreeGenusRich ~ AllS_15$Plot_type)
```

```
## Levene's Test for Homogeneity of Variance (center = median)
```

```
##       Df F value Pr(>F)
## group  2  0.1429 0.8683
##       12
```

```
outlierTest(mod)
```

```
## No Studentized residuals with Bonferonni p < 0.05
## Largest |rstudent|:
##    rstudent unadjusted p-value Bonferonni p
## 12 -2.38195           0.036376      0.54563
```

```
#Tree height - assumptions met
ex1 <- AllS_15 %>%
  group_by(Plot_type) %>%
  summarise(mean(Sum_height20), sd(Sum_height20))
head(ex1)
```

```
## # A tibble: 3 x 3
##   Plot_type `mean(Sum_height20)` `sd(Sum_height20)`
##   <fct>                    <dbl>              <dbl>
## 1 MS                       1384.               291.
## 2 PC                        945                346.
## 3 ST                       1295.               611.
```

```
mod <- lm(Sum_height20 ~ Plot_type, data = AllS_15)
anv <- aov(Sum_height20 ~ Plot_type, data = AllS_15)
summary(anv)
```

```
##             Df  Sum Sq Mean Sq F value Pr(>F)
## Plot_type    2  538041  269020   1.399  0.284
## Residuals   12 2306874  192239
```

```
emmeans(mod, pairwise ~ Plot_type, adjust = "Tukey")
```

```
## $emmeans
##  Plot_type emmean  SE df lower.CL upper.CL
##  MS          1384 196 12      956     1811
##  PC           945 196 12      518     1372
##  ST          1295 196 12      868     1722
##
## Confidence level used: 0.95
##
## $contrasts
##  contrast estimate  SE df t.ratio p.value
##  MS - PC     438.6 277 12  1.582  0.2905
##  MS - ST      88.4 277 12  0.319  0.9458
##  PC - ST    -350.2 277 12 -1.263  0.4413
##
## P value adjustment: tukey method for comparing a family of 3 estimates
```

```
shapiro.test(anv$residuals)
```

```
##
##  Shapiro-Wilk normality test
##
## data:  anv$residuals
## W = 0.95548, p-value = 0.6145
```

```
leveneTest(AllS_15$Sum_height20 ~ AllS_15$Plot_type)
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value Pr(>F)
## group  2  1.0961 0.3654
##       12
```

```
outlierTest(mod)
```

```
## No Studentized residuals with Bonferonni p < 0.05
## Largest |rstudent|:
##   rstudent unadjusted p-value Bonferonni p
## 8 2.628603           0.023466      0.35199
```

```
#Tree diameter - assumptions met
ex1 <- AllS_15 %>%
  group_by(Plot_type) %>%
  summarise(mean(Sum_diam), sd(Sum_diam))
head(ex1)
```

```
## # A tibble: 3 x 3
##   Plot_type `mean(Sum_diam)` `sd(Sum_diam)`
##   <fct>                <dbl>          <dbl>
## 1 MS                    180.           34.2
## 2 PC                    151.           50.0
## 3 ST                    227            93.3
```

```
mod <- lm(Sum_diam ~ Plot_type, data = AllS_15)
anv <- aov(Sum_diam ~ Plot_type, data = AllS_15)
summary(anv)
```

```
##             Df Sum Sq Mean Sq F value Pr(>F)
## Plot_type    2  14558    7279   1.766  0.213
## Residuals   12  49470    4122
```

```
emmeans(mod, pairwise ~ Plot_type, adjust = "Tukey")
```

```
## $emmeans
##  Plot_type emmean   SE df lower.CL upper.CL
##  MS           180 28.7 12    117.6      243
##  PC           151 28.7 12     88.8      214
##  ST           227 28.7 12    164.4      290
##
## Confidence level used: 0.95
##
## $contrasts
##  contrast estimate   SE df t.ratio p.value
##  MS - PC      28.8 40.6 12  0.709  0.7628
##  MS - ST     -46.8 40.6 12 -1.152  0.5020
##  PC - ST     -75.6 40.6 12 -1.862  0.1921
##
## P value adjustment: tukey method for comparing a family of 3 estimates
```

```
shapiro.test(anv$residuals)
```

```
##
##  Shapiro-Wilk normality test
##
## data:  anv$residuals
## W = 0.95285, p-value = 0.5704
```

```
leveneTest(AllS_15$Sum_diam ~ AllS_15$Plot_type)
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value Pr(>F)
## group  2  0.9807 0.4032
##       12
```

```
outlierTest(mod)
```

```
## No Studentized residuals with Bonferonni p < 0.05
## Largest |rstudent|:
##    rstudent unadjusted p-value Bonferonni p
## 2 -2.941466           0.013413      0.20119
```

Average NOT NORMALIZED temp 2015 Reforestation July

Temp over time 2015 Reforestation - July

```
TV <- read.csv("ThermVegAvgNo3rd.csv")

TV <- filter(TV, Field == "YA2015", Month == "July")
sumYA2015July<- read.csv("f_hours_2015.csv")
```

12

```
TV12 <- filter(TV, Flight_hour == "12")

mod <-lmer(Avg ~ Plot_type * Date + (1|Plot_id), data = TV12)

anova(mod, ddf="Kenward-Roger")
```

```
## Type III Analysis of Variance Table with Kenward-Roger's method
##                 Sum Sq Mean Sq NumDF DenDF F value    Pr(>F)
## Plot_type        1.587   0.794     2    12  0.6464    0.5412
## Date           121.033  60.517     2    24 49.2986 3.168e-09 ***
## Plot_type:Date  10.104   2.526     4    24  2.0577    0.1181
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

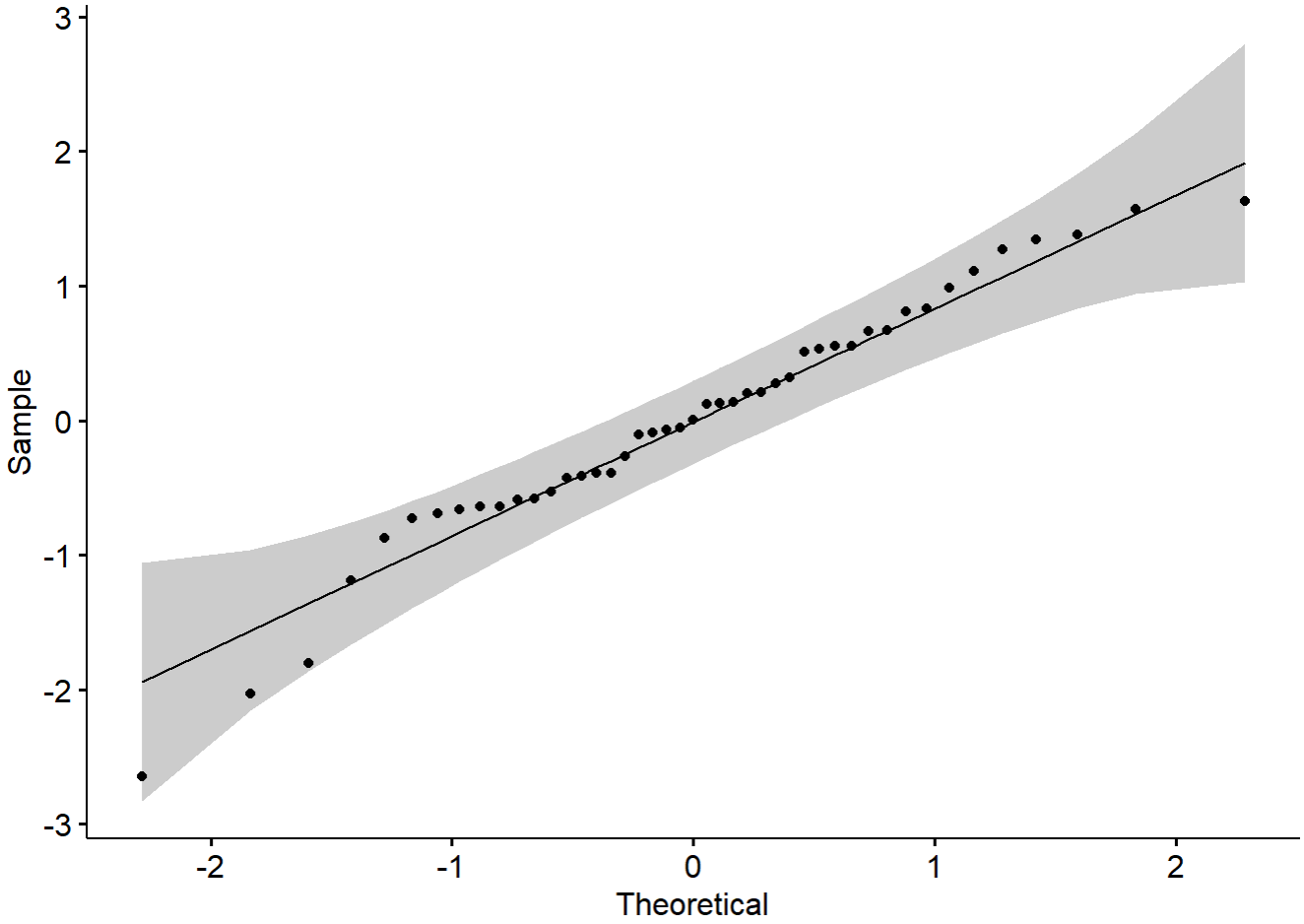
```
em <-emmeans(mod, pairwise ~ Plot_type, adjust = "Tukey")
```

```
## NOTE: Results may be misleading due to involvement in interactions
```

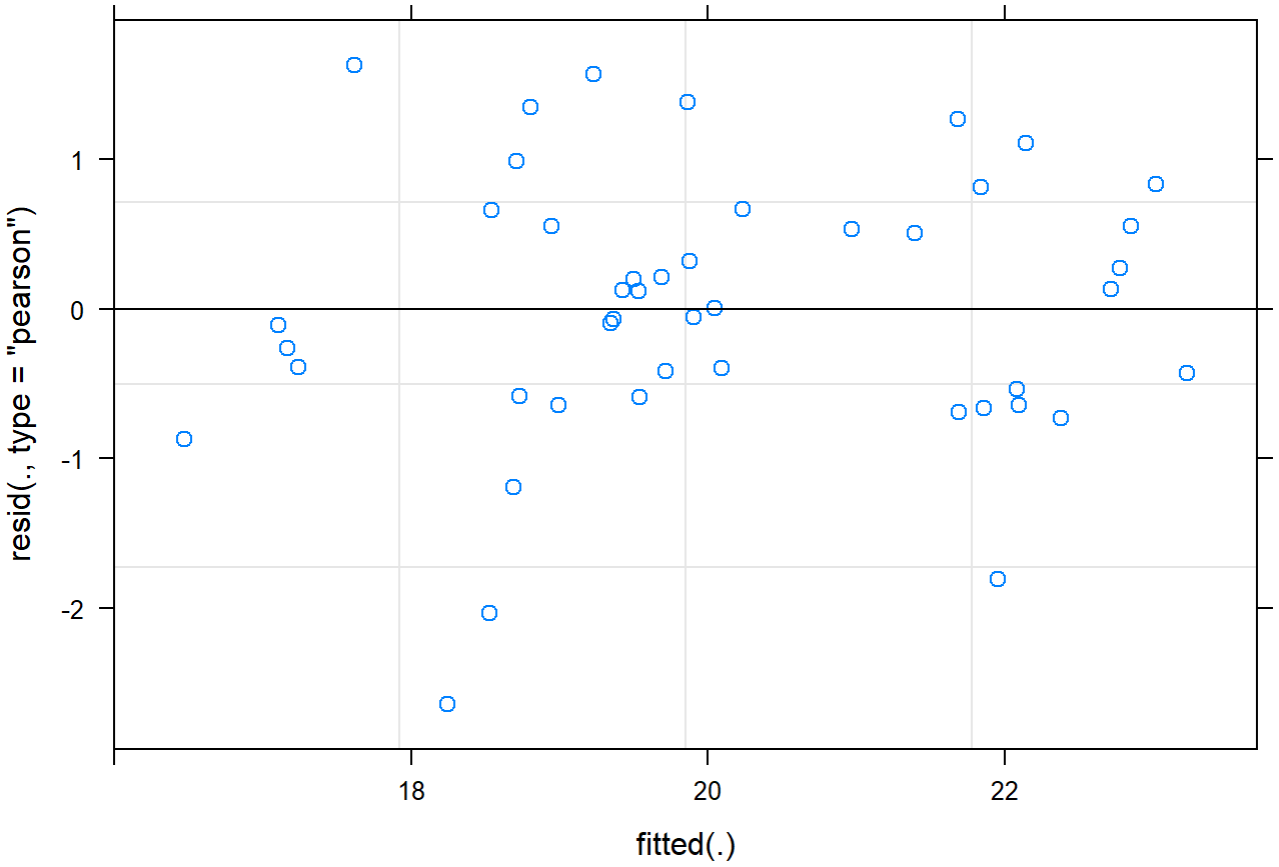
```
em
```

```
## $emmeans
##  Plot_type emmean    SE df lower.CL upper.CL
##  MS          19.7 0.402 12     18.9     20.6
##  PC          20.4 0.402 12     19.5     21.3
##  ST          20.1 0.402 12     19.2     21.0
##
## Results are averaged over the levels of: Date
## Degrees-of-freedom method: kenward-roger
## Confidence level used: 0.95
##
## $contrasts
##  contrast estimate    SE df t.ratio p.value
##  MS - PC    -0.643 0.569 12 -1.131  0.5143
##  MS - ST    -0.380 0.569 12 -0.668  0.7860
##  PC - ST     0.263 0.569 12  0.463  0.8897
##
## Results are averaged over the levels of: Date
## P value adjustment: tukey method for comparing a family of 3 estimates
```

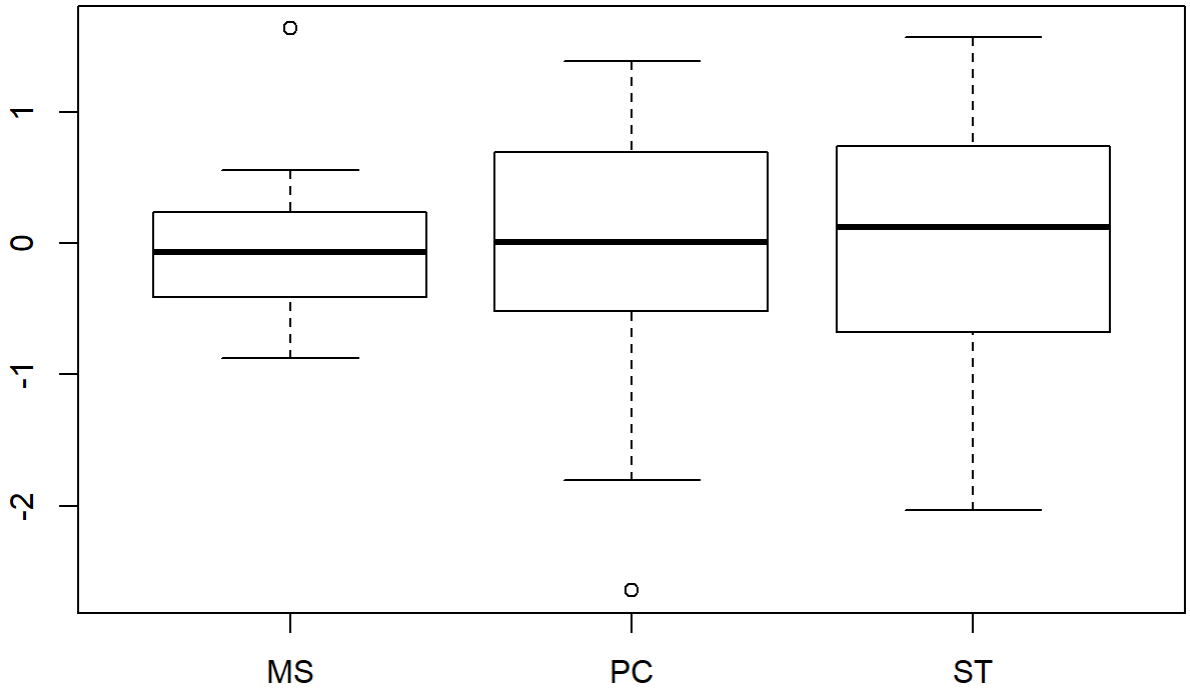
```
sumYA2015July[c(1:3),c(2:7)] <- summary(em)$emmeans

ggqqplot(residuals(mod))
```



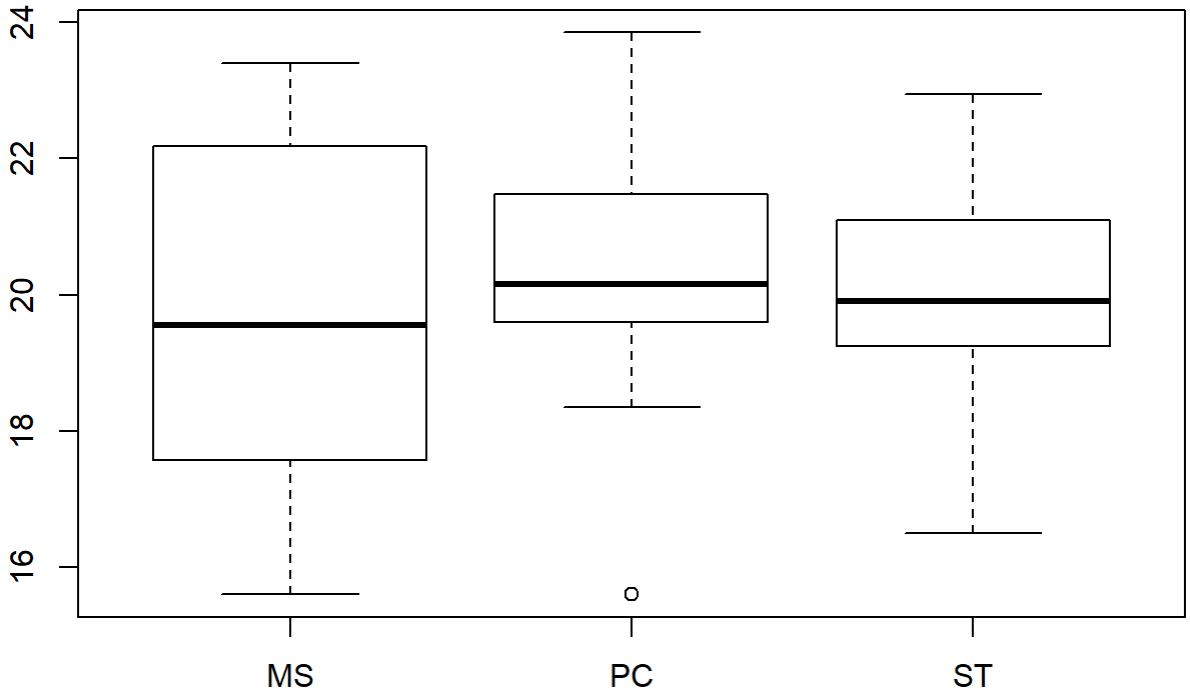

```
plot(mod)
```



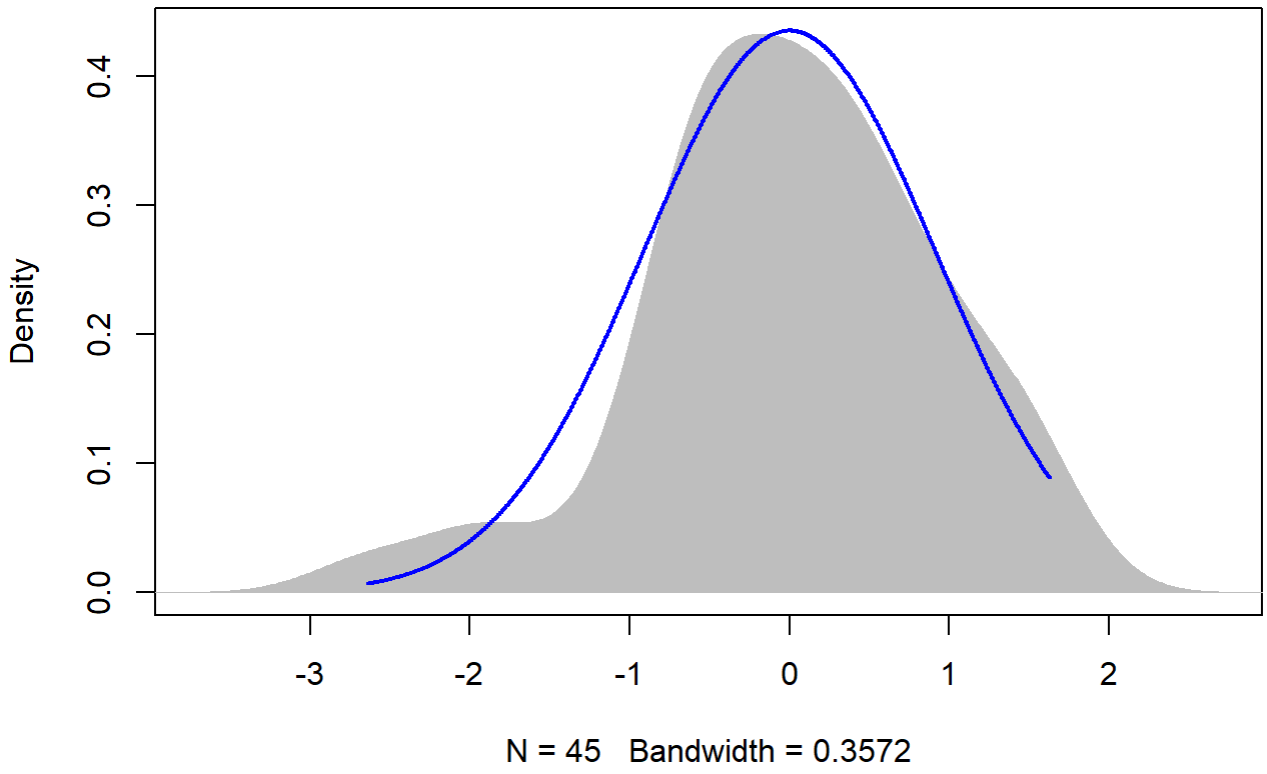

```
boxplot(residuals(mod) ~ TV12$Plot_type)
```




```
boxplot(TV12$Avg~ TV12$Plot_type)
```




```
plotNormalDensity(resid(mod))
```



14

```
TV14 <- filter(TV, Flight_hour == "14")

outlierTest(lm(Avg ~ Plot_type, data = TV14))
```

```
## No Studentized residuals with Bonferonni p < 0.05
## Largest |rstudent|:
##    rstudent unadjusted p-value Bonferonni p
## 35 2.251447           0.029919           NA
```

```
mod <-lmer(Avg ~ Plot_type * Date + (1|Plot_id), data = TV14)

anova(mod, ddf="Kenward-Roger")
```

```
## Type III Analysis of Variance Table with Kenward-Roger's method
##                Sum Sq Mean Sq NumDF  DenDF F value    Pr(>F)
## Plot_type       6.732  3.3660     2 11.934  1.7609 0.2137347
## Date           48.046 24.0232     2 23.356 12.5676 0.0001972 ***
## Plot_type:Date 13.167  3.2918     4 23.336  1.7221 0.1789504
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

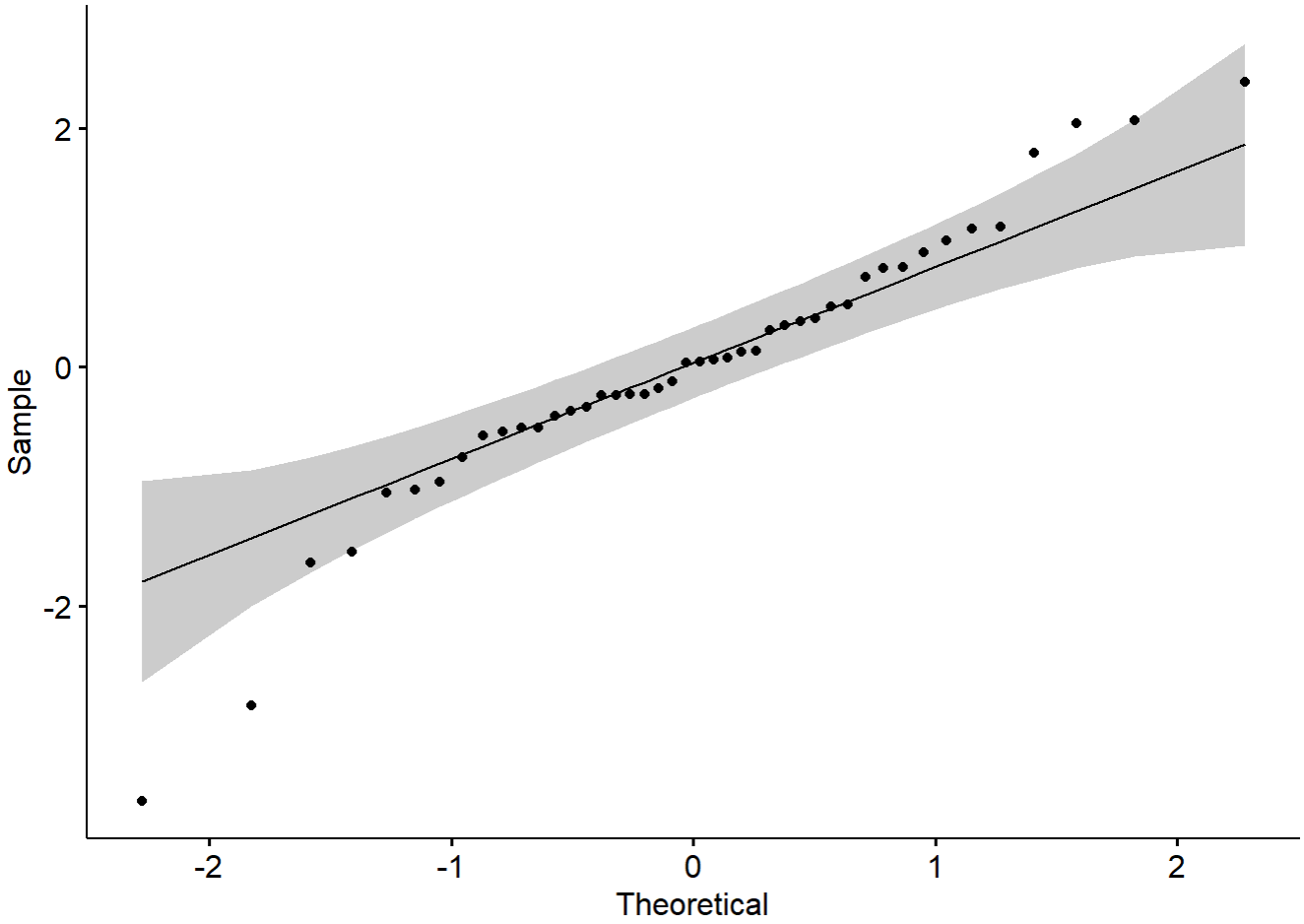
```
em <-emmeans(mod, pairwise ~ Plot_type, adjust = "Tukey")
```

```
## NOTE: Results may be misleading due to involvement in interactions
```

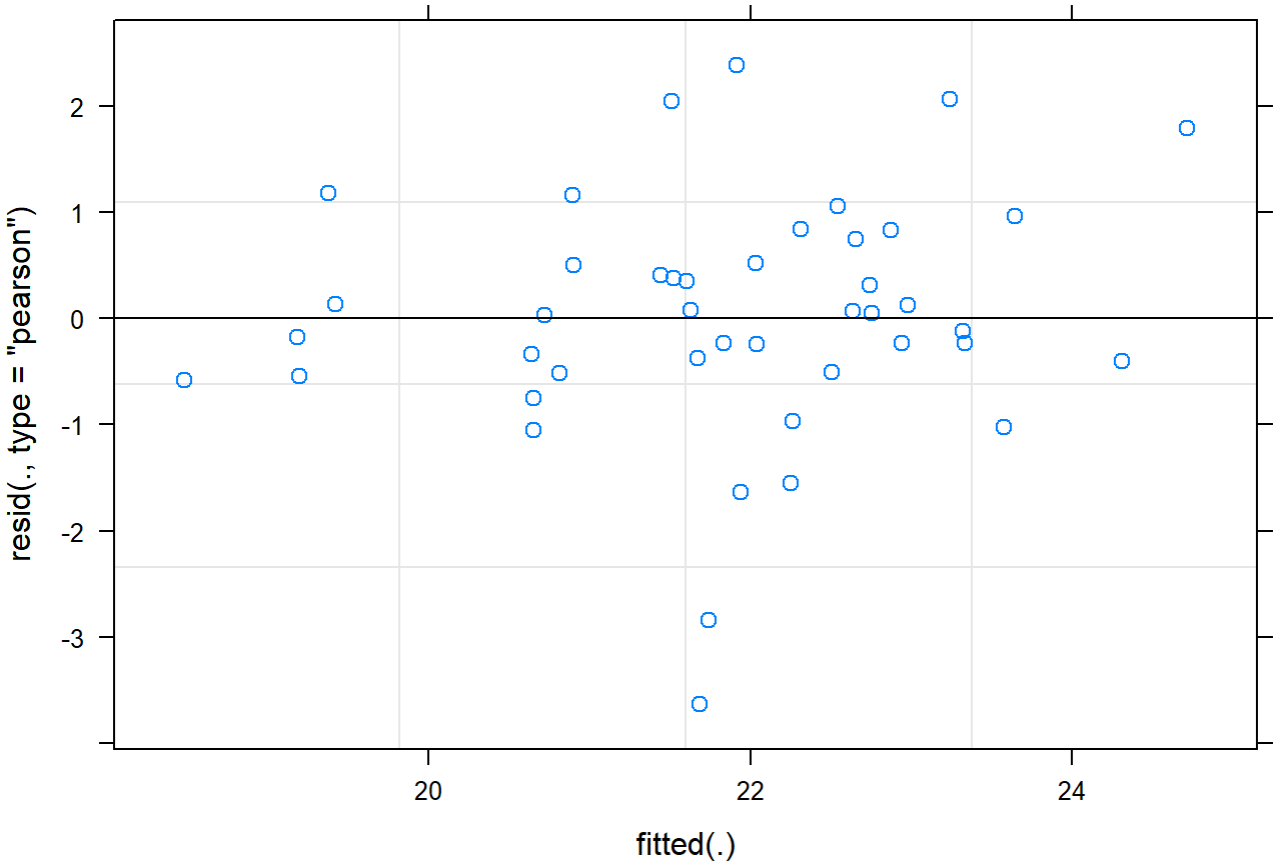
```
em
```

```
## $emmeans
##  Plot_type emmean    SE   df lower.CL upper.CL
##  MS          21.5 0.492 12.6     20.4     22.5
##  PC          22.6 0.478 11.6     21.6     23.6
##  ST          21.5 0.478 11.6     20.5     22.6
##
## Results are averaged over the levels of: Date
## Degrees-of-freedom method: kenward-roger
## Confidence level used: 0.95
##
## $contrasts
##  contrast estimate    SE   df t.ratio p.value
##  MS - PC   -1.1311 0.686 12.1 -1.649  0.2638
##  MS - ST   -0.0544 0.686 12.1 -0.079  0.9965
##  PC - ST    1.0767 0.676 11.6  1.593  0.2873
##
## Results are averaged over the levels of: Date
## P value adjustment: tukey method for comparing a family of 3 estimates
```

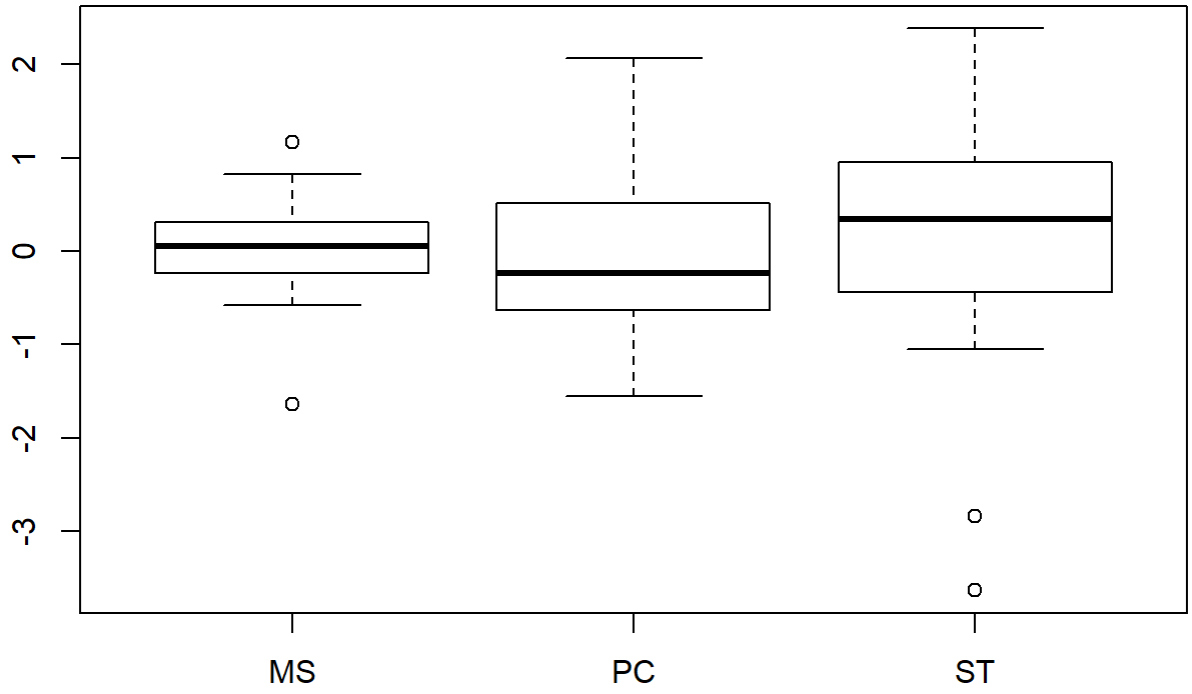
```
sumYA2015July[c(4:6),c(2:7)] <- summary(em)$emmeans

ggqqplot(residuals(mod))
```



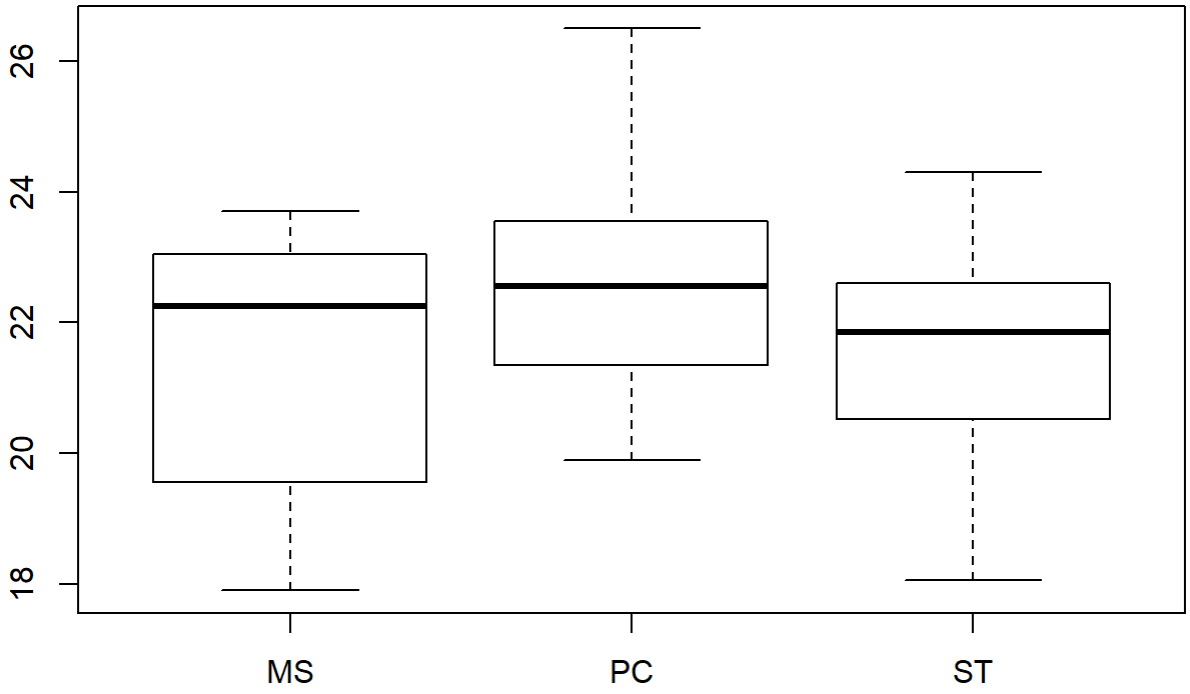

```
plot(mod)
```



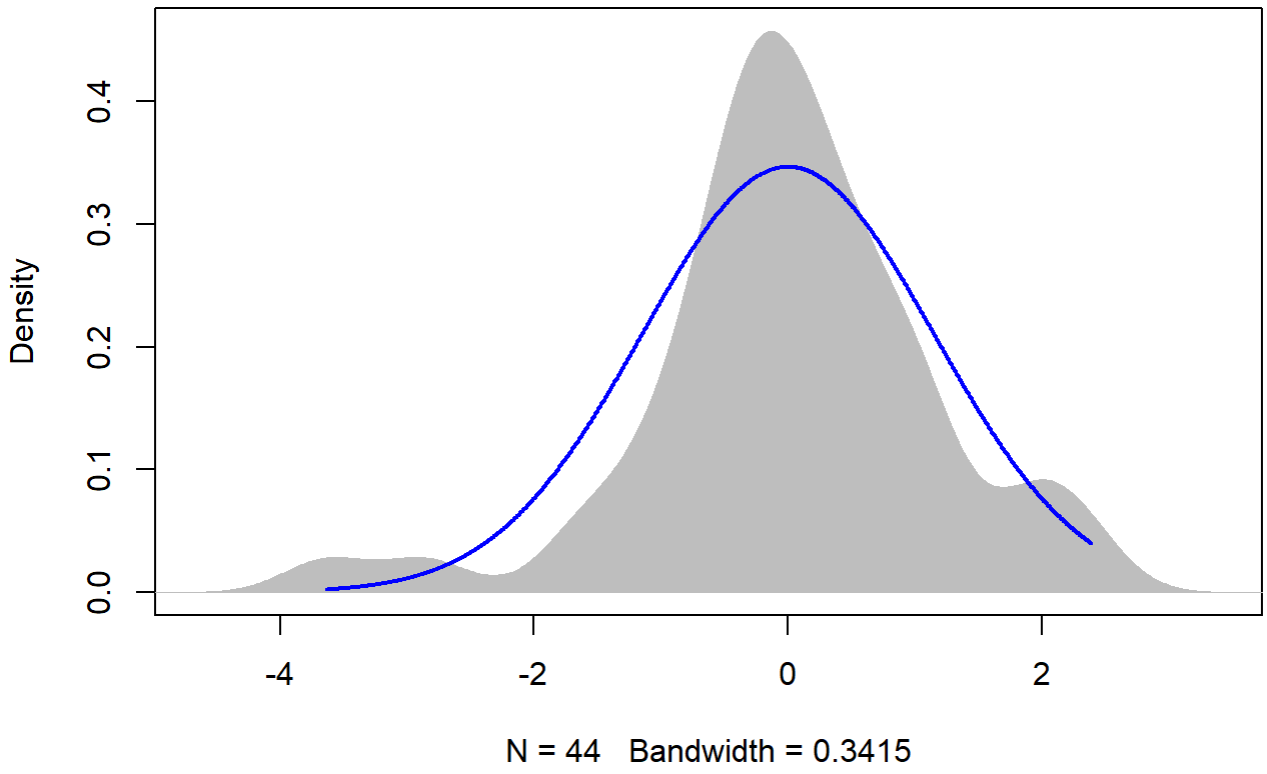

```
boxplot(residuals(mod) ~ TV14$Plot_type)
```




```
boxplot(TV14$Avg~ TV14$Plot_type)
```




```
plotNormalDensity(resid(mod))
```



16

```
TV16 <- filter(TV, Flight_hour == "16")

mod <-lmer(Avg ~ Plot_type * Date + (1|Plot_id), data = TV16)

anova(mod, ddf="Kenward-Roger")
```

```
## Type III Analysis of Variance Table with Kenward-Roger's method
##                Sum Sq Mean Sq NumDF DenDF F value    Pr(>F)
## Plot_type      14.429  7.2145     2    12  4.2311 0.0406786 *
## Date           46.564 23.2820     2    24 13.6544 0.0001097 ***
## Plot_type:Date 21.364  5.3409     4    24  3.1323 0.0330950 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
r.squaredGLMM(mod)
```

```
##            R2m       R2c
## [1,] 0.4638128 0.7034193
```

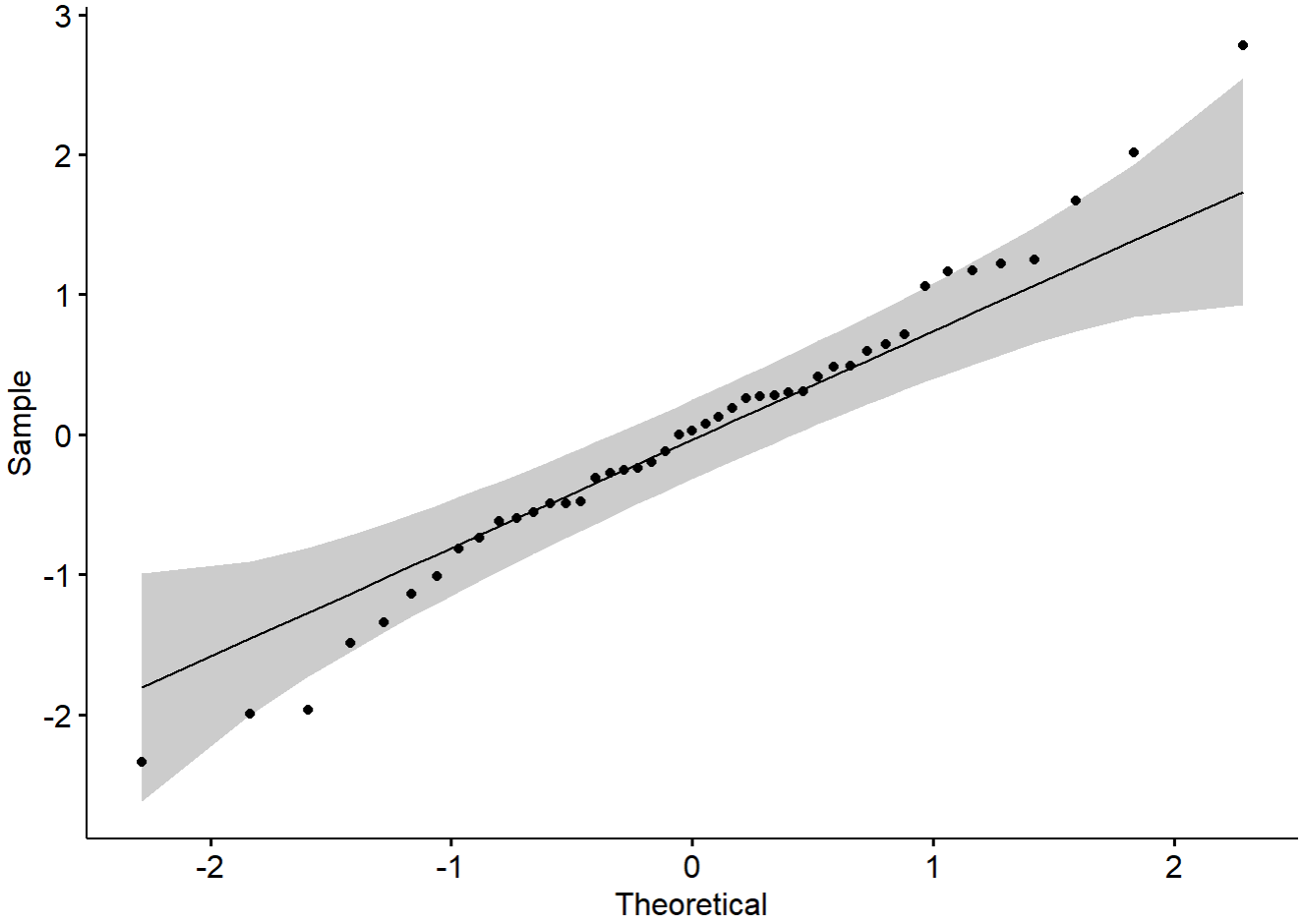
```
em <-emmeans(mod, pairwise ~ Plot_type, adjust = "Tukey")
```

```
## NOTE: Results may be misleading due to involvement in interactions
```

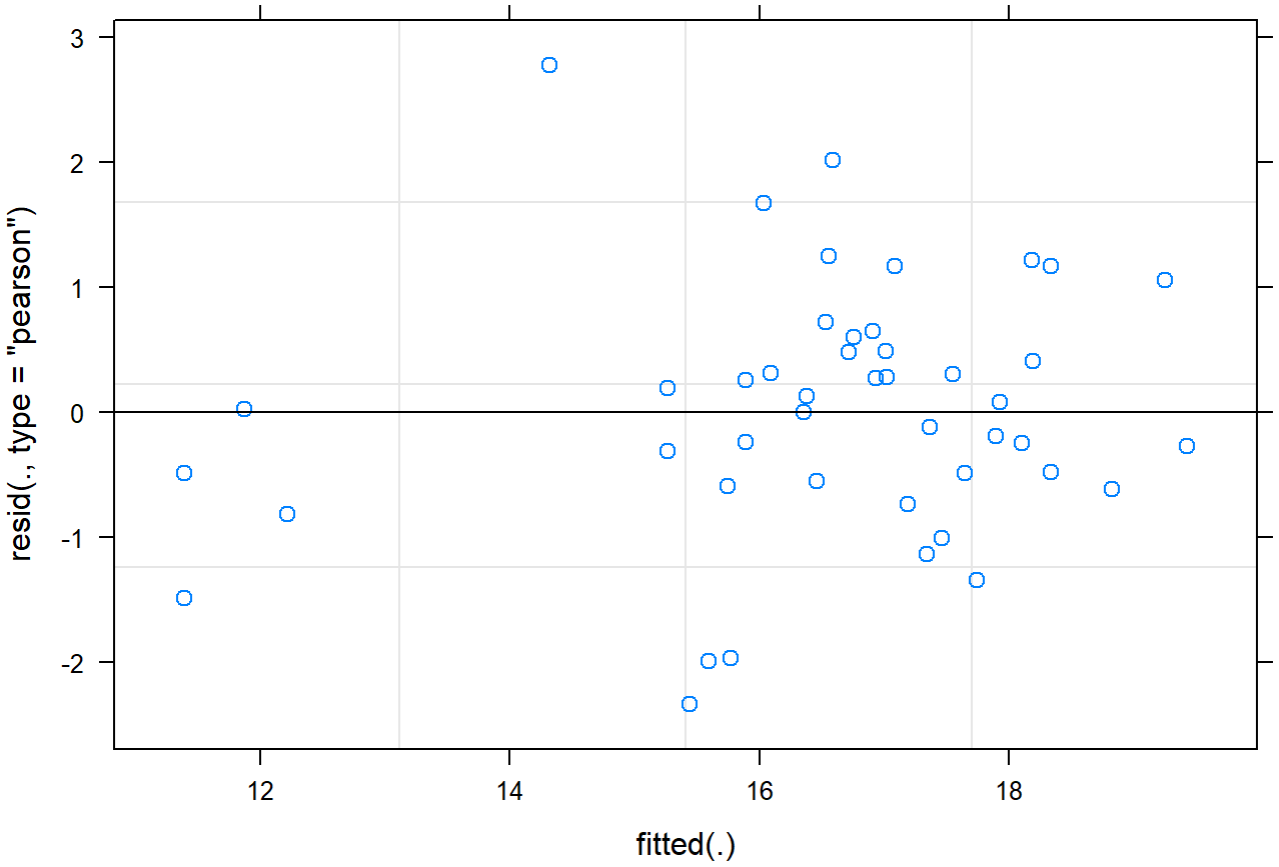
```
em
```

```
## $emmeans
##  Plot_type emmean    SE df lower.CL upper.CL
##  MS          15.0 0.624 12     13.7     16.4
##  PC          17.4 0.624 12     16.1     18.8
##  ST          17.0 0.624 12     15.7     18.4
##
## Results are averaged over the levels of: Date
## Degrees-of-freedom method: kenward-roger
## Confidence level used: 0.95
##
## $contrasts
##  contrast estimate    SE df t.ratio p.value
##  MS - PC    -2.397 0.882 12 -2.717  0.0459
##  MS - ST    -1.993 0.882 12 -2.259  0.1010
##  PC - ST     0.403 0.882 12  0.457  0.8922
##
## Results are averaged over the levels of: Date
## P value adjustment: tukey method for comparing a family of 3 estimates
```

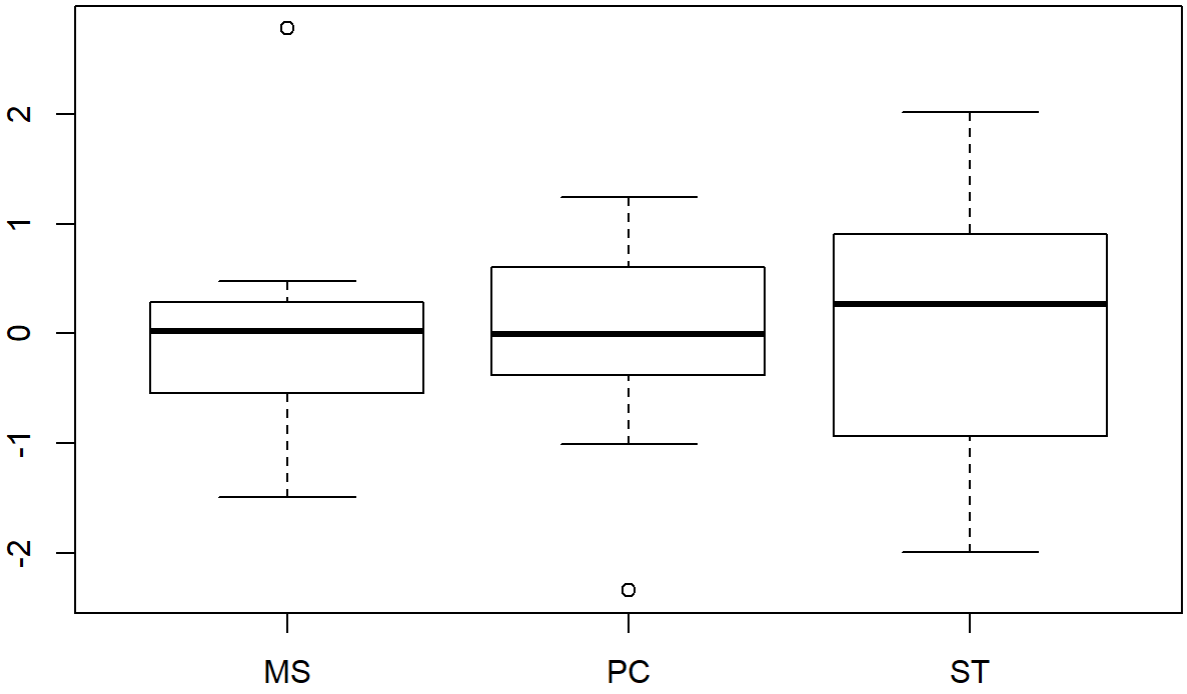
```
sumYA2015July[c(7:9),c(2:7)] <- summary(em)$emmeans

ggqqplot(residuals(mod))
```



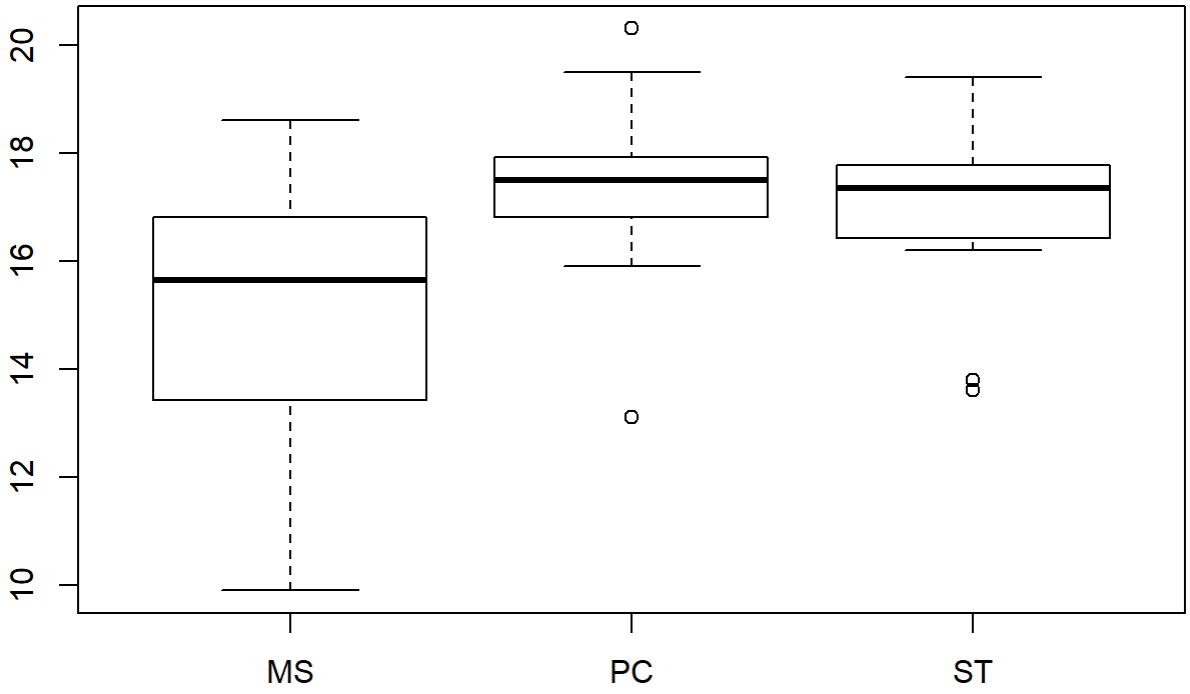

```
plot(mod)
```



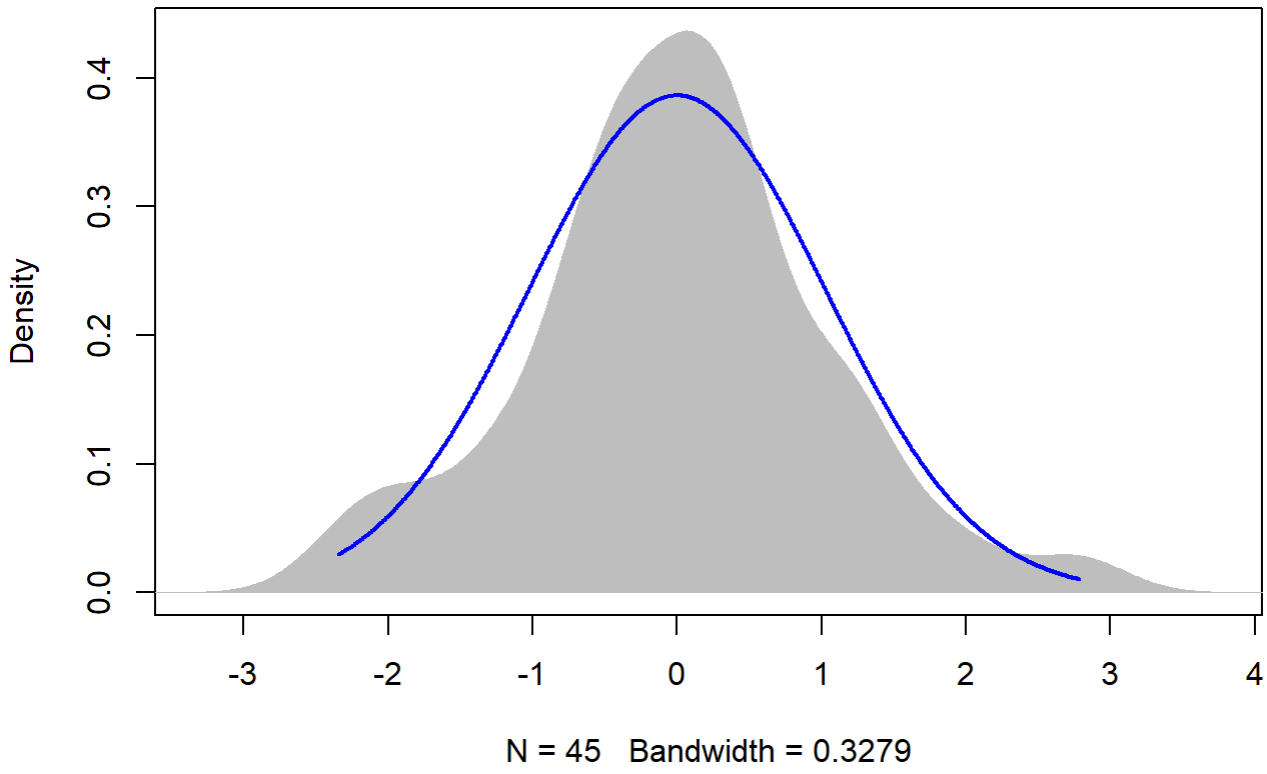

```
boxplot(residuals(mod) ~ TV16$Plot_type)
```




```
boxplot(TV16$Avg~ TV16$Plot_type)
```




```
plotNormalDensity(resid(mod))
```



20

```
TV20 <- filter(TV, Flight_hour == "20")

mod <-lmer(Avg ~ Plot_type * Date + (1|Plot_id), data = TV20)

anova(mod, ddf="Kenward-Roger")
```

```
## Type III Analysis of Variance Table with Kenward-Roger's method
##                Sum Sq Mean Sq NumDF DenDF  F value Pr(>F)
## Plot_type        0.37   0.186     2    12   0.4209 0.6658
## Date           583.88 291.942     2    24 659.5008 <2e-16 ***
## Plot_type:Date   1.62   0.405     4    24   0.9141 0.4717
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
em <-emmeans(mod, pairwise ~ Plot_type, adjust = "Tukey")
```

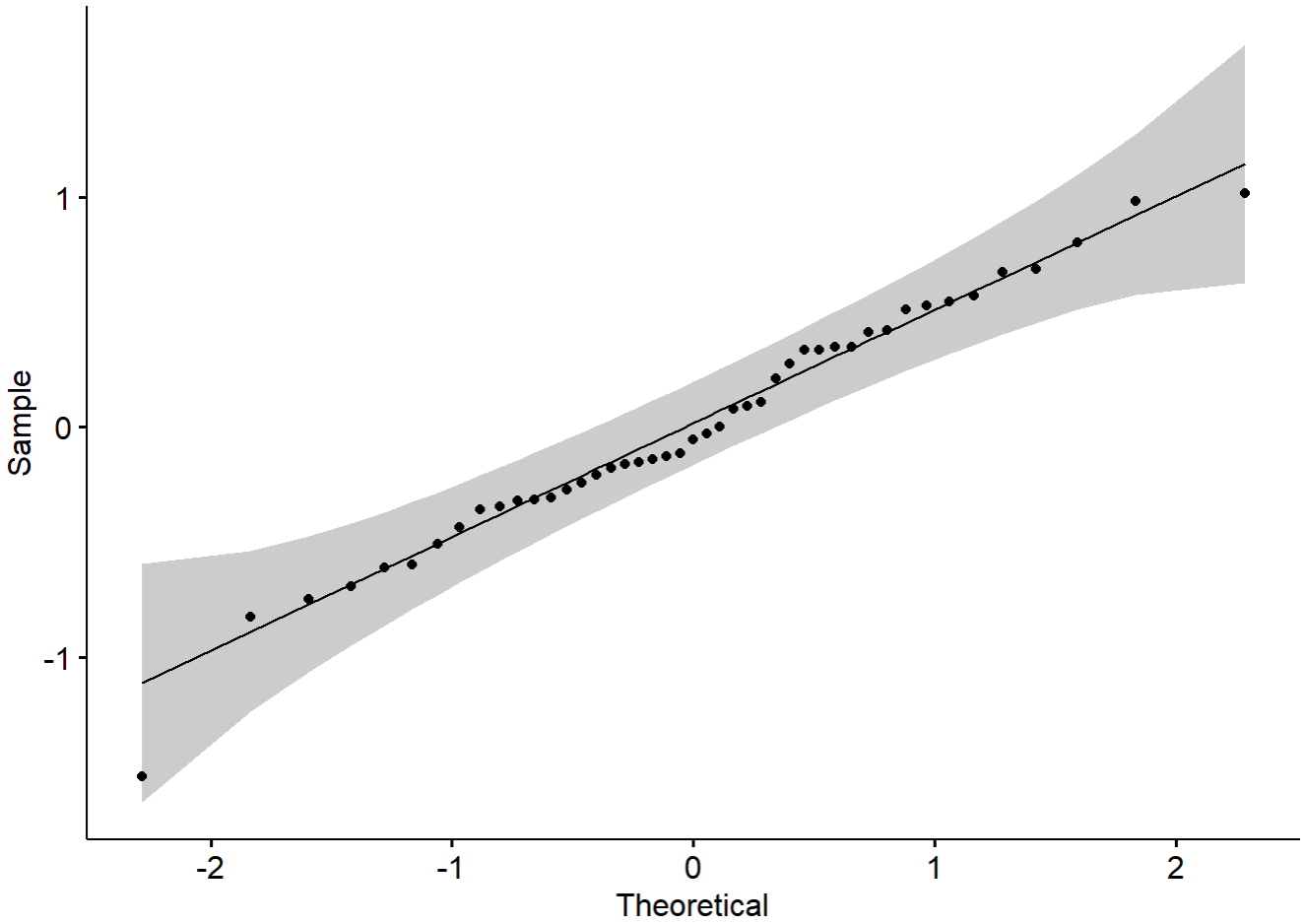
```
## NOTE: Results may be misleading due to involvement in interactions
```

```
em
```

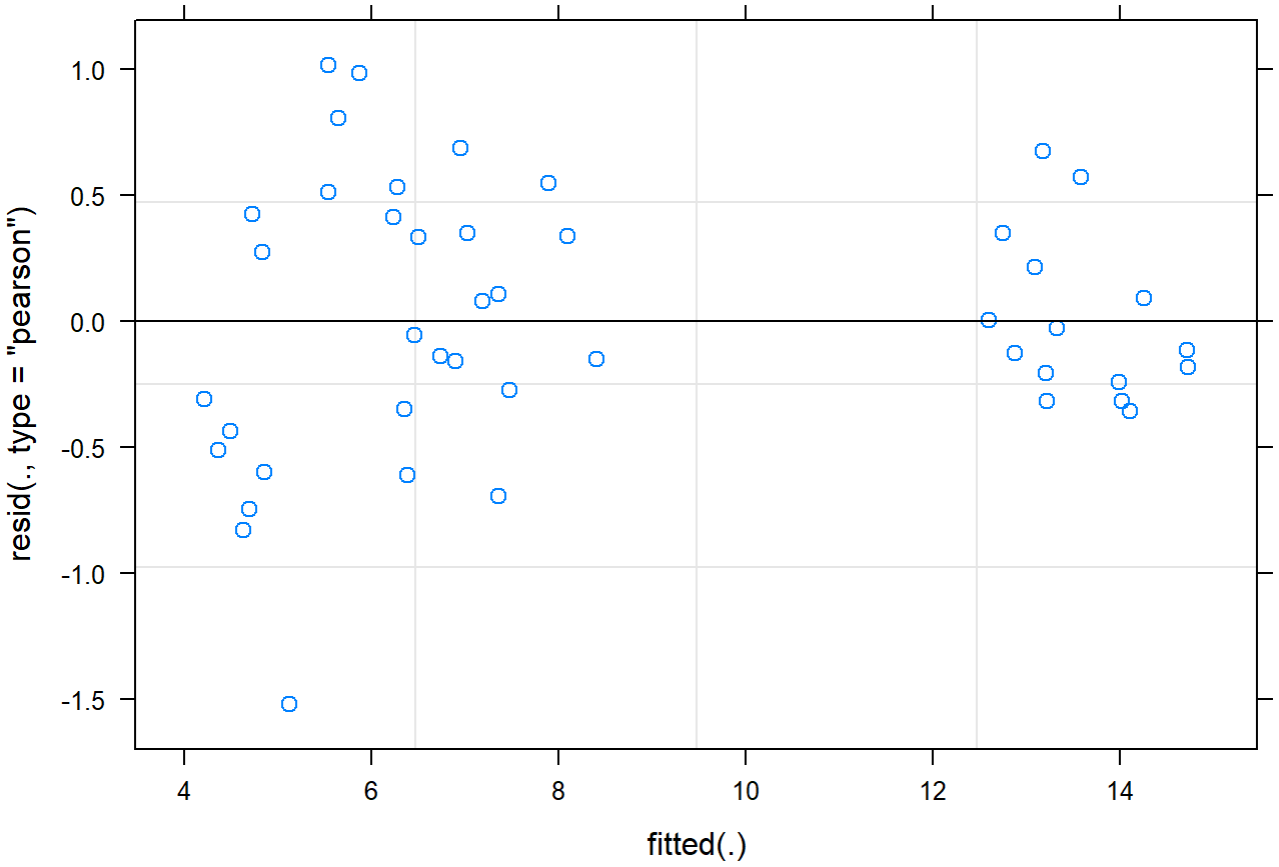
```
## $emmeans
```

```
##  Plot_type emmean   SE df lower.CL upper.CL
##  MS          8.39 0.37 12     7.58     9.20
##  PC          8.87 0.37 12     8.06     9.68
##  ST          8.59 0.37 12     7.78     9.39
##
## Results are averaged over the levels of: Date
## Degrees-of-freedom method: kenward-roger
## Confidence level used: 0.95
##
## $contrasts
##  contrast estimate    SE df t.ratio p.value
##  MS - PC    -0.478 0.524 12 -0.913  0.6430
##  MS - ST    -0.196 0.524 12 -0.374  0.9264
##  PC - ST     0.282 0.524 12  0.539  0.8539
##
## Results are averaged over the levels of: Date
## P value adjustment: tukey method for comparing a family of 3 estimates
```

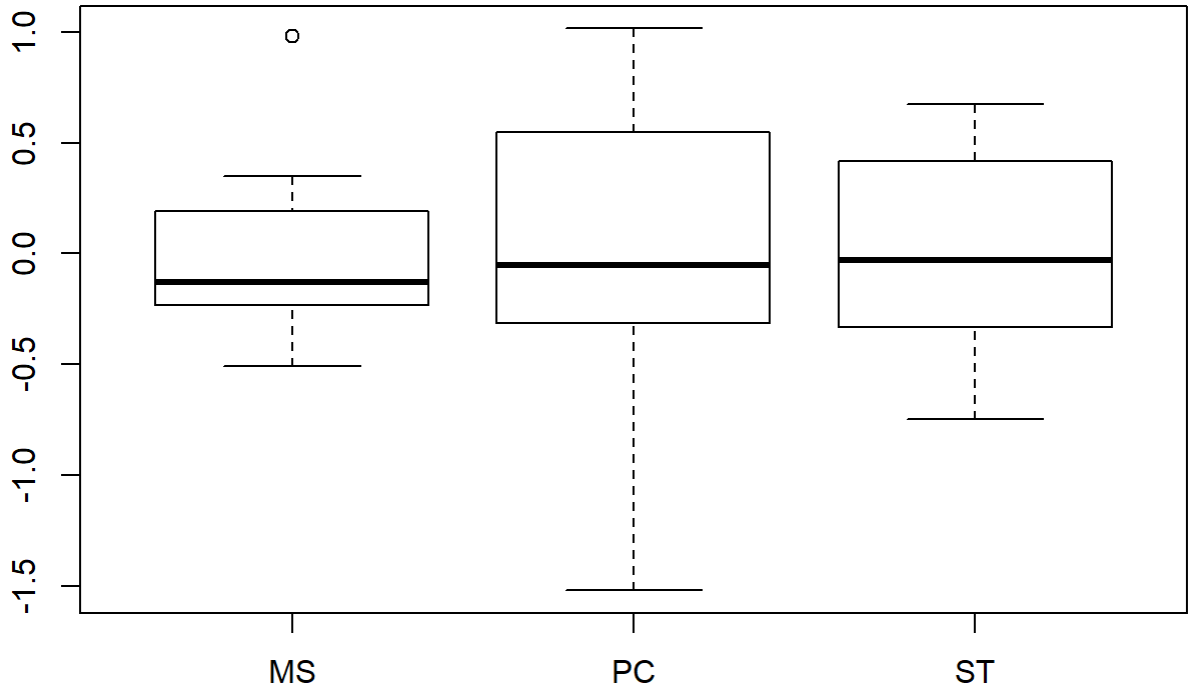
```
sumYA2015July[c(10:12),c(2:7)] <- summary(em)$emmeans

ggqqplot(residuals(mod))
```



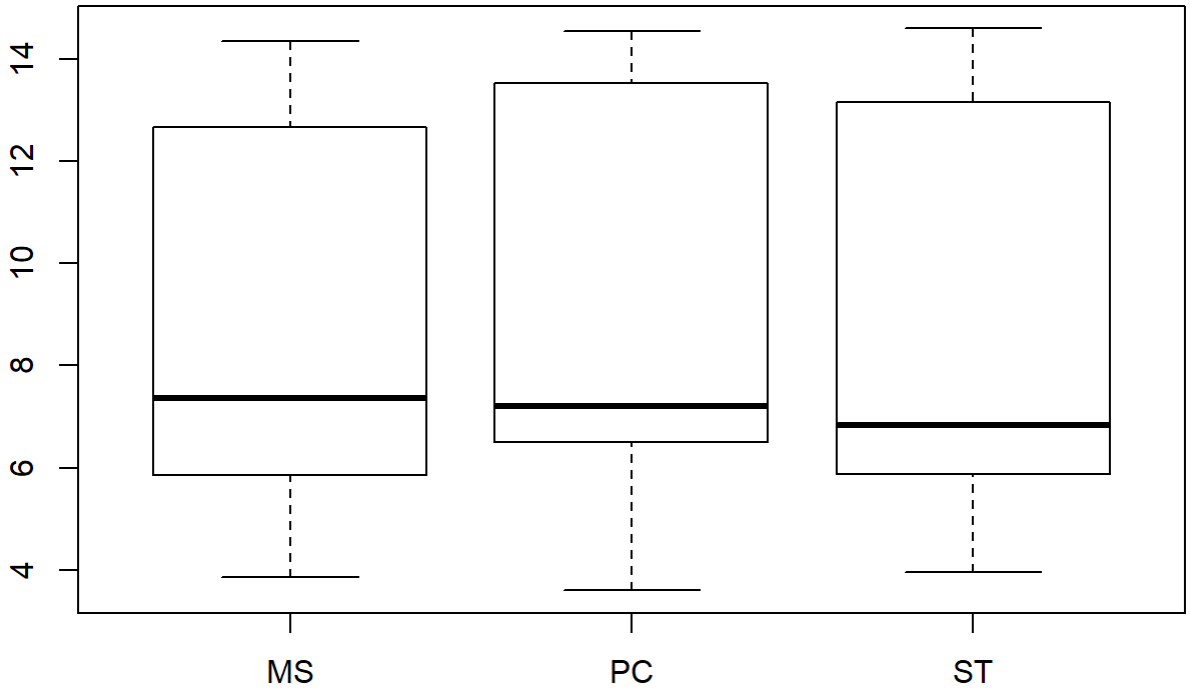

```
plot(mod)
```



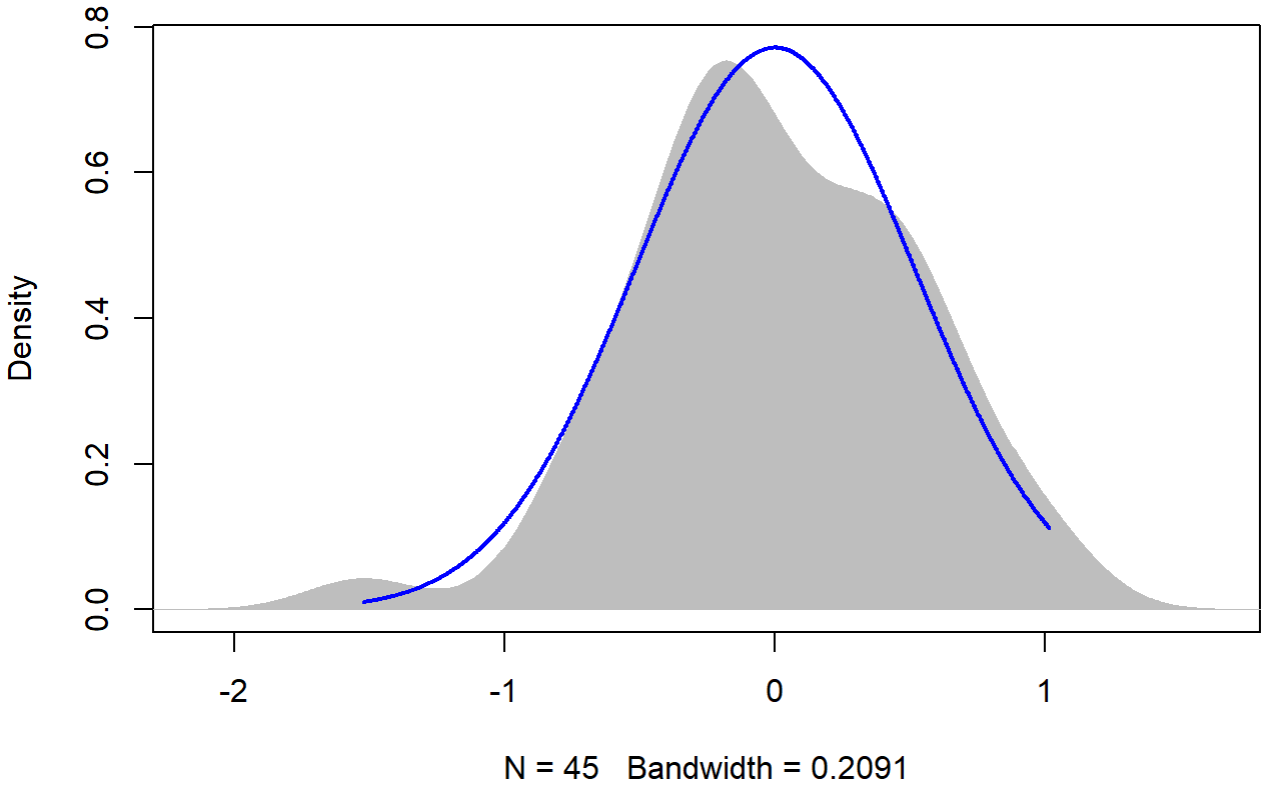

```
boxplot(residuals(mod) ~ TV20$Plot_type)
```




```
boxplot(TV20$Avg~ TV20$Plot_type)
```




```
plotNormalDensity(resid(mod))
```



Graph over time - 2015 Reforestation July - NOT NORMALIZED

```
sumYA2015July[,'Plot_type']<-factor(sumYA2015July[,'Plot_type'])
tiff("YA2015JulyNONNORM.tiff", width = 7, height = 4, units = 'in', res = 100)

pd <- position_dodge(0.3)

ggplot(sumYA2015July, aes(x=Flight_hour, y=emmeans, colour=Plot_type)) +
  geom_errorbar(aes(ymin=lower.CL, ymax=Upper.cl), width=.3, position=position_dodge(width=0.3
)) +
  geom_point(position=pd, size=3, shape=21, fill="white") +
  geom_line(position=pd, linetype = "dashed") +
  xlab("Time of day (24-hr format)") +
  ylab(expression("EM Mean Surface Temperature  " ( degree*C))) +
  scale_colour_manual(values = c("#9449CC", "#C5433A", "#008C91"), name="Plot type",
                      breaks=c("1", "2", "3"),
                      labels=c("Spray-and-Mow Control", "Passive Control", "Topsoil Recipient"))
+
  expand_limits(y=c(-4,4)) +
  scale_y_continuous(breaks=c(0, 5, 10, 15, 20, 25)) +
  scale_x_continuous(breaks=c(12,14,16,18,20)) +
  theme_bw() +
  theme(legend.position=c(0.2,0.2), legend.title = element_text(size = 12, face = "bold"),
        legend.text = element_text(size = 12), text = element_text(size=12), axis.text = eleme
nt_text(color = "black", size=12.5), axis.title=element_text(size=12.5)) +
```

```
  annotate(geom="label",x = 12.2,  y = 15,
           label = "p = 0.063 \n(6, 3)", fontface = "plain", col ="black", size = 3.5, fill =
"white") +
  annotate(geom="label",x = 14,  y = 15,
           label ="p = 0.214 \n(5, 3)", fontface = "plain", col ="black", size = 3.5, fill = "
white") +
   annotate(geom="label",x = 16,  y = 7.5,
           label = "TR-MS p = 0.101\nTR-PC p = 0.089\nMS-PC p = 0.046\nmR^2 = 0.42\n (5, 3)",
           fontface = "plain", col ="black", size = 3.5, fill = "white") +
  annotate(geom="label",x = 19.7,  y = 15,
           label = "p = 0.519 \n(6, 3)", fontface = "plain", col ="black", size = 3.5, fill =
"white") +
    annotate(geom="label",x = 12,  y = 23,
           label = "A", fontface = "bold", col ="black", size = 4)


dev.off()
```

```
## png
##   2
```

NORMALIZED mean temp 2015 Reforestation July

Temp over time 2015 Reforestation - July

```
TV <- read.csv("ThermVegAvgNo3rd.csv")

TV <- filter(TV, Field == "YA2015", Month == "July")
sumYA2015July<- read.csv("f_hours_2015.csv")
```

12

```
TV12 <- filter(TV, Flight_hour == "12")

mod <-lmer(AvgMout ~ Plot_type * Date + (1|Plot_id), data = TV12)

anova(mod, ddf="Kenward-Roger")
```

```
## Type III Analysis of Variance Table with Kenward-Roger's method
##                Sum Sq Mean Sq NumDF DenDF F value  Pr(>F)
## Plot_type      0.8052 0.40259     2    12  1.1855 0.33899
## Date           0.2110 0.10550     2    24  0.3106 0.73587
## Plot_type:Date 4.4050 1.10125     4    24  3.2427 0.02918 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

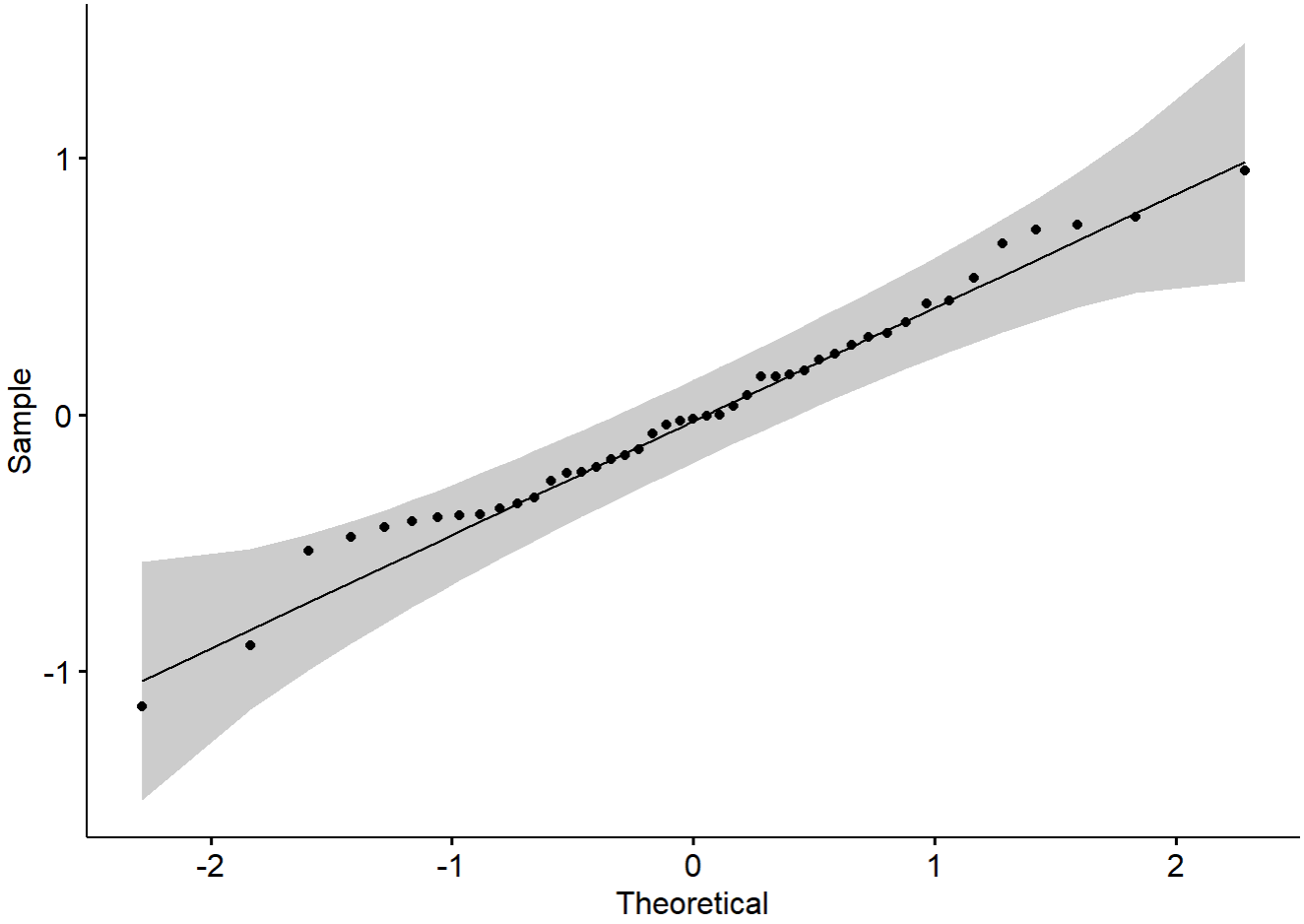
```
em <-emmeans(mod, pairwise ~ Plot_type, adjust = "Tukey")
```

```
## NOTE: Results may be misleading due to involvement in interactions
```

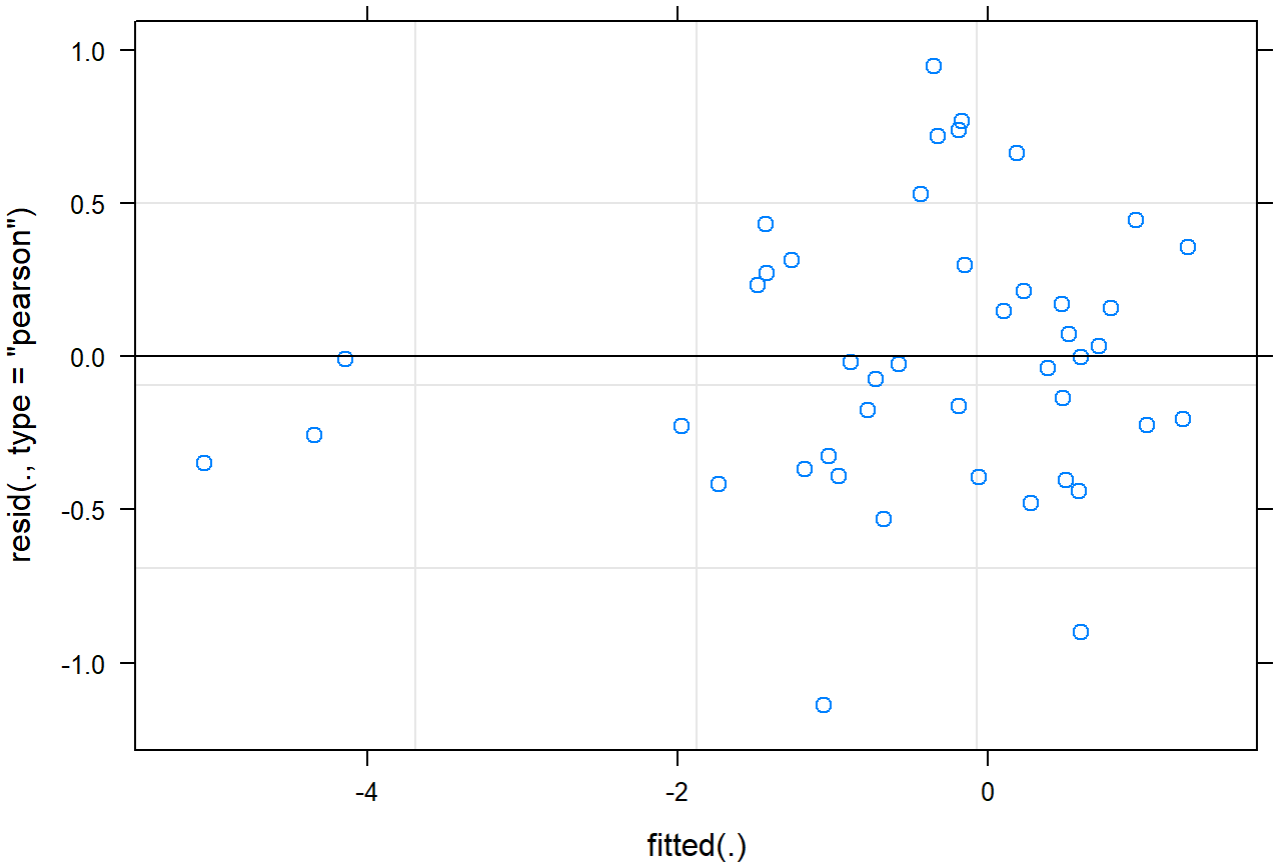
```
em
```

```
## $emmeans
##  Plot_type emmean    SE df lower.CL upper.CL
##  MS         -0.54 0.631 12    -1.92    0.835
##  PC          0.24 0.631 12    -1.14    1.615
##  ST         -1.13 0.631 12    -2.51    0.245
##
## Results are averaged over the levels of: Date
## Degrees-of-freedom method: kenward-roger
## Confidence level used: 0.95
##
## $contrasts
##  contrast estimate    SE df t.ratio p.value
##  MS - PC     -0.78 0.893 12 -0.874  0.6662
##  MS - ST      0.59 0.893 12  0.661  0.7898
##  PC - ST      1.37 0.893 12  1.535  0.3101
##
## Results are averaged over the levels of: Date
## P value adjustment: tukey method for comparing a family of 3 estimates
```

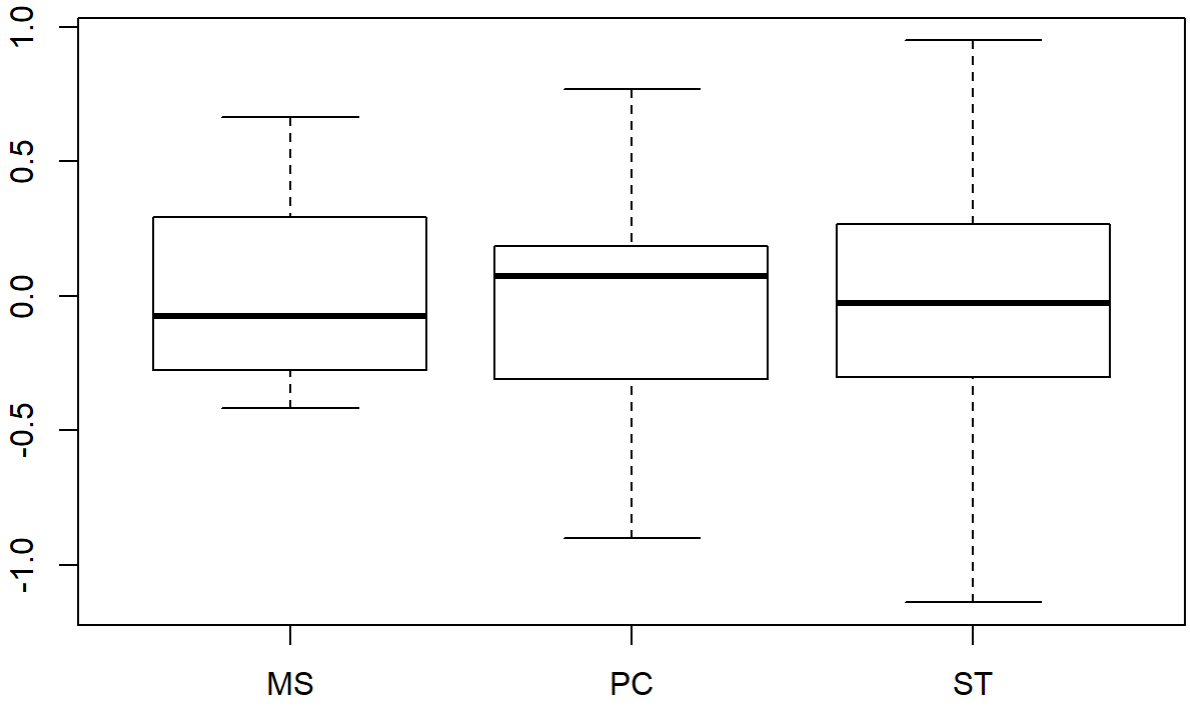
```
sumYA2015July[c(1:3),c(2:7)] <- summary(em)$emmeans

ggqqplot(residuals(mod))
```



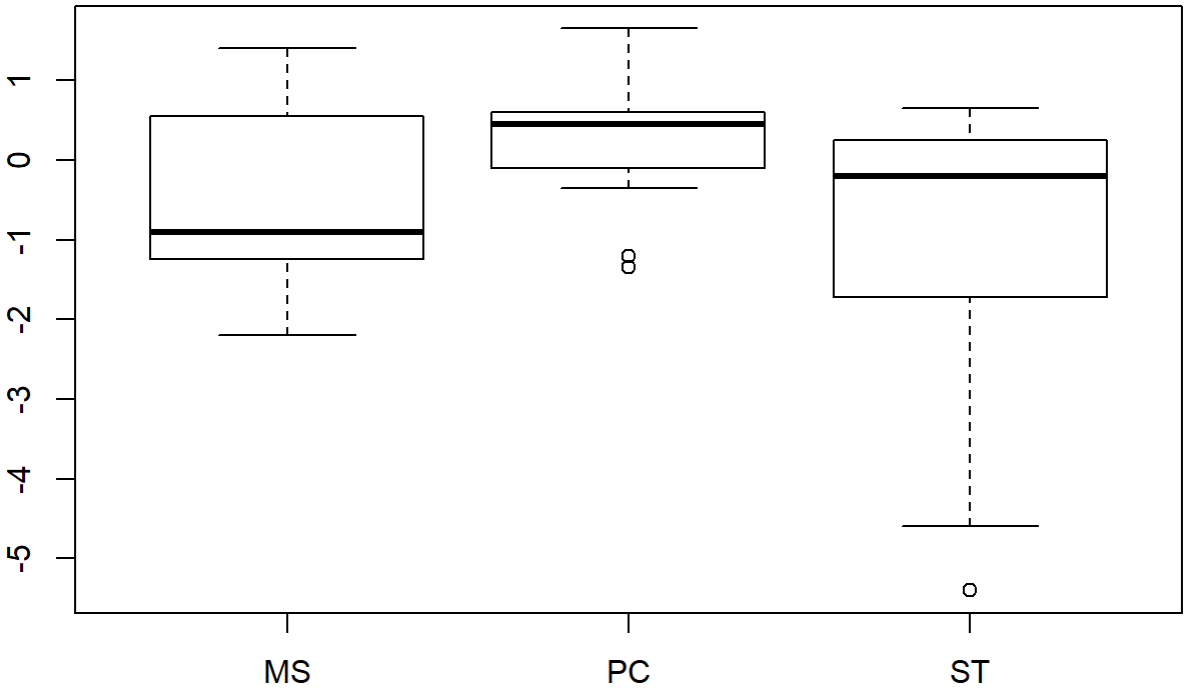
```
plot(mod)
```



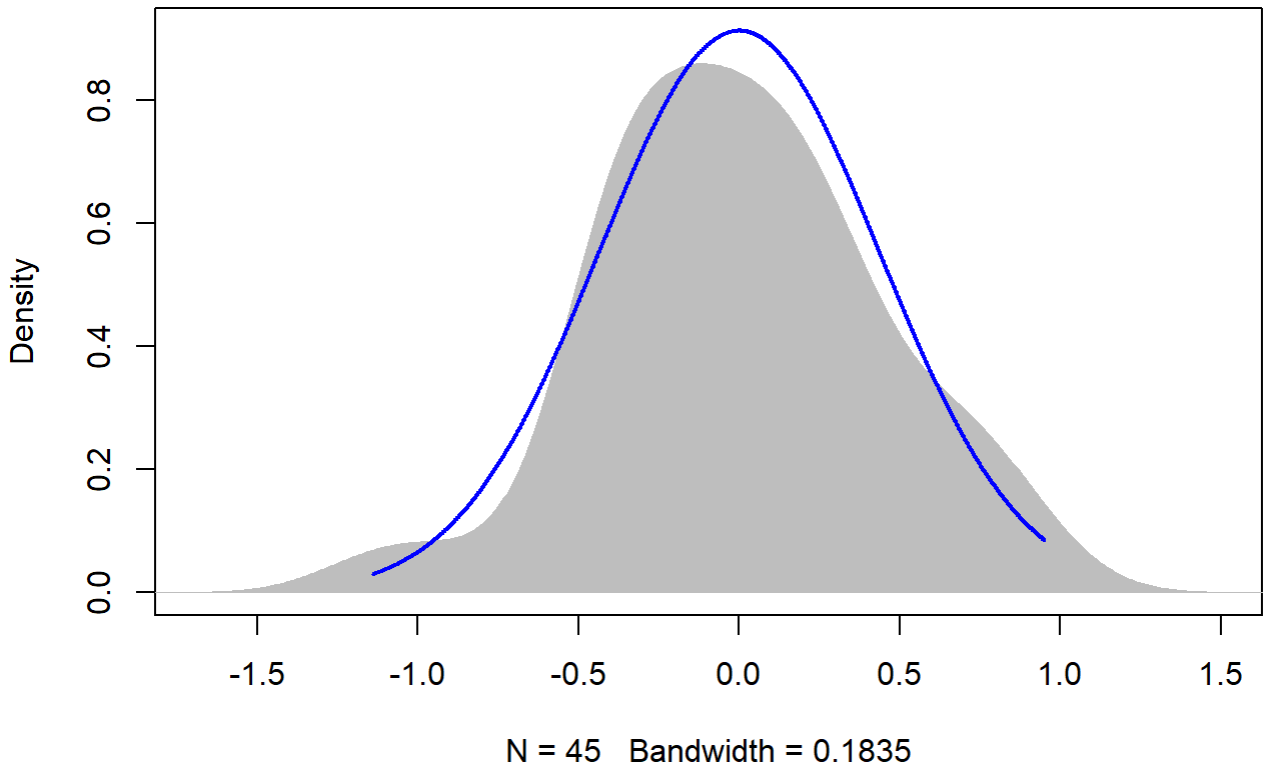

```
boxplot(residuals(mod) ~ TV12$Plot_type)
```




```
boxplot(TV12$AvgMout~ TV12$Plot_type)
```




```
plotNormalDensity(resid(mod))
```



14

```
TV14 <- filter(TV, Flight_hour == "14")

mod <-lmer(AvgMout ~ Plot_type * Date + (1|Plot_id), data = TV14)

anova(mod, ddf="Kenward-Roger")
```

```
## Type III Analysis of Variance Table with Kenward-Roger's method
##                Sum Sq Mean Sq NumDF  DenDF F value Pr(>F)
## Plot_type      3.5524 1.77620     2 11.996  1.9329 0.1872
## Date           2.7772 1.38858     2 23.092  1.5111 0.2417
## Plot_type:Date 3.9751 0.99376     4 23.086  1.0814 0.3886
```

```
em <-emmeans(mod, pairwise ~ Plot_type, adjust = "Tukey")
```

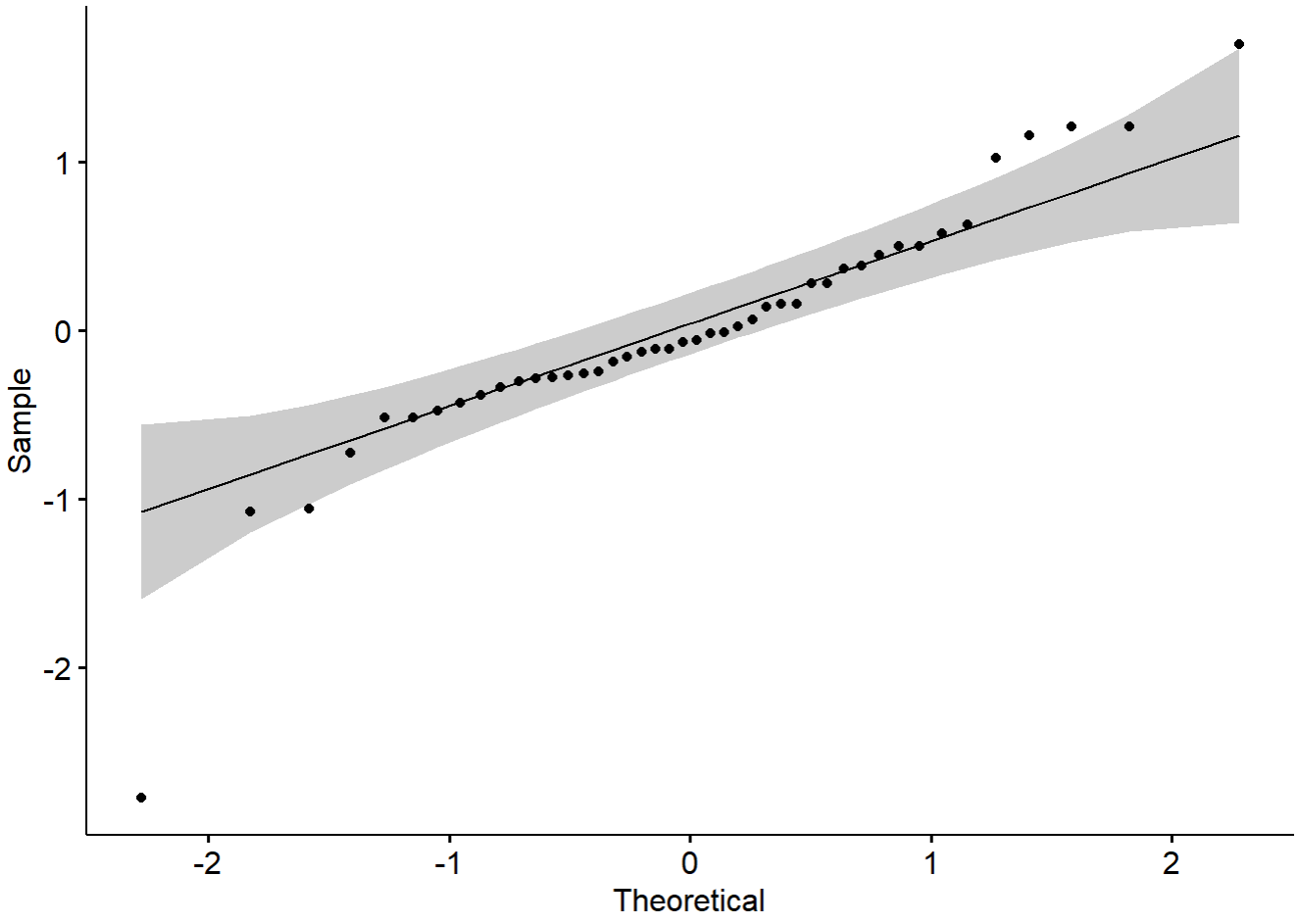
```
## NOTE: Results may be misleading due to involvement in interactions
```

```
em
```

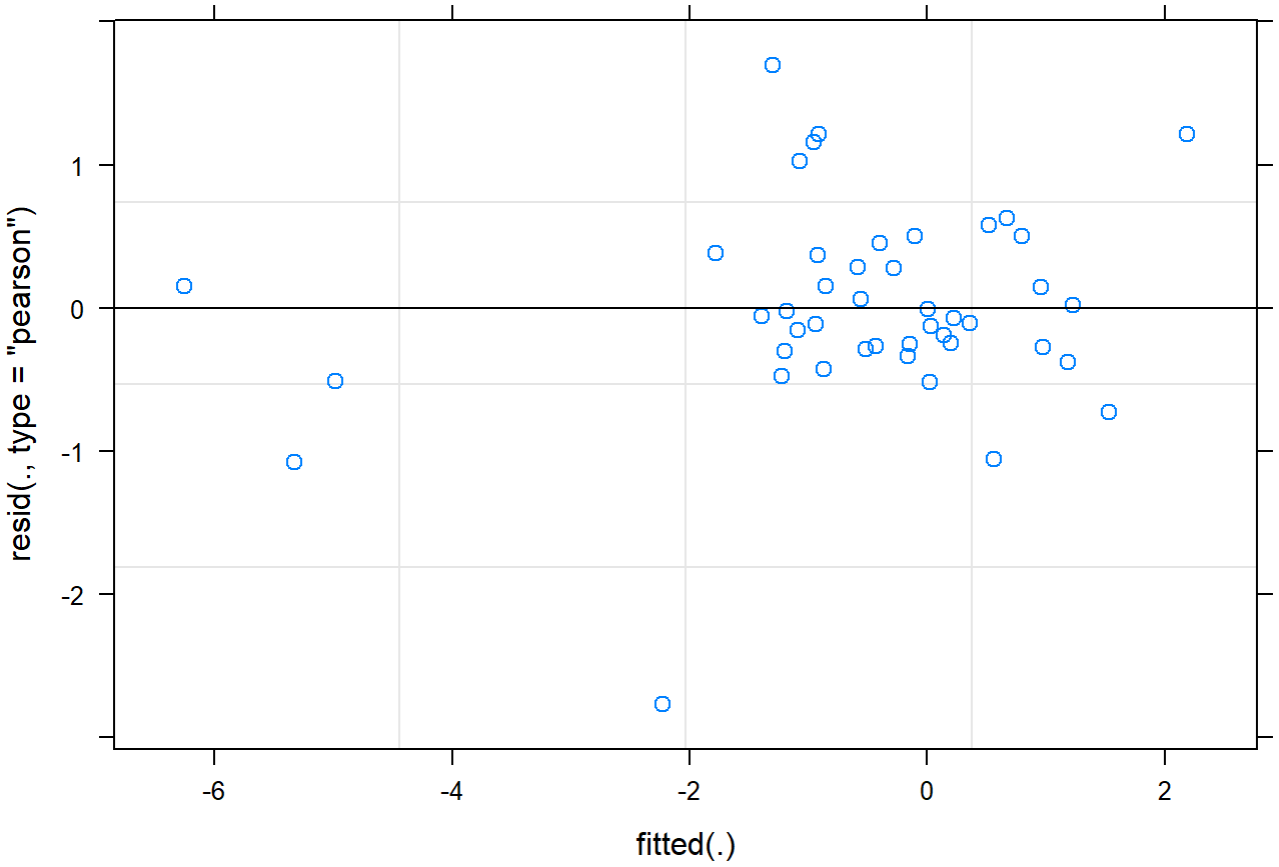
```
## $emmeans
##  Plot_type emmean    SE   df lower.CL upper.CL
##  MS        -0.439 0.745 12.2    -2.06    1.182
```

```
##  PC         0.320 0.740 11.9    -1.29    1.934
##  ST        -1.717 0.740 11.9    -3.33   -0.102
##
## Results are averaged over the levels of: Date
## Degrees-of-freedom method: kenward-roger
## Confidence level used: 0.95
##
## $contrasts
##  contrast estimate   SE   df t.ratio p.value
##  MS - PC    -0.759 1.05 12.1 -0.723  0.7551
##  MS - ST     1.278 1.05 12.1  1.216  0.4665
##  PC - ST     2.037 1.05 11.9  1.945  0.1689
##
## Results are averaged over the levels of: Date
## P value adjustment: tukey method for comparing a family of 3 estimates
```

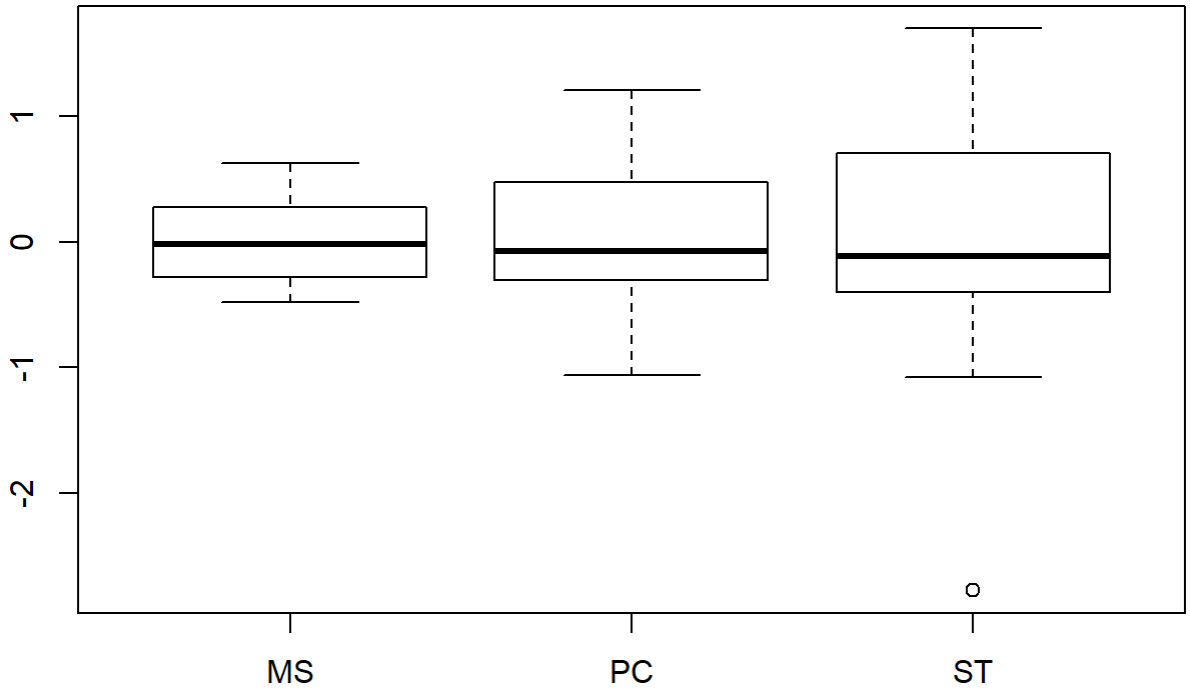
```
sumYA2015July[c(4:6),c(2:7)] <- summary(em)$emmeans

ggqqplot(residuals(mod))
```



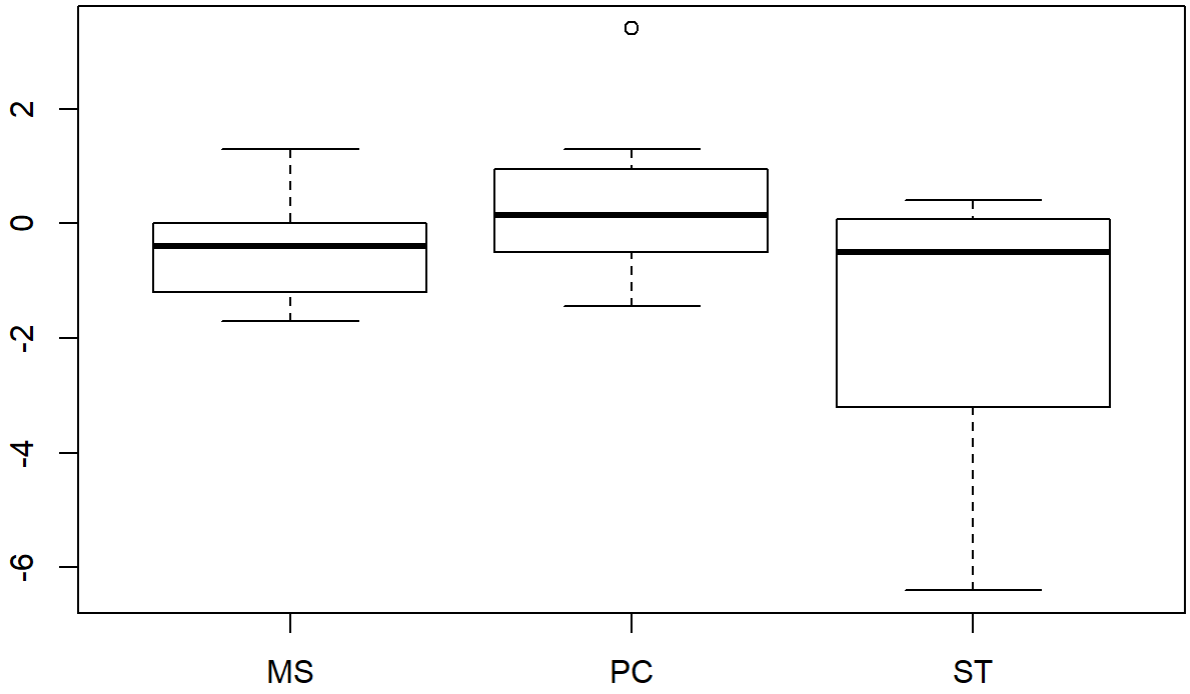

```
plot(mod)
```



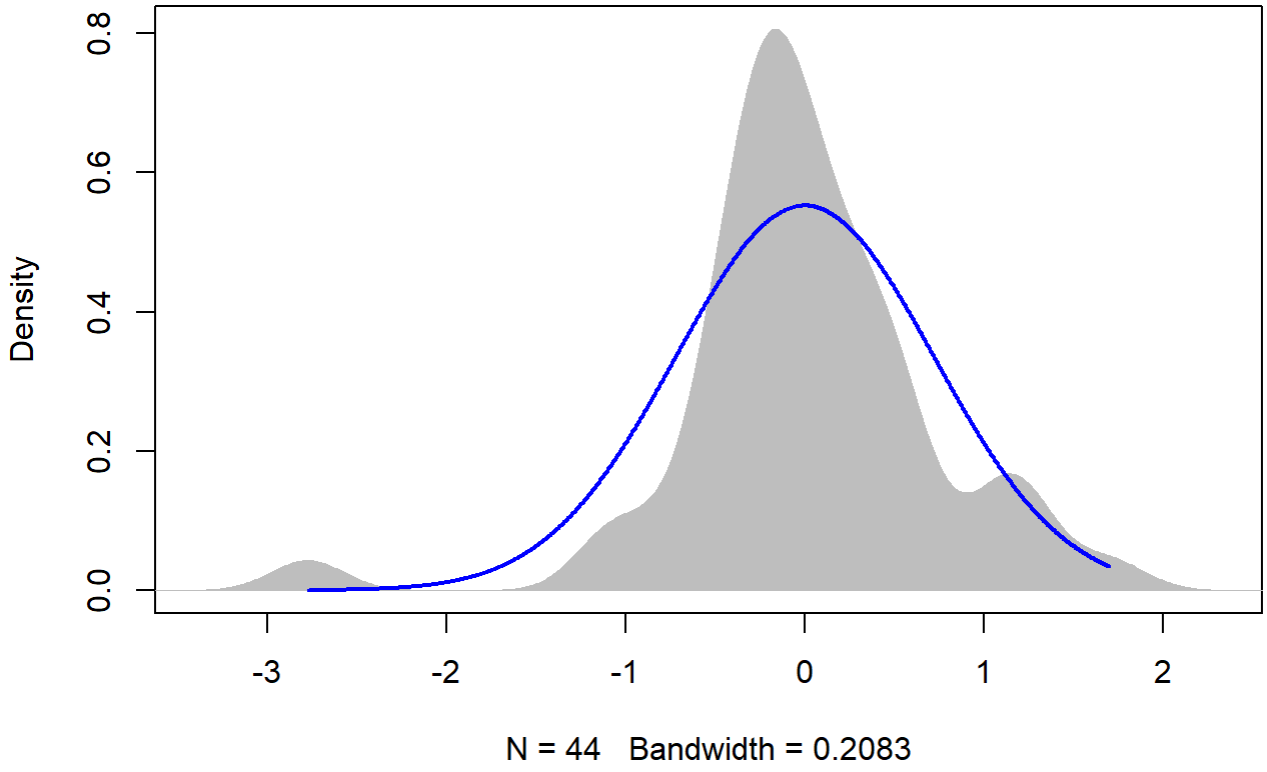

```
boxplot(residuals(mod) ~ TV14$Plot_type)
```




```
boxplot(TV14$AvgMout~ TV14$Plot_type)
```




```
plotNormalDensity(resid(mod))
```




```
outlierTest(lm(AvgMout ~ Plot_type, data = TV14))
```

```
## No Studentized residuals with Bonferonni p < 0.05
## Largest |rstudent|:
##    rstudent unadjusted p-value Bonferonni p
## 7 -3.039643          0.0041634      0.18319
```

16

```
TV16 <- filter(TV, Flight_hour == "16")

mod <-lmer(AvgMout ~ Plot_type * Date + (1|Plot_id), data = TV16)

anova(mod, ddf="Kenward-Roger")
```

```
## Type III Analysis of Variance Table with Kenward-Roger's method
##                  Sum Sq Mean Sq NumDF DenDF F value Pr(>F)
## Plot_type      0.56637 0.28319     2    12  0.6938 0.5187
## Date           0.74100 0.37050     2    24  0.9077 0.4169
## Plot_type:Date 0.50267 0.12567     4    24  0.3079 0.8698
```

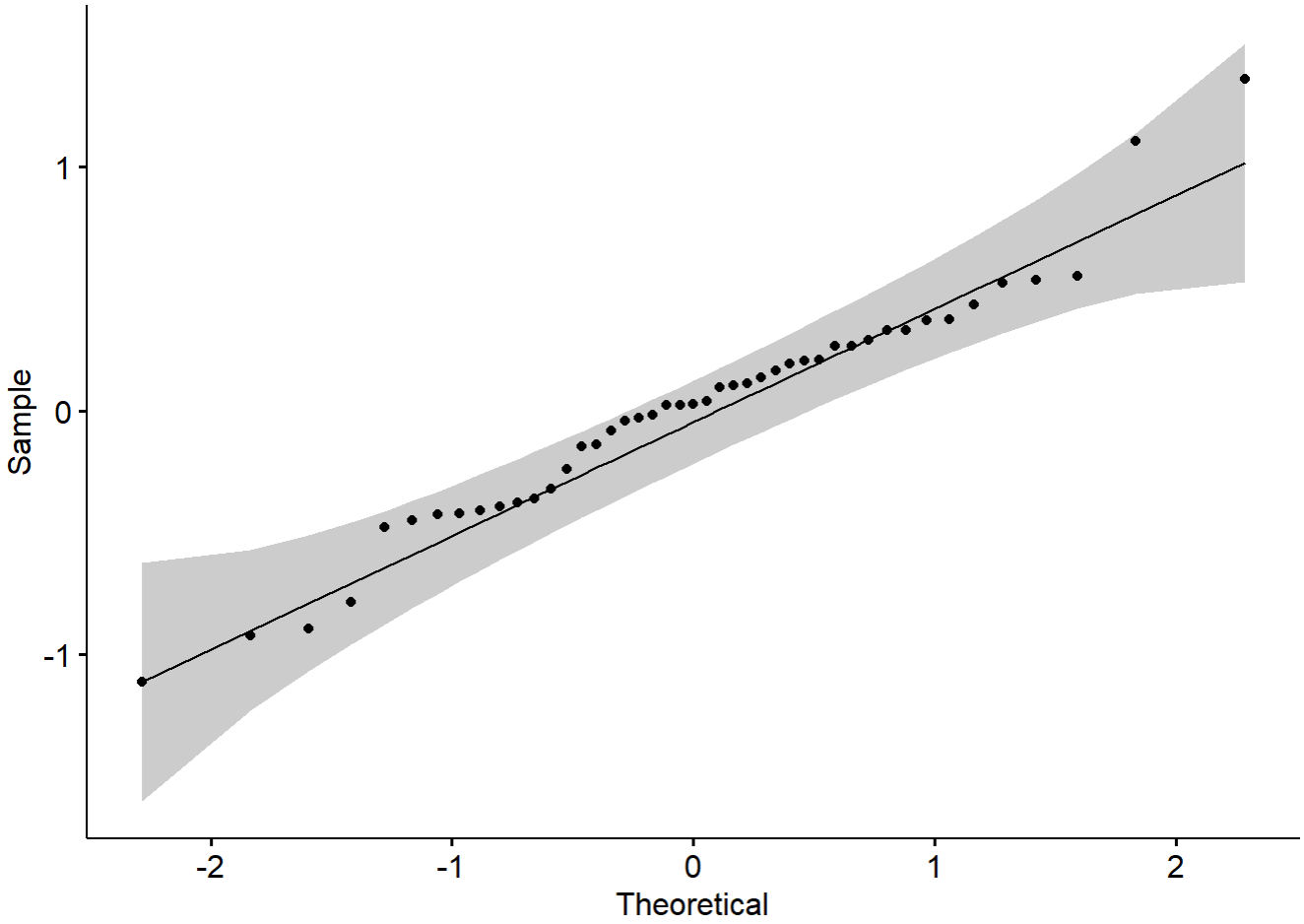
```
em <-emmeans(mod, pairwise ~ Plot_type, adjust = "Tukey")
```

```
## NOTE: Results may be misleading due to involvement in interactions
```

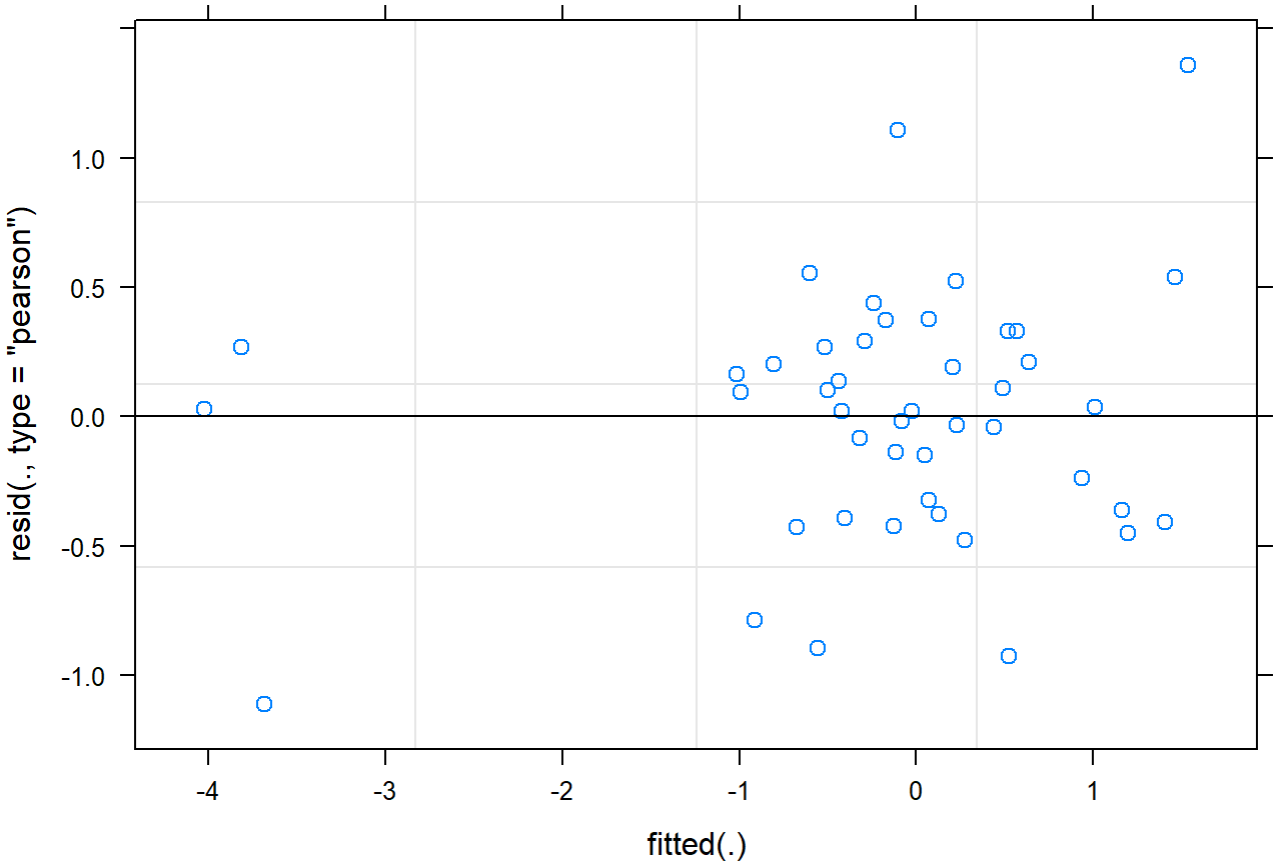
```
em
```

```
## $emmeans
##  Plot_type emmean    SE df lower.CL upper.CL
##  MS        -0.283 0.592 12    -1.57    1.007
##  PC         0.370 0.592 12    -0.92    1.660
##  ST        -0.597 0.592 12    -1.89    0.693
##
## Results are averaged over the levels of: Date
## Degrees-of-freedom method: kenward-roger
## Confidence level used: 0.95
##
## $contrasts
##  contrast estimate    SE df t.ratio p.value
##  MS - PC    -0.653 0.837 12 -0.780  0.7217
##  MS - ST     0.313 0.837 12  0.374  0.9262
##  PC - ST     0.967 0.837 12  1.154  0.5010
##
## Results are averaged over the levels of: Date
## P value adjustment: tukey method for comparing a family of 3 estimates
```

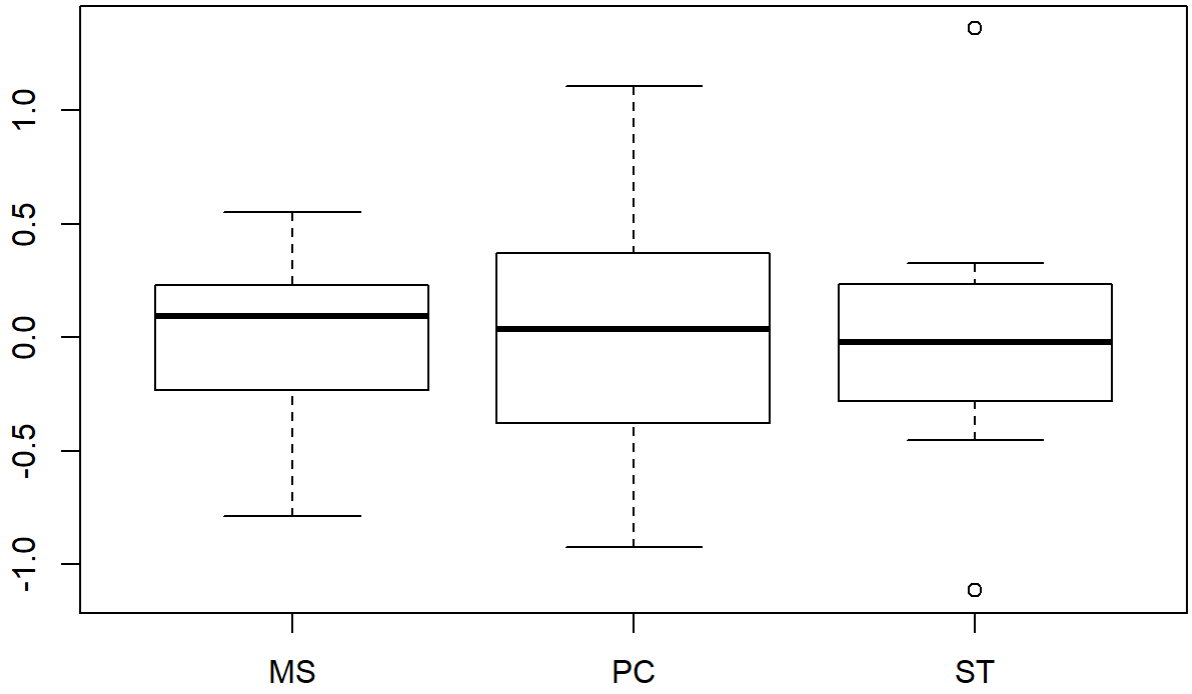
```
sumYA2015July[c(7:9),c(2:7)] <- summary(em)$emmeans

ggqqplot(residuals(mod))
```



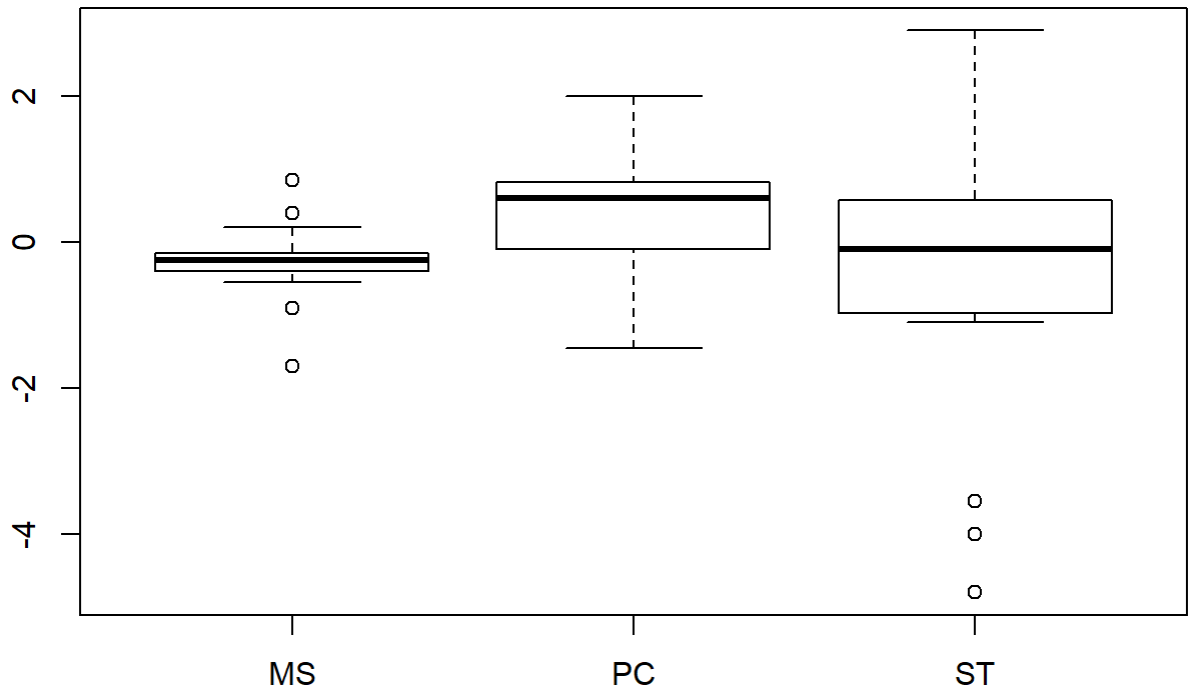

```
plot(mod)
```



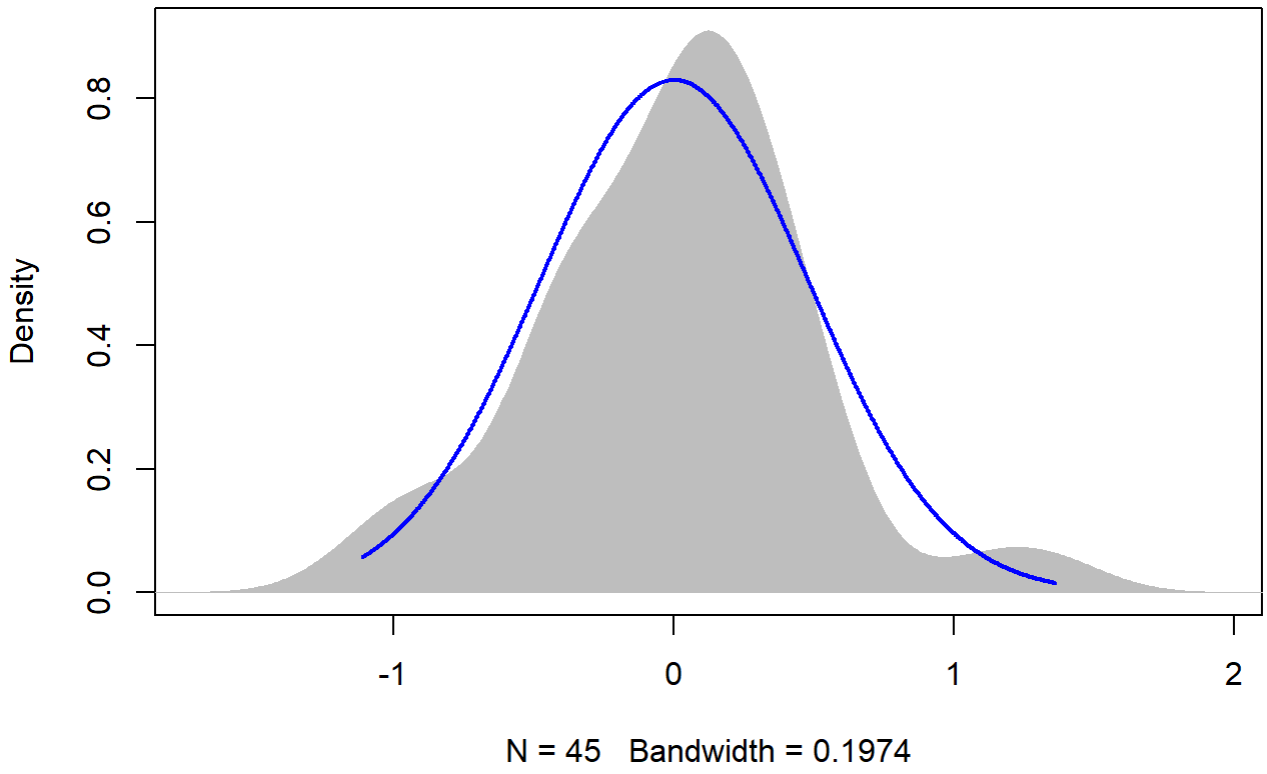

```
boxplot(residuals(mod) ~ TV16$Plot_type)
```




```
boxplot(TV16$AvgMout~ TV16$Plot_type)
```




```
plotNormalDensity(resid(mod))
```



20

```
TV20 <- filter(TV, Flight_hour == "20")

mod <-lmer(AvgMout ~ Plot_type * Date + (1|Plot_id), data = TV20)

r.squaredGLMM(mod)
```

```
##            R2m       R2c
## [1,] 0.4093752 0.7100132
```

```
anova(mod, ddf="Kenward-Roger")
```

```
## Type III Analysis of Variance Table with Kenward-Roger's method
##                 Sum Sq Mean Sq NumDF DenDF F value  Pr(>F)
## Plot_type      1.05220 0.52610     2    12  6.0657 0.01512 *
## Date           0.48775 0.24387     2    24  2.8117 0.07997 .
## Plot_type:Date 0.57500 0.14375     4    24  1.6574 0.19268
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

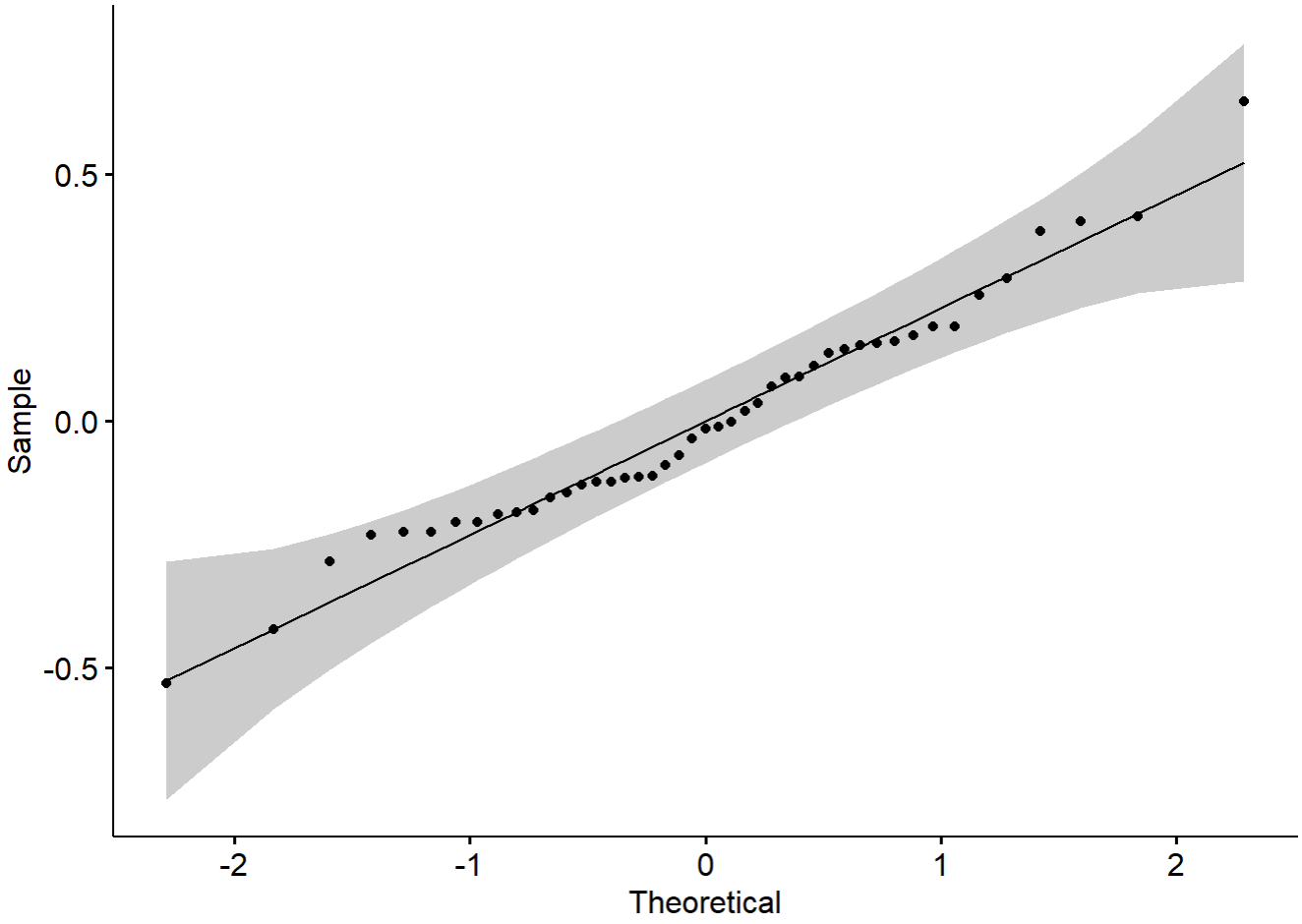
```
em <-emmeans(mod, pairwise ~ Plot_type, adjust = "Tukey")
```

```
## NOTE: Results may be misleading due to involvement in interactions
```

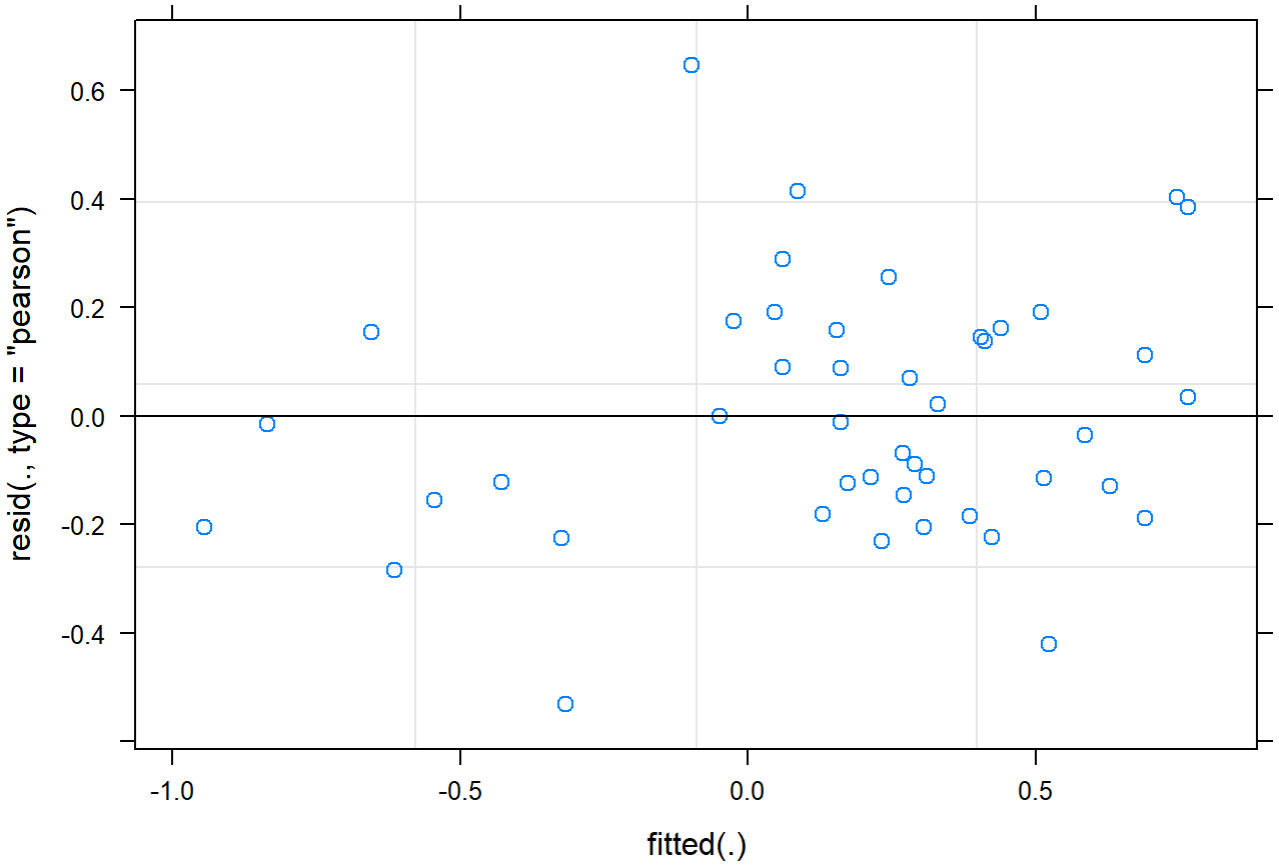
```
em
```

```
## $emmeans
##  Plot_type emmean    SE df lower.CL upper.CL
##  MS         0.377 0.154 12   0.0408   0.7126
##  PC         0.392 0.154 12   0.0558   0.7276
##  ST        -0.273 0.154 12  -0.6092   0.0626
##
## Results are averaged over the levels of: Date
## Degrees-of-freedom method: kenward-roger
## Confidence level used: 0.95
##
## $contrasts
##  contrast estimate    SE df t.ratio p.value
##  MS - PC    -0.015 0.218 12 -0.069  0.9974
##  MS - ST     0.650 0.218 12  2.981  0.0287
##  PC - ST     0.665 0.218 12  3.050  0.0253
##
## Results are averaged over the levels of: Date
## P value adjustment: tukey method for comparing a family of 3 estimates
```

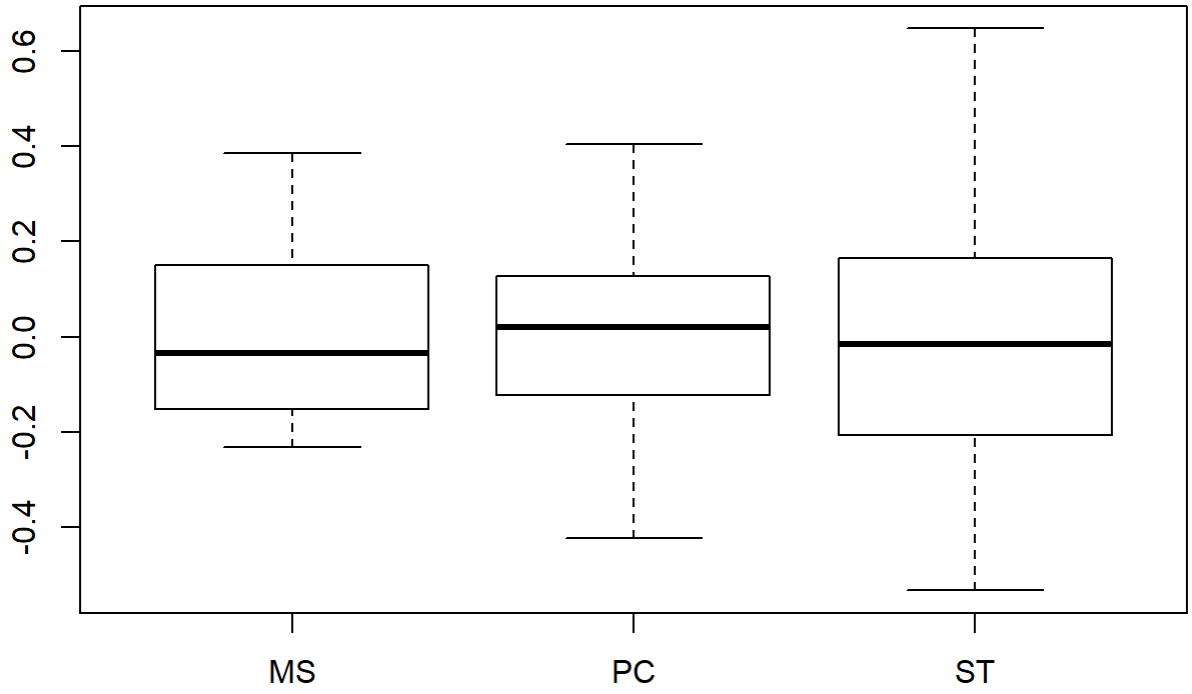
```
sumYA2015July[c(10:12),c(2:7)] <- summary(em)$emmeans

ggqqplot(residuals(mod))
```



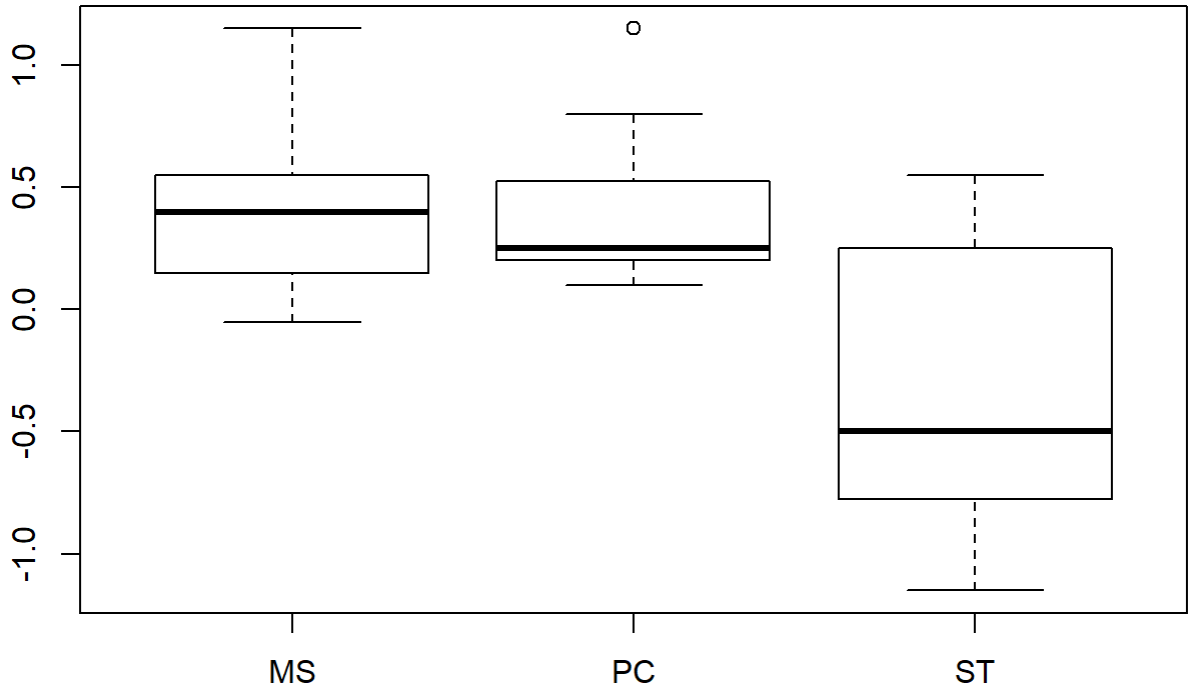

```
plot(mod)
```



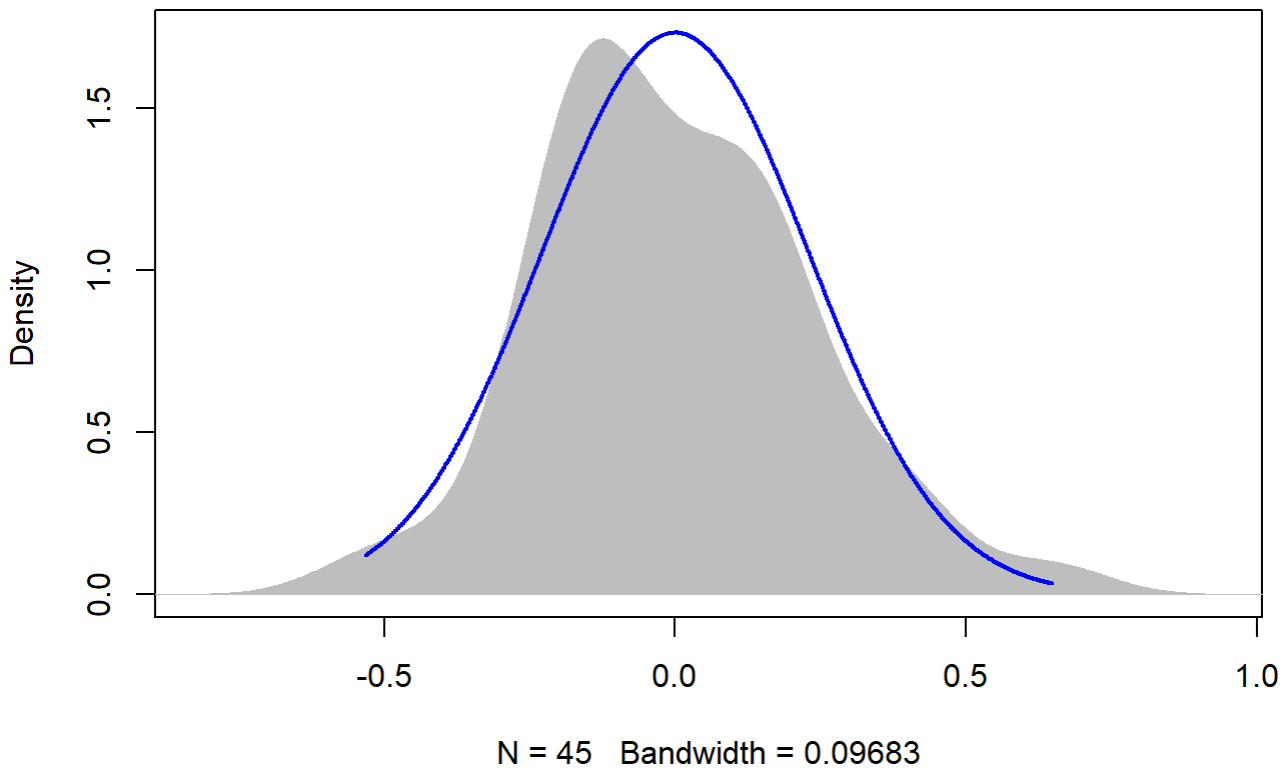

```
boxplot(residuals(mod) ~ TV20$Plot_type)
```




```
boxplot(TV20$AvgMout~ TV20$Plot_type)
```




```
plotNormalDensity(resid(mod))
```



Graph over time - 2015 Reforestation July - NORMALIZED

```
sumYA2015July[,'Plot_type']<-factor(sumYA2015July[,'Plot_type'])
tiff("YA2015July.tiff", width = 7, height = 4, units = 'in', res = 100)

pd <- position_dodge(0.3)

ggplot(sumYA2015July, aes(x=Flight_hour, y=emmeans, colour=Plot_type)) +
  geom_errorbar(aes(ymin=lower.CL, ymax=Upper.cl), width=.3, position=position_dodge(width=0.3
)) +
  geom_point(position=pd, size=3, shape=21, fill="white") +
  geom_line(position=pd, linetype = "dashed") +
  xlab("Time of day (24-hr format)") +
  ylab(expression("Norm. EM Mean Surface Net-Temperature  " ( degree*C))) +
  scale_colour_manual(values = c("#9449CC", "#C5433A", "#008C91"), name="Plot type",
                      breaks=c("1", "2", "3"),
                      labels=c("Spray-and-Mow Control", "Passive Control", "Topsoil Recipient"))
+
  expand_limits(y=c(-4,4)) +
  scale_y_continuous(breaks=c(-4, -2, 0, 2, 4)) +
  scale_x_continuous(breaks=c(12,14,16,18,20)) +
  theme_bw() +
  theme(legend.position=c(0.8,0.2), legend.title = element_text(size = 12, face = "bold"),
        legend.text = element_text(size = 12), text = element_text(size=12), axis.text = eleme
nt_text(color = "black", size=12.5), axis.title=element_text(size=12.5)) +
  annotate(geom="label",x = 12.2,  y = 2.8,
```

```
           label = "p = 0.729 \n(6, 3)", fontface = "plain", col ="black", size = 3.5, fill =
"white") +
  annotate(geom="label",x = 14,  y = 2.8,
           label ="p = 0.187 \n(5, 3)", fontface = "plain", col ="black", size = 3.5, fill = "
white") +
  annotate(geom="label",x = 16,  y = 2.8,
           label = "p = 0.519 \n(5, 3)", fontface = "plain", col ="black", size = 3.5, fill =
"white") +
  annotate(geom="label",x = 19.5,  y = 2.5,
           label = "TR-MS p = 0.028\nTR-PC p = 0.025\nMS-PC p = 0.997\nmR^2 = 0.41\n (6, 3)",
fontface = "plain", col ="black", size = 3.5, fill = "white") +
    annotate(geom="label",x = 12,  y = 3.8,
           label = "B", fontface = "bold", col ="black", size = 4)

dev.off()
```

```
## png
##   2
```

Temp over time 2015 Reforestation - September - NOT NORMALIZED

```
TV <-read.csv("ThermVegAvg.csv")
sumYA2015September <- read.csv("f_hours_2015.csv")

TV <- filter(TV, Field == "YA2015", Month == "September")
```

12

```
TV12 <- filter(TV, Flight_hour == "12")

outlierTest(lm(Avg~Plot_type * Date, data = TV12))
```

```
## No Studentized residuals with Bonferonni p < 0.05
## Largest |rstudent|:
##    rstudent unadjusted p-value Bonferonni p
## 32 2.952814          0.0055931      0.25169
```

```
mod <-lmer(Avg ~ Plot_type * Date + (1|Plot_id), data = TV12)

anova(mod, ddf="Kenward-Roger")
```

```
## Type III Analysis of Variance Table with Kenward-Roger's method
##                Sum Sq Mean Sq NumDF DenDF  F value    Pr(>F)
## Plot_type        1.27   0.633     2    12   0.4763    0.6323
## Date           325.24 162.622     2    24 122.2888 2.592e-13 ***
## Plot_type:Date   7.05   1.763     4    24   1.3257    0.2890
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

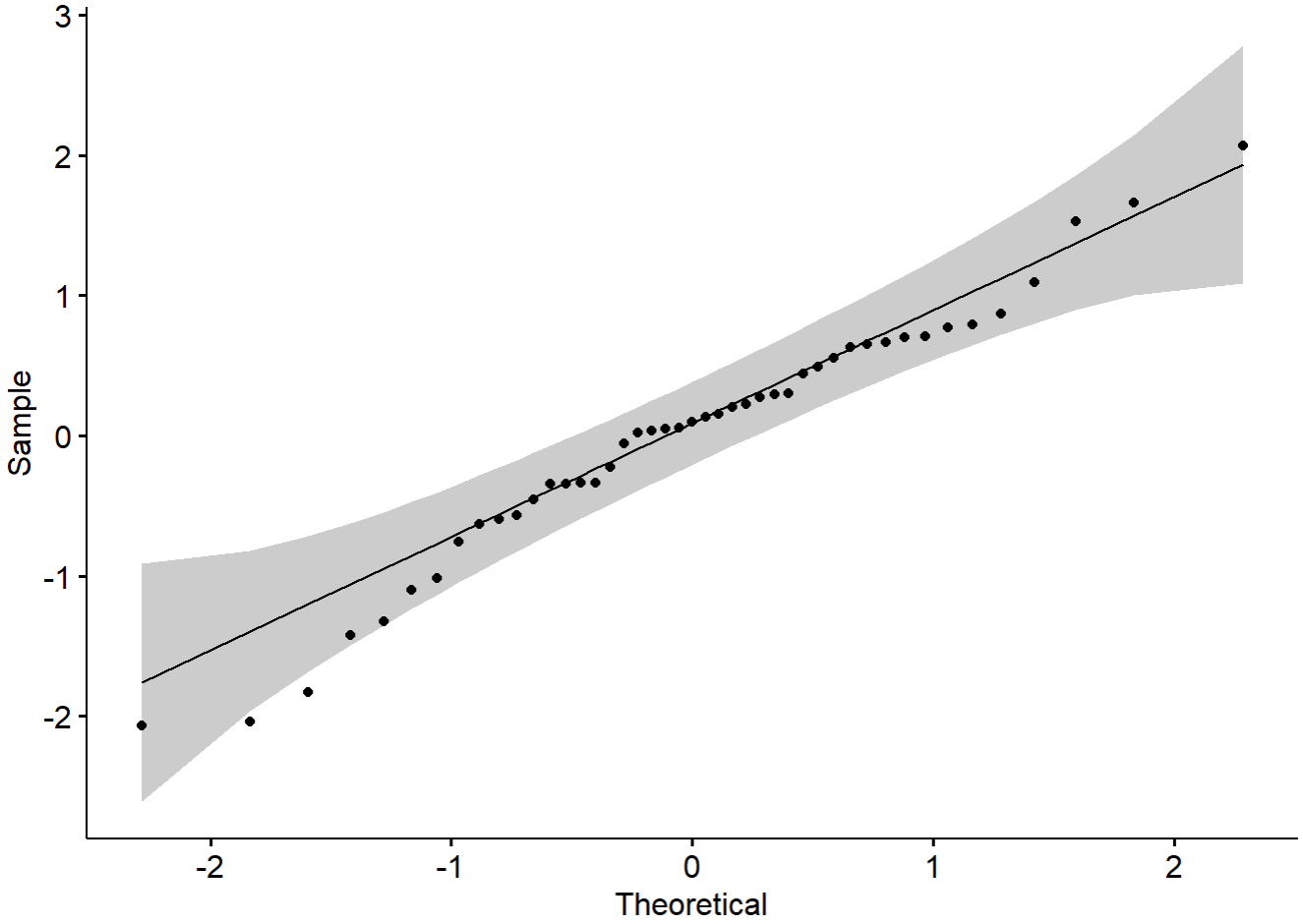
```
em <-emmeans(mod, pairwise ~ Plot_type, adjust = "Tukey")
```

```
## NOTE: Results may be misleading due to involvement in interactions
```

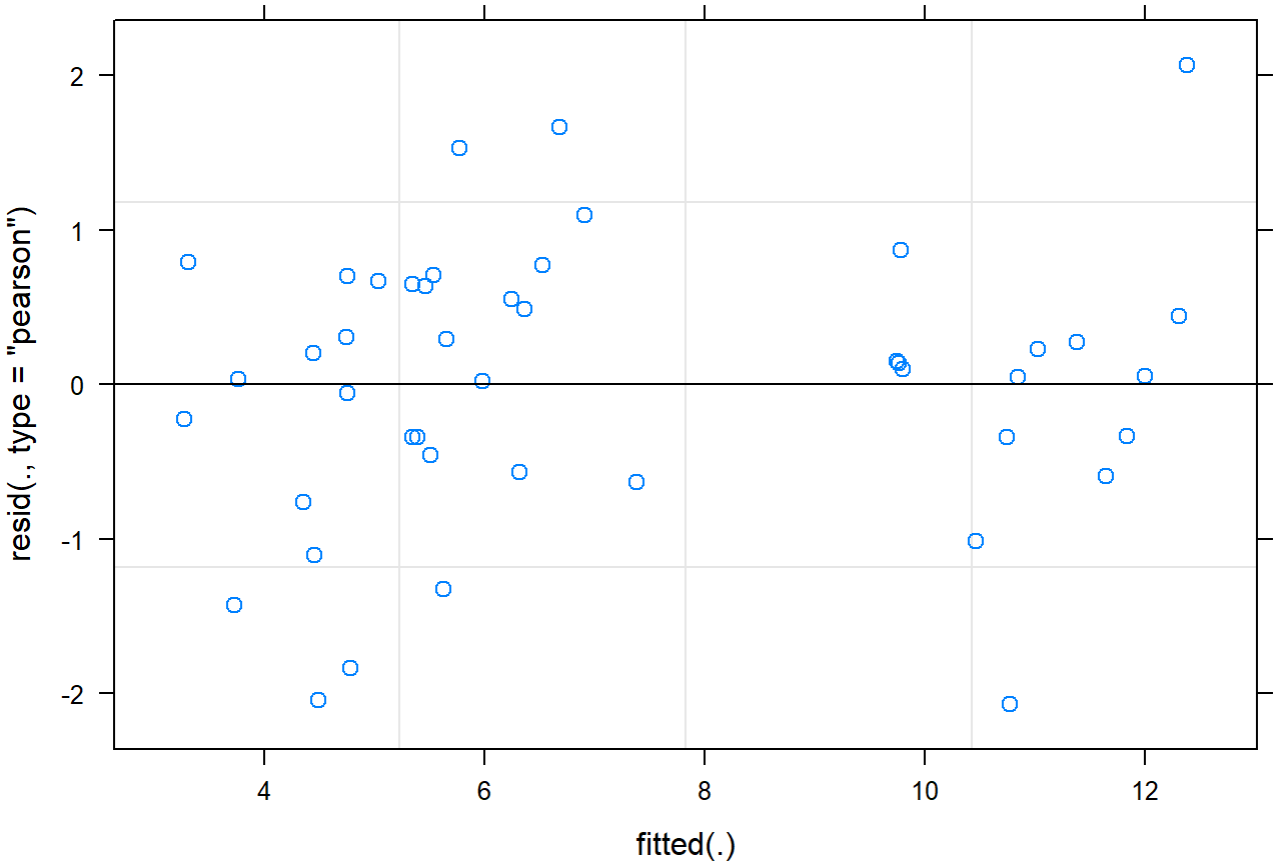
```
em
```

```
## $emmeans
##  Plot_type emmean    SE df lower.CL upper.CL
##  MS          6.92 0.575 12     5.66     8.17
##  PC          7.62 0.575 12     6.37     8.88
##  ST          6.96 0.575 12     5.70     8.21
##
## Results are averaged over the levels of: Date
## Degrees-of-freedom method: kenward-roger
## Confidence level used: 0.95
##
## $contrasts
##  contrast estimate    SE df t.ratio p.value
##  MS - PC    -0.707 0.813 12 -0.869  0.6692
##  MS - ST    -0.040 0.813 12 -0.049  0.9987
##  PC - ST     0.667 0.813 12  0.820  0.6985
##
## Results are averaged over the levels of: Date
## P value adjustment: tukey method for comparing a family of 3 estimates
```

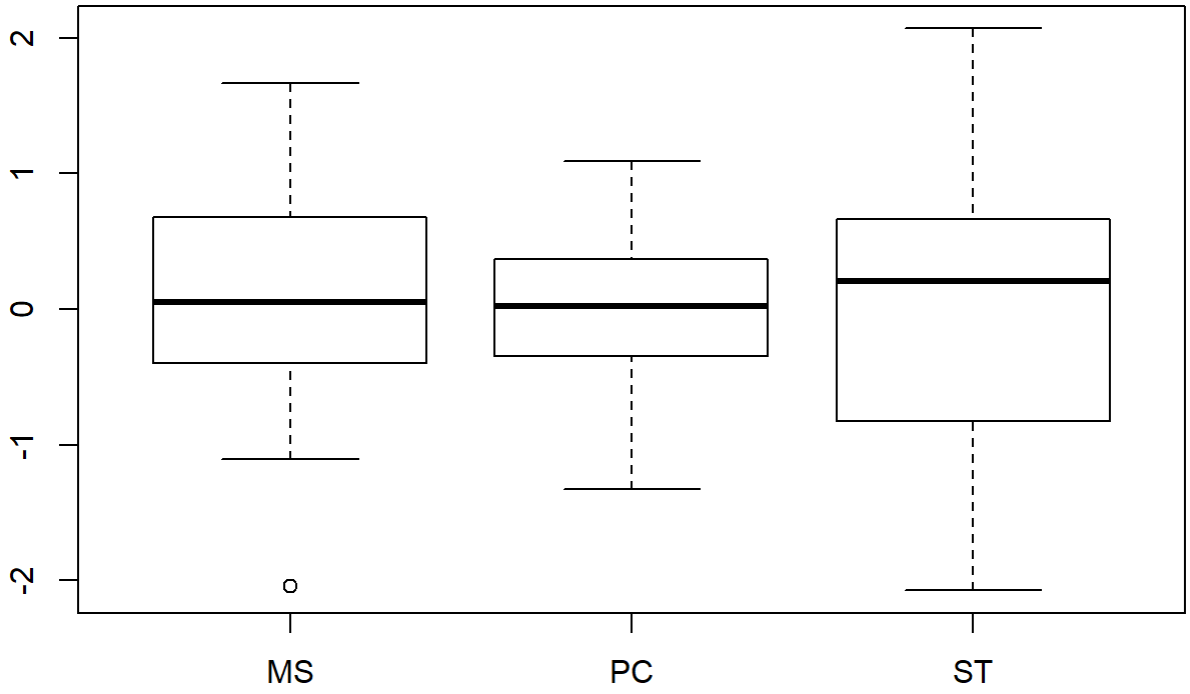
```
sumYA2015September[c(1:3),c(2:7)] <- summary(em)$emmeans

ggqqplot(residuals(mod))
```



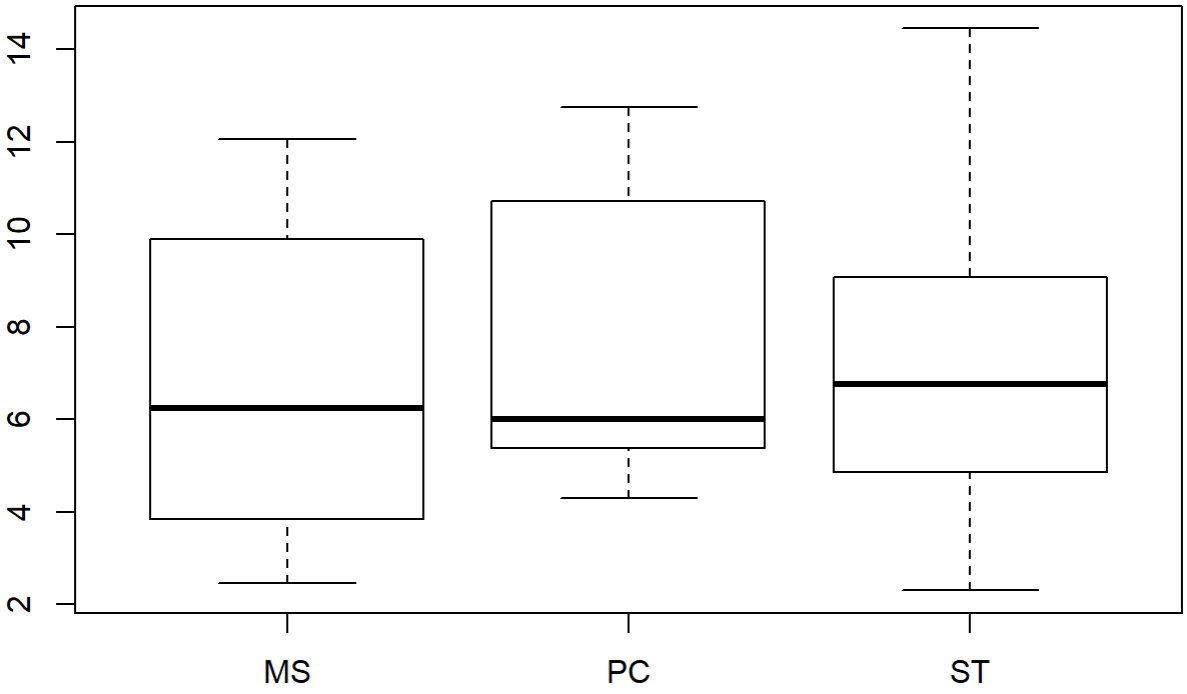

```
plot(mod)
```



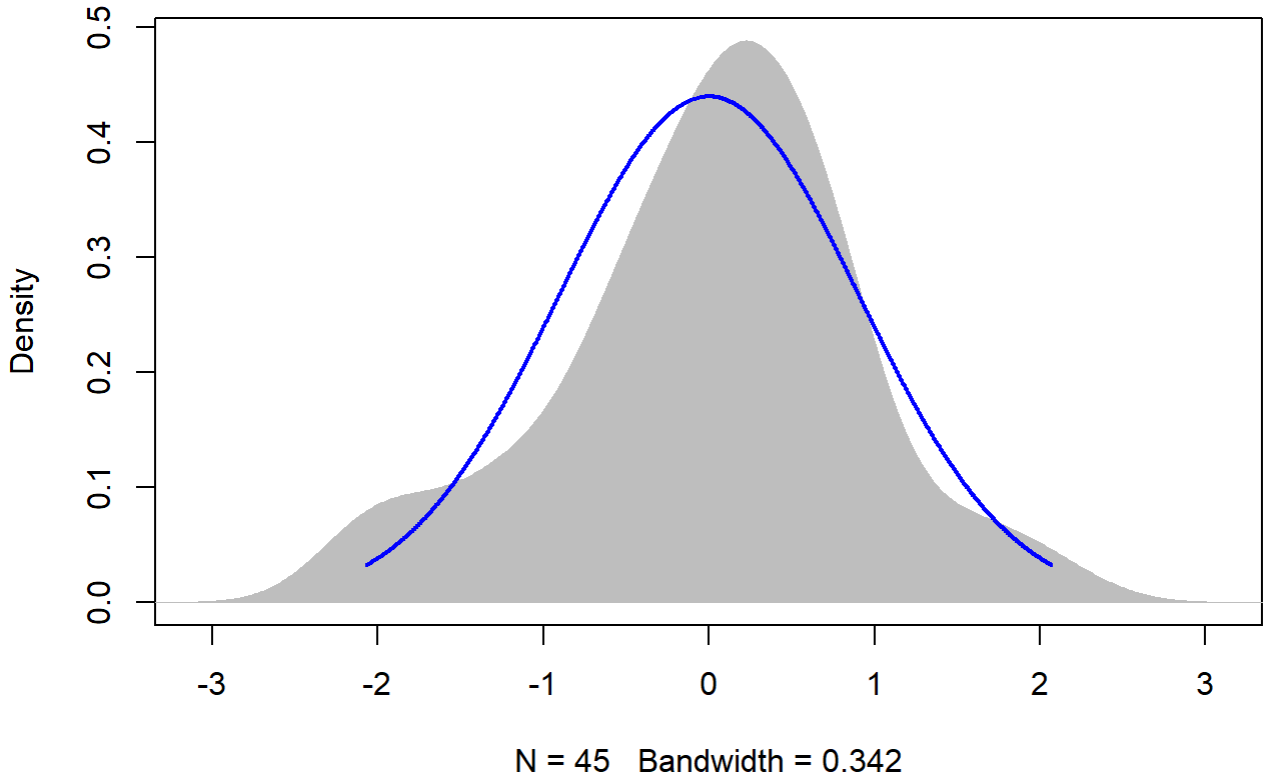

```
boxplot(residuals(mod) ~ TV12$Plot_type)
```




```
boxplot(TV12$Avg~ TV12$Plot_type)
```




```
plotNormalDensity(resid(mod))
```



14

```
TV14 <- filter(TV, Flight_hour == "14")

mod <-lmer(Avg ~ Plot_type * Date + (1|Plot_id), data = TV14)

anova(mod, ddf="Kenward-Roger")
```

```
## Type III Analysis of Variance Table with Kenward-Roger's method
##                 Sum Sq Mean Sq NumDF DenDF  F value    Pr(>F)
## Plot_type        1.680   0.840     2    12   1.5355    0.2548
## Date           184.081  92.041     2    24 168.2347 7.588e-15 ***
## Plot_type:Date   2.202   0.550     4    24   1.0060    0.4239
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
em <-emmeans(mod, pairwise ~ Plot_type, adjust = "Tukey")
```

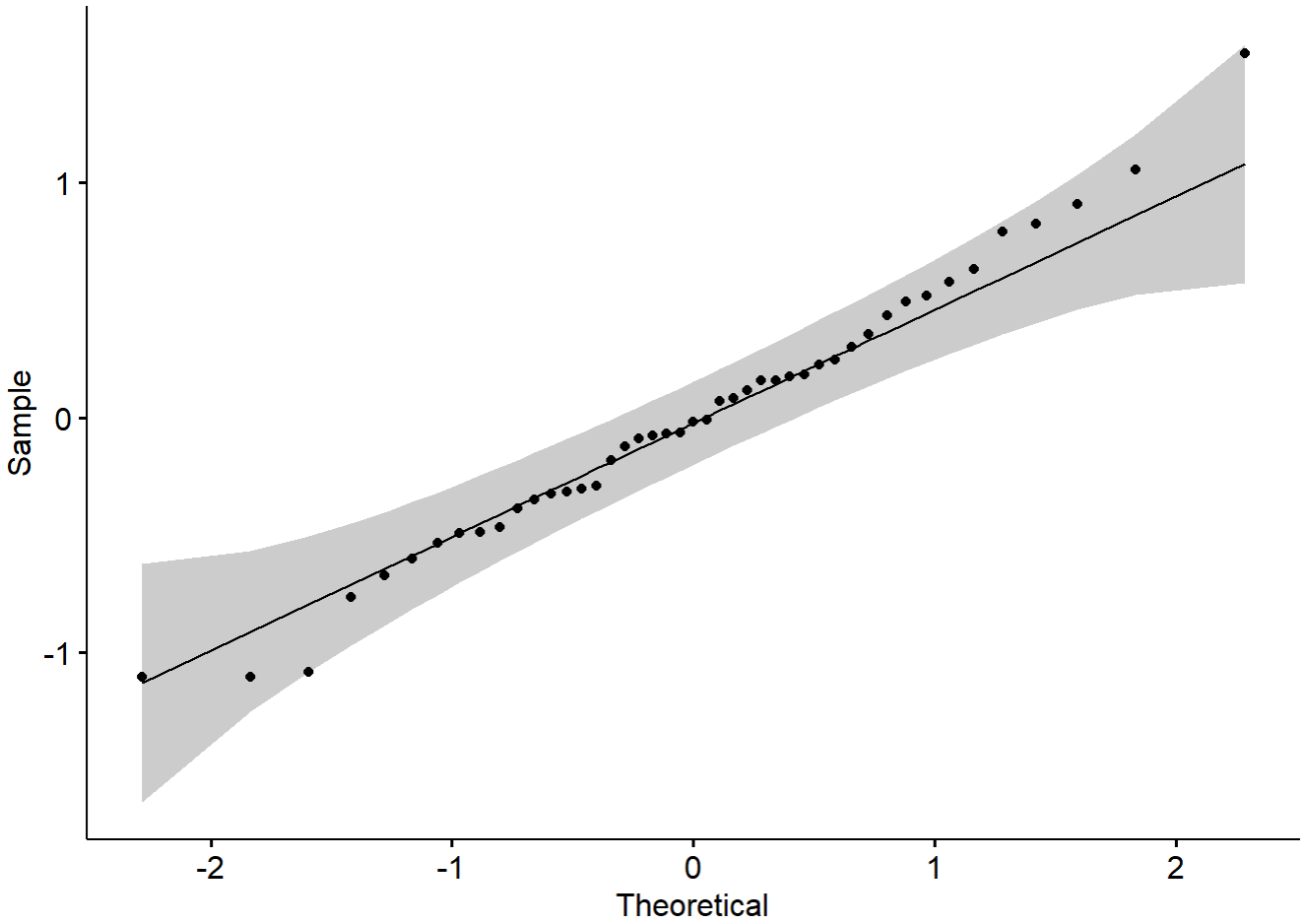
```
## NOTE: Results may be misleading due to involvement in interactions
```

```
em
```

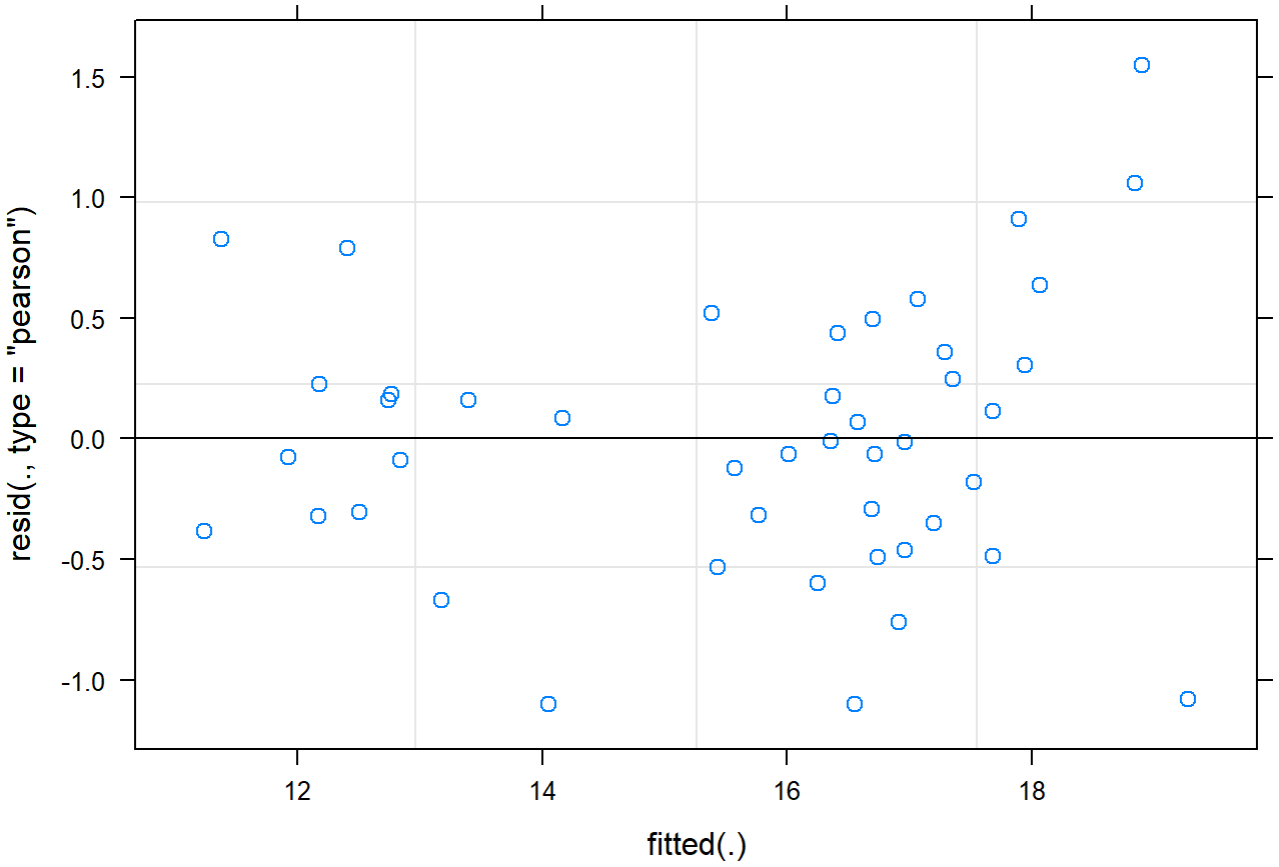
```
## $emmeans
```

```
##  Plot_type emmean    SE df lower.CL upper.CL
##  MS          15.1 0.461 12     14.1     16.1
##  PC          16.3 0.461 12     15.3     17.3
##  ST          15.5 0.461 12     14.5     16.5
##
## Results are averaged over the levels of: Date
## Degrees-of-freedom method: kenward-roger
## Confidence level used: 0.95
##
## $contrasts
##  contrast estimate    SE df t.ratio p.value
##  MS - PC    -1.127 0.652 12 -1.728  0.2350
##  MS - ST    -0.400 0.652 12 -0.614  0.8155
##  PC - ST     0.727 0.652 12  1.115  0.5236
##
## Results are averaged over the levels of: Date
## P value adjustment: tukey method for comparing a family of 3 estimates
```

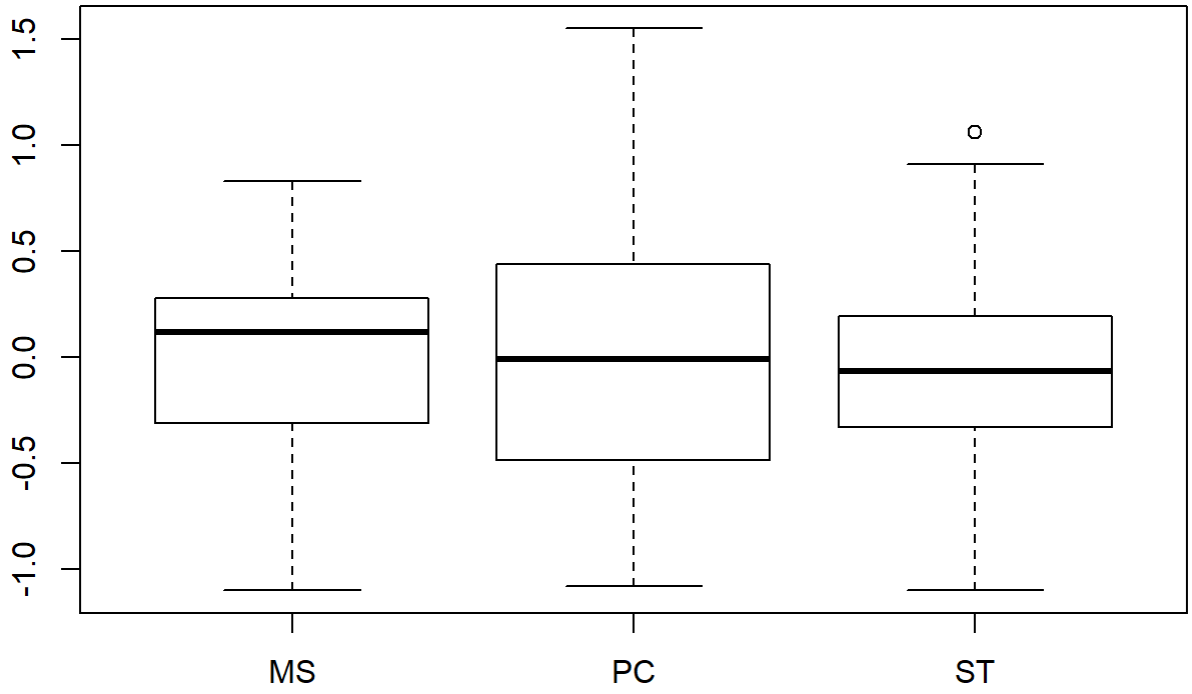
```
sumYA2015September[c(4:6),c(2:7)] <- summary(em)$emmeans

ggqqplot(residuals(mod))
```



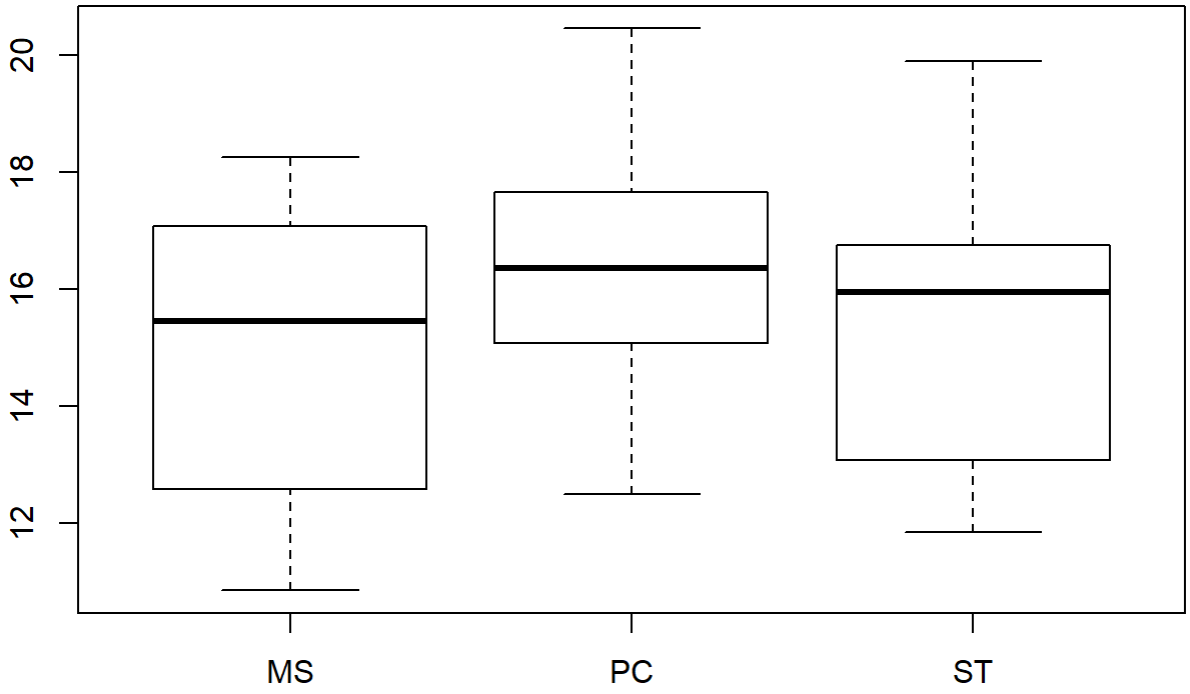

```
plot(mod)
```



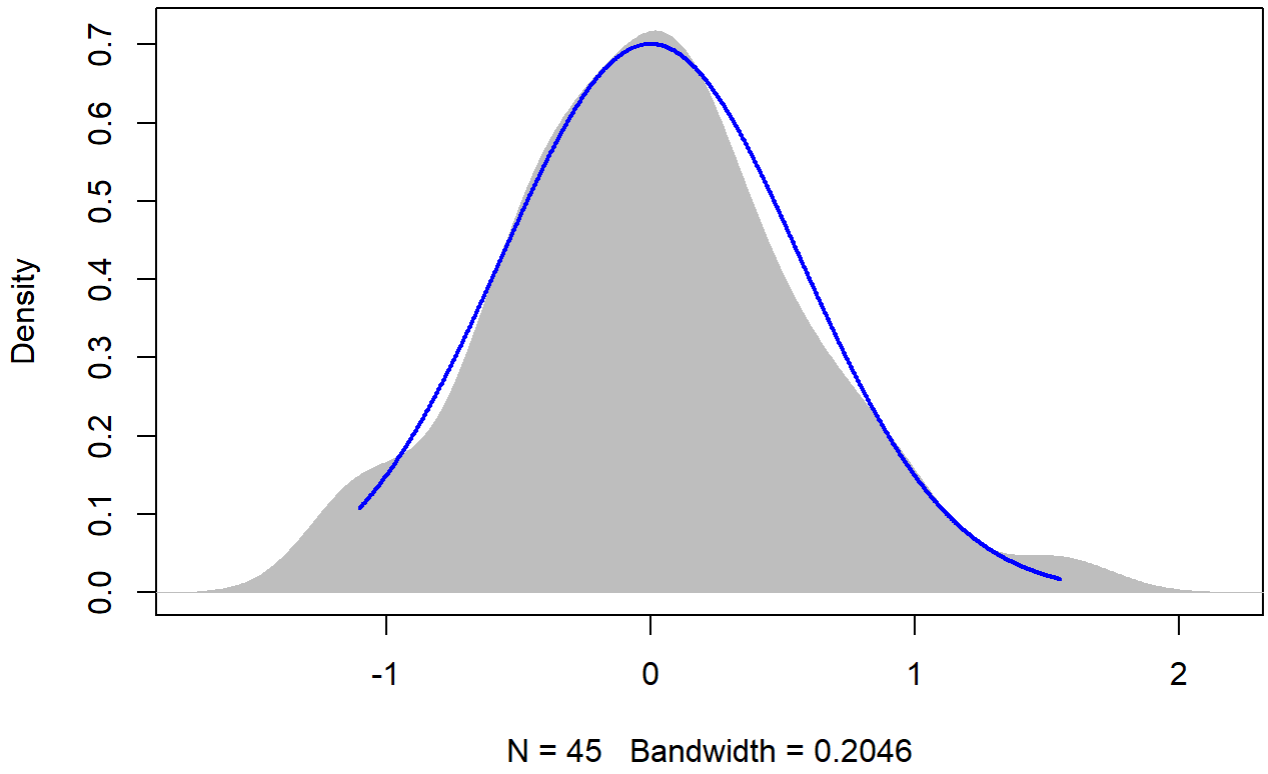

```
boxplot(residuals(mod) ~ TV14$Plot_type)
```




```
boxplot(TV14$Avg~ TV14$Plot_type)
```




```
plotNormalDensity(resid(mod))
```



16

```
TV16 <- filter(TV, Flight_hour == "16")

mod <-lmer(Avg ~ Plot_type * Date + (1|Plot_id), data = TV16)

anova(mod, ddf="Kenward-Roger")
```

```
## Type III Analysis of Variance Table with Kenward-Roger's method
##                 Sum Sq Mean Sq NumDF DenDF  F value Pr(>F)
## Plot_type        1.953   0.977     2    12   2.2931 0.1434
## Date           275.236 137.618     2    24 323.1523 <2e-16 ***
## Plot_type:Date   3.697   0.924     4    24   2.1701 0.1030
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
em <-emmeans(mod, pairwise ~ Plot_type, adjust = "Tukey")
```

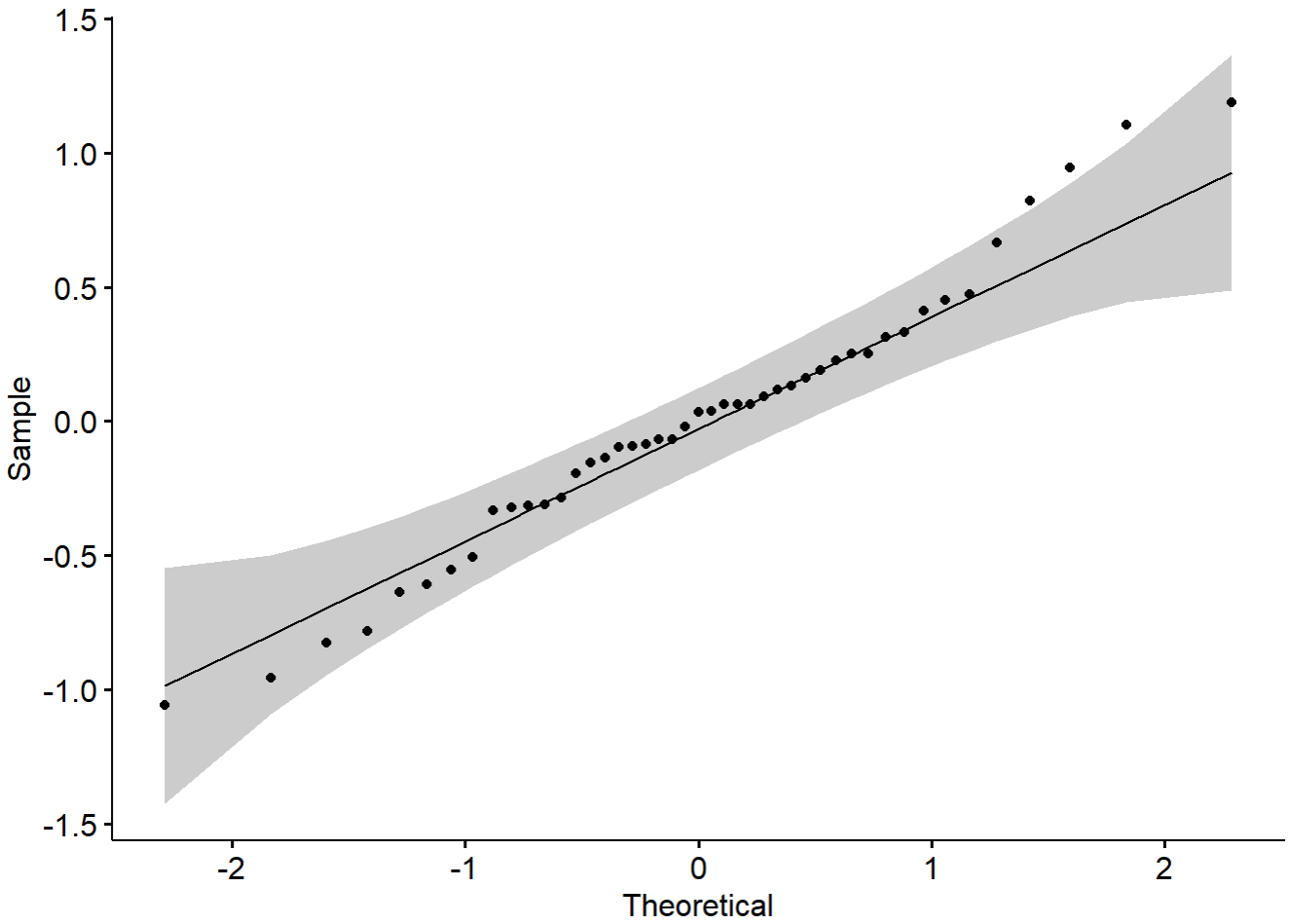
```
## NOTE: Results may be misleading due to involvement in interactions
```

```
em
```

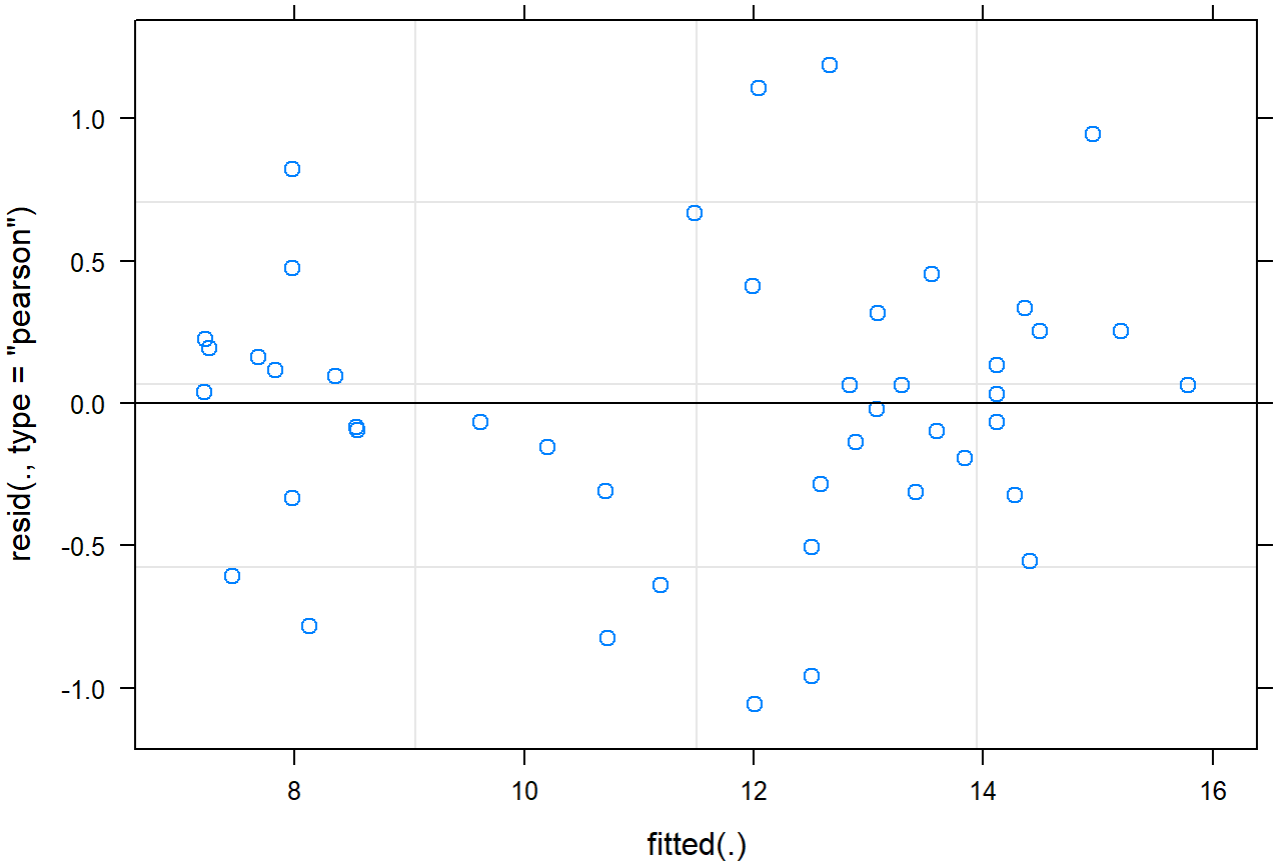
```
## $emmeans
```

```
##  Plot_type emmean    SE df lower.CL upper.CL
##  MS          10.8 0.424 12     9.93     11.8
##  PC          12.1 0.424 12    11.21     13.1
##  ST          11.5 0.424 12    10.61     12.5
##
## Results are averaged over the levels of: Date
## Degrees-of-freedom method: kenward-roger
## Confidence level used: 0.95
##
## $contrasts
##  contrast estimate  SE df t.ratio p.value
##  MS - PC    -1.283 0.6 12 -2.140  0.1232
##  MS - ST    -0.687 0.6 12 -1.145  0.5063
##  PC - ST     0.597 0.6 12  0.995  0.5938
##
## Results are averaged over the levels of: Date
## P value adjustment: tukey method for comparing a family of 3 estimates
```

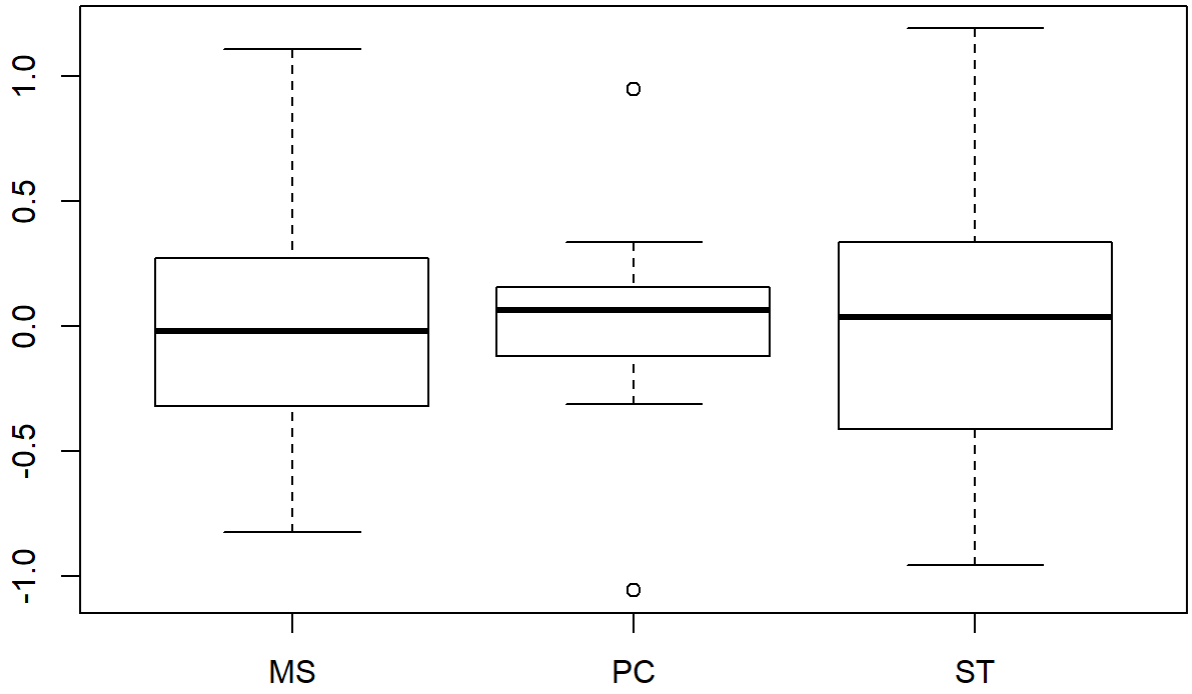
```
sumYA2015September[c(7:9),c(2:7)] <- summary(em)$emmeans

ggqqplot(residuals(mod))
```



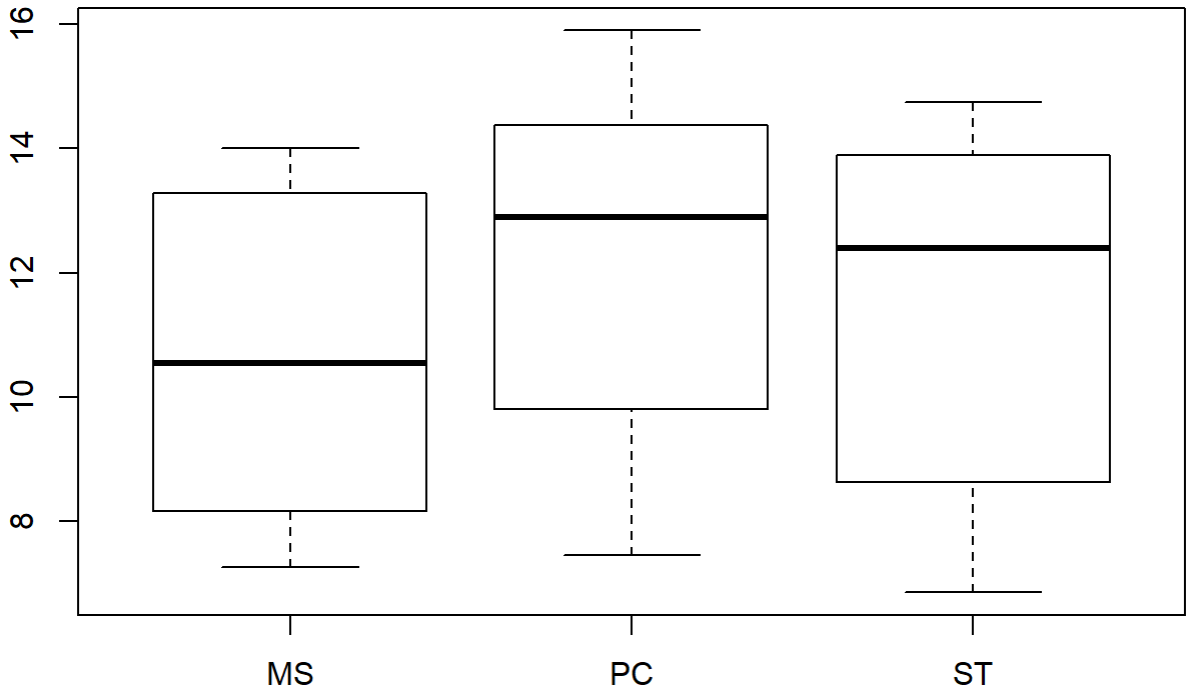

```
plot(mod)
```



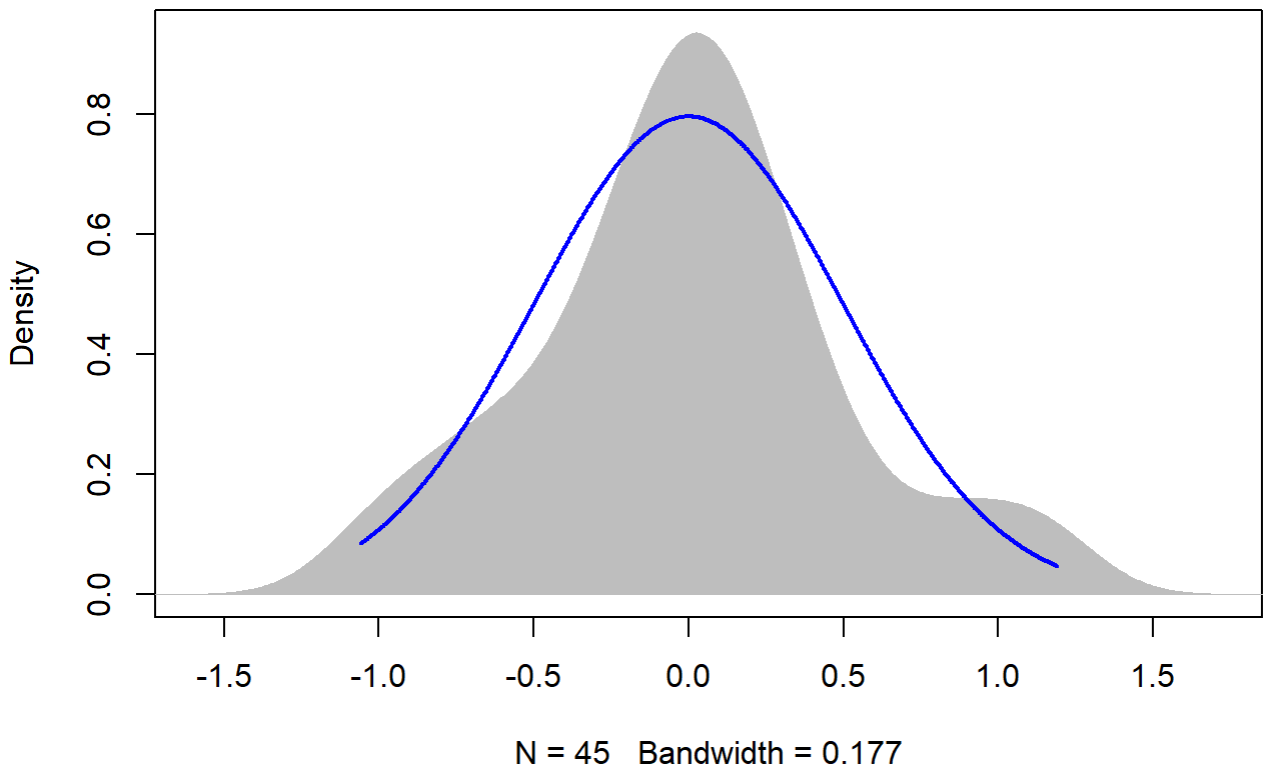

```
boxplot(residuals(mod) ~ TV16$Plot_type)
```




```
boxplot(TV16$Avg~ TV16$Plot_type)
```




```
plotNormalDensity(resid(mod))
```



20

```
sumYA2015September[c(10:12),c(2:7)] <- NA
```

Graph over time - 2015 Reforestation September - NOT NORMALIZED

```
sumYA2015September[,'Plot_type']<-factor(sumYA2015September[,'Plot_type'])

tiff("YA2015SeptemberNONNORM.tiff", width = 7, height = 4, units = 'in', res = 100)

pd <- position_dodge(0.3)

ggplot(sumYA2015September, aes(x=Flight_hour, y=emmeans, colour=Plot_type)) +
  geom_errorbar(aes(ymin=lower.CL, ymax=Upper.cl), width=.3, position=position_dodge(width=0.3
)) +
  geom_point(position=pd, size=3, shape=21, fill="white") +
  geom_line(position=pd, linetype = "dashed") +
  xlab("Time of day (24-hr format)") +
  ylab(expression("EM Mean Surface Temperature   " (  degree*C))) +
  scale_colour_manual(values = c("#9449CC", "#C5433A", "#008C91"), name="Plot type",
                      breaks=c("1", "2", "3"),
                      labels=c("Spray-and-Mow Control", "Passive Control", "Topsoil Recipient"
)) +
  expand_limits(y=c(0,20)) +
  scale_y_continuous(breaks=c(0, 5, 10, 15, 20)) +
  scale_x_continuous(breaks=c(12,14,16,18,20)) +
```

```
  theme_bw() +
  theme(legend.position=c(0.8,0.2), legend.title = element_text(size = 12, face = "bold"),
        legend.text = element_text(size = 12), text = element_text(size=12), axis.text = eleme
nt_text(color = "black", size=12.5), axis.title.x=element_text(size=12.5), axis.title.y=elemen
t_text(size=12.5)) +
  annotate(geom="label",x = 12.2,  y = 3.5,
           label = "p = 0.632\n(6, 3)", fontface = "plain", col ="black", size = 3.5, fill = "
white") +
  annotate(geom="label",x = 14,  y = 10,
           label ="p = 0.255\n(6, 3)", fontface = "plain", col ="black", size = 3.5, fill = "w
hite") +
  annotate(geom="label",x = 16,  y = 7,
           label = "p = 0.143\n(6, 3)", fontface = "plain", col ="black", size = 3.5, fill = "
white") +
  annotate(geom="label",x = 12,  y = 19,
           label = "A", fontface = "bold", col ="black", size = 4)
```

```
## Warning: Removed 3 rows containing missing values (geom_point).
```

```
## Warning: Removed 3 row(s) containing missing values (geom_path).
```

```
dev.off()
```

```
## png
##   2
```

Temp over time 2015 Reforestation - September - NORMALIZED

```
TV <-read.csv("ThermVegAvg.csv")
sumYA2015September <- read.csv("f_hours_2015.csv")

TV <- filter(TV, Field == "YA2015", Month == "September")
```

12

```
TV12 <- filter(TV, Flight_hour == "12")

outlierTest(lm(AvgMout~Plot_type * Date, data = TV12))
```

```
##     rstudent unadjusted p-value Bonferonni p
## 38 -4.251161         0.00015007    0.0067531
```

```
mod <-lmer(AvgMout ~ Plot_type * Date + (1|Plot_id), data = TV12)

anova(mod, ddf="Kenward-Roger")
```

```
## Type III Analysis of Variance Table with Kenward-Roger's method
##                 Sum Sq Mean Sq NumDF DenDF F value Pr(>F)
```

```
## Plot_type      0.45215 0.22607     2    12  0.5750 0.5775
## Date           1.83478 0.91739     2    24  2.3333 0.1186
## Plot_type:Date 0.46089 0.11522     4    24  0.2931 0.8796
```

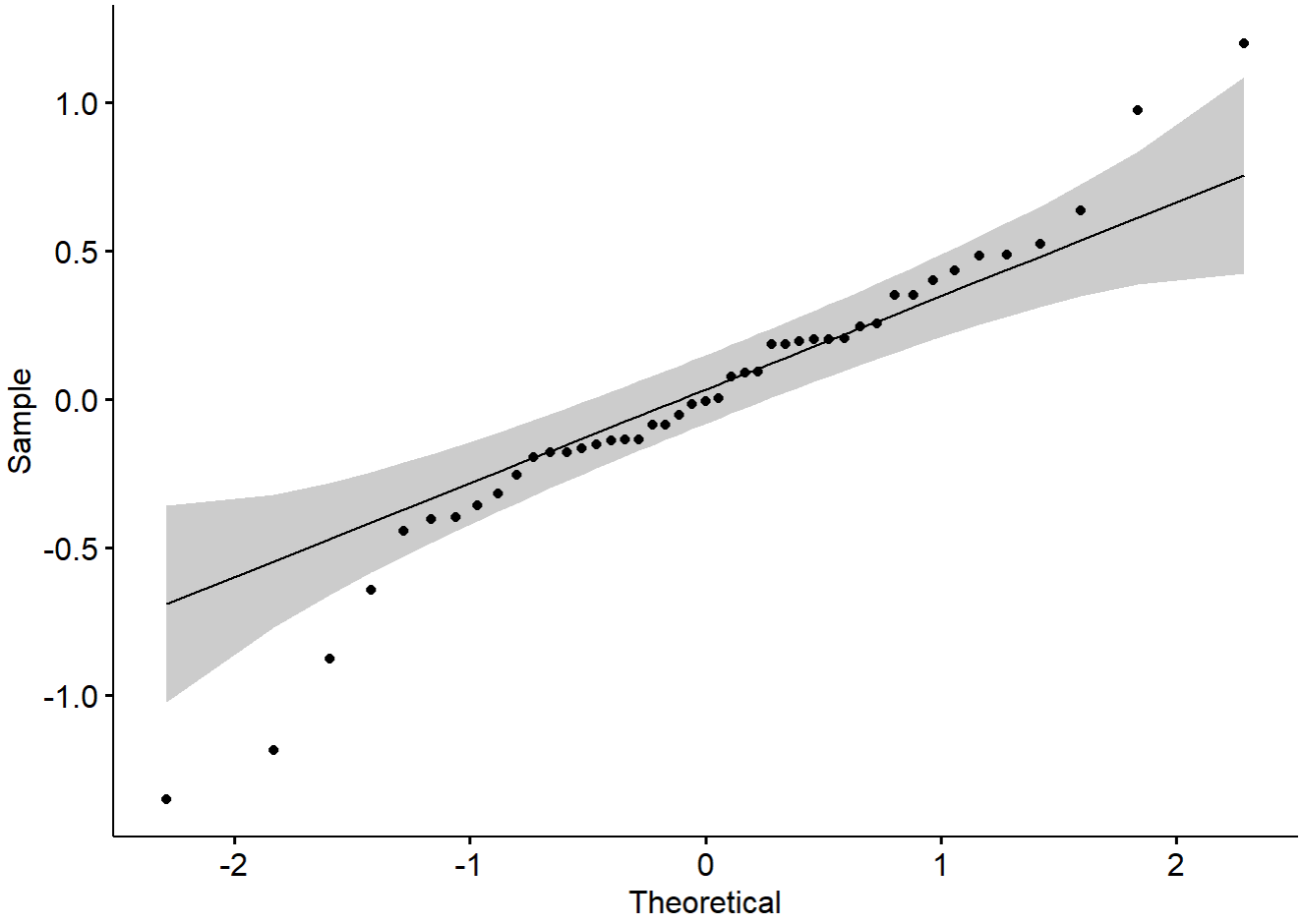
```
em <-emmeans(mod, pairwise ~ Plot_type, adjust = "Tukey")
```

```
## NOTE: Results may be misleading due to involvement in interactions
```

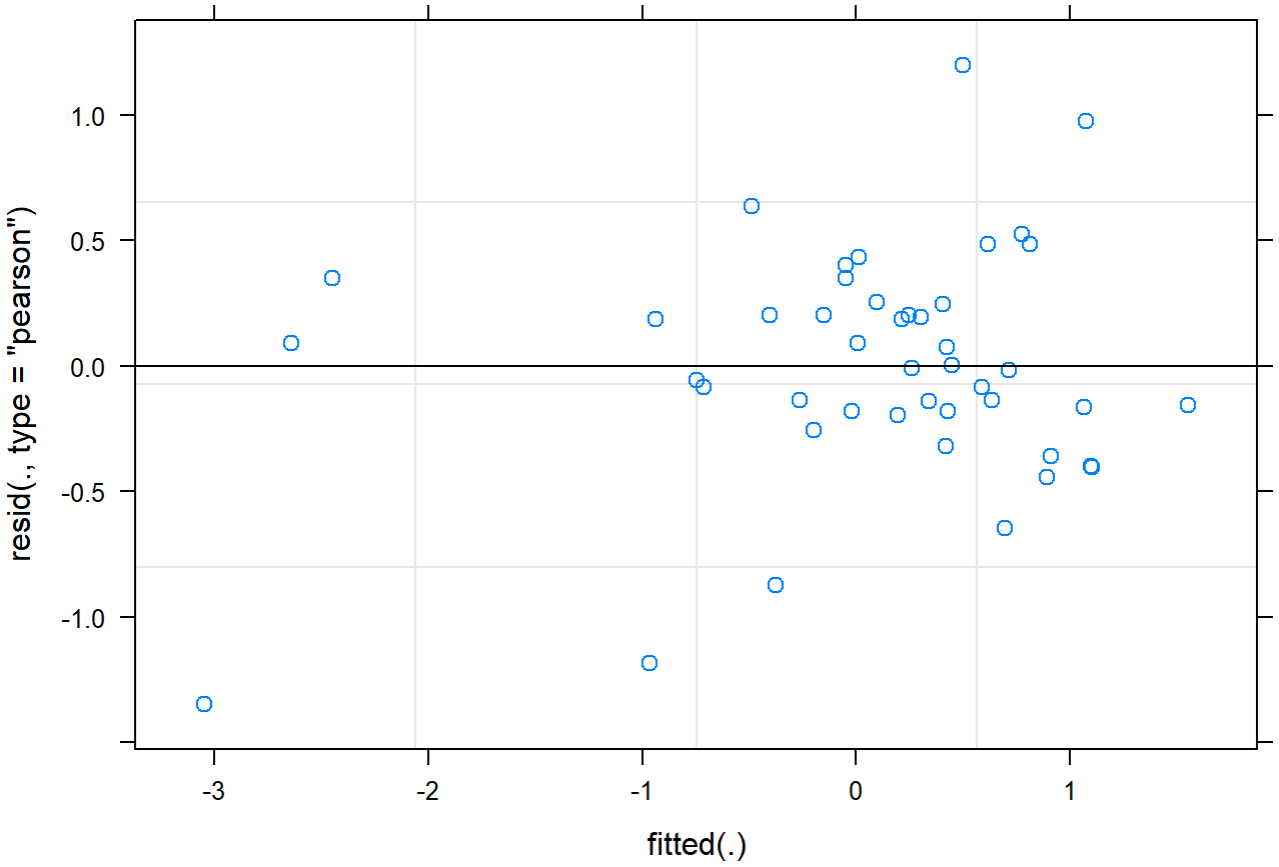
```
em
```

```
## $emmeans
##  Plot_type emmean    SE df lower.CL upper.CL
##  MS         0.150 0.483 12   -0.901    1.201
##  PC         0.397 0.483 12   -0.655    1.448
##  ST        -0.323 0.483 12   -1.375    0.728
##
## Results are averaged over the levels of: Date
## Degrees-of-freedom method: kenward-roger
## Confidence level used: 0.95
##
## $contrasts
##  contrast estimate    SE df t.ratio p.value
##  MS - PC    -0.247 0.682 12 -0.361  0.9309
##  MS - ST     0.473 0.682 12  0.694  0.7716
##  PC - ST     0.720 0.682 12  1.055  0.5582
##
## Results are averaged over the levels of: Date
## P value adjustment: tukey method for comparing a family of 3 estimates
```

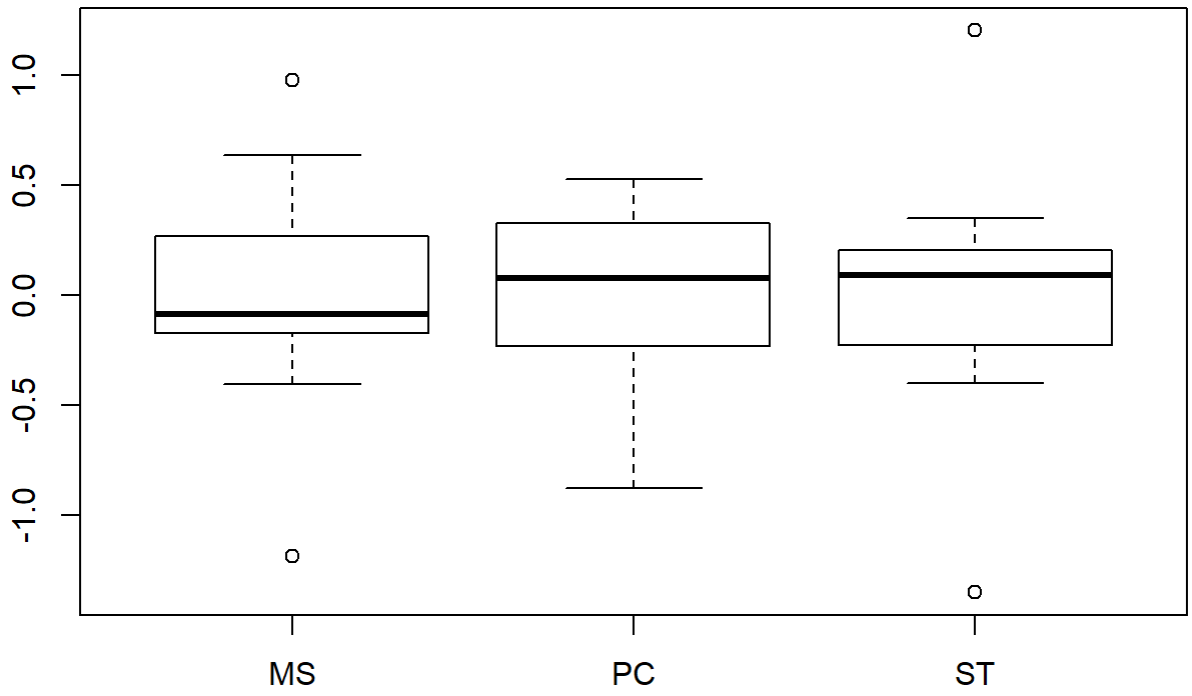
```
sumYA2015September[c(1:3),c(2:7)] <- summary(em)$emmeans

ggqqplot(residuals(mod))
```



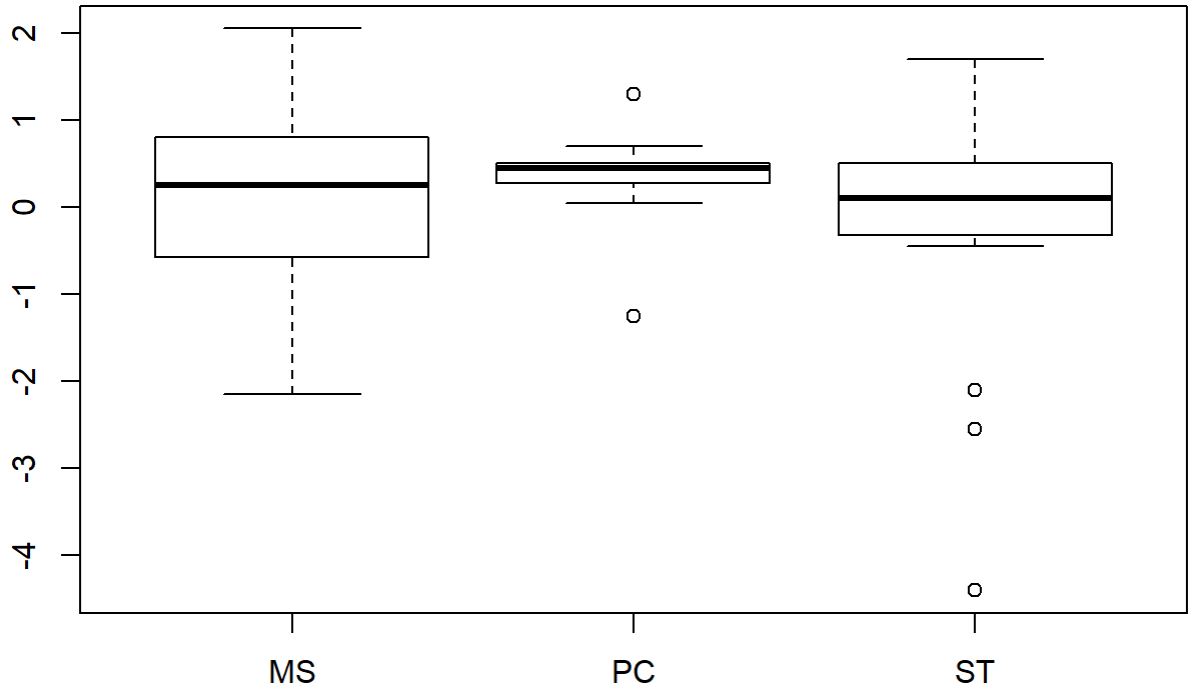

```
plot(mod)
```



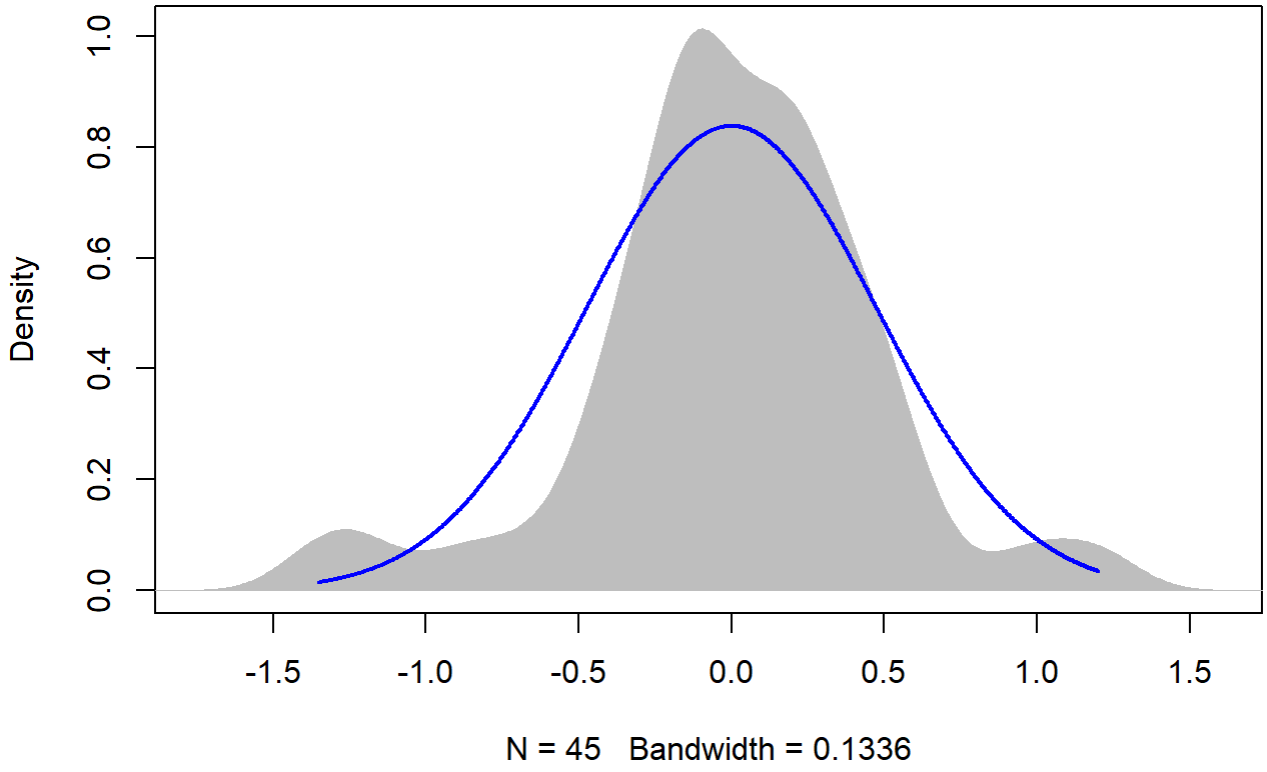

```
boxplot(residuals(mod) ~ TV12$Plot_type)
```




```
boxplot(TV12$AvgMout~ TV12$Plot_type)
```




```
plotNormalDensity(resid(mod))
```



14

```
TV14 <- filter(TV, Flight_hour == "14")

mod <-lmer(AvgMout ~ Plot_type * Date + (1|Plot_id), data = TV14)

anova(mod, ddf="Kenward-Roger")
```

```
## Type III Analysis of Variance Table with Kenward-Roger's method
##                  Sum Sq  Mean Sq NumDF DenDF F value Pr(>F)
## Plot_type      0.20060 0.100298     2    12  0.4386 0.6549
## Date           0.19878 0.099389     2    24  0.4346 0.6525
## Plot_type:Date 0.33456 0.083639     4    24  0.3657 0.8306
```

```
em <-emmeans(mod, pairwise ~ Plot_type, adjust = "Tukey")
```

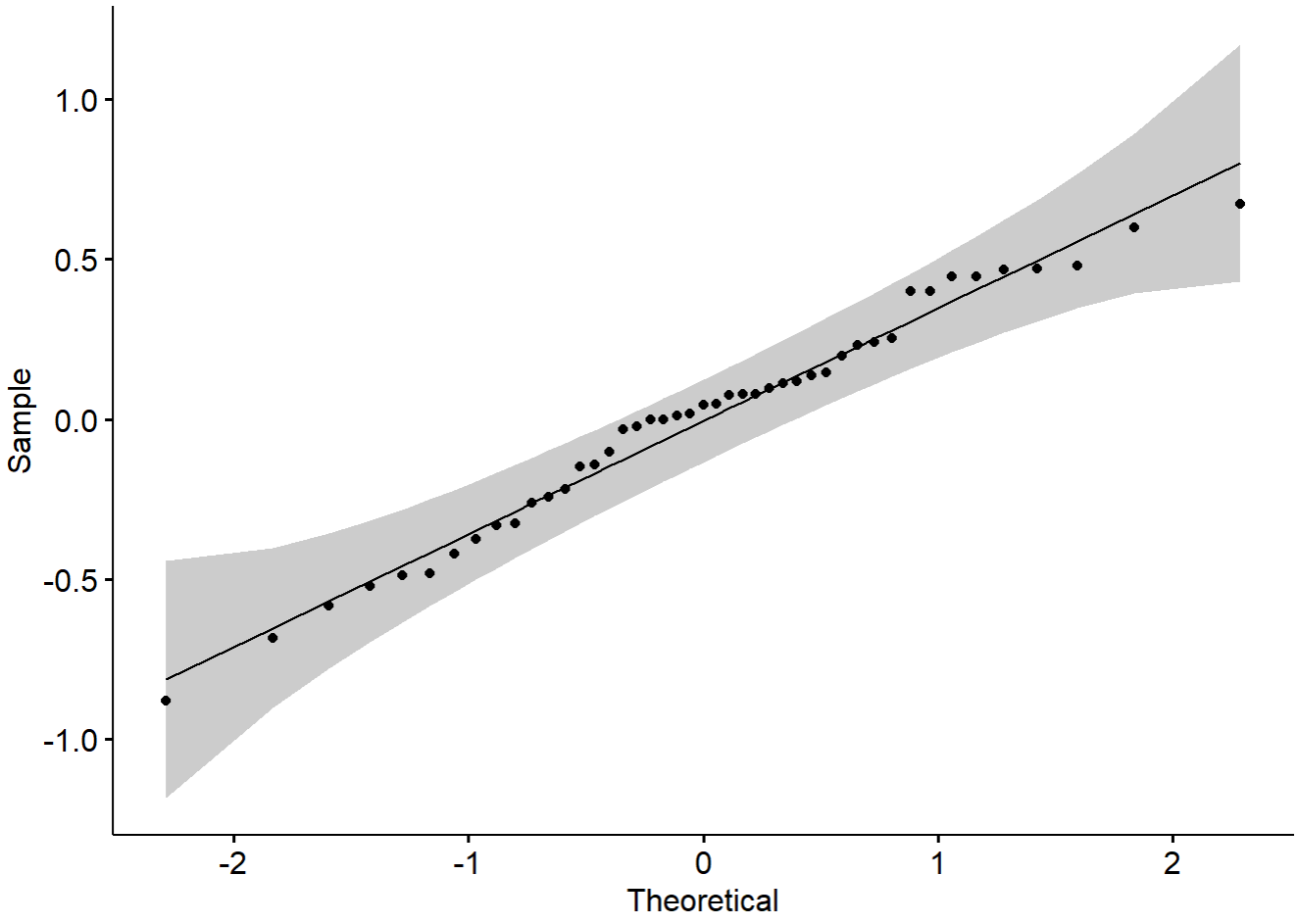
```
## NOTE: Results may be misleading due to involvement in interactions
```

```
em
```

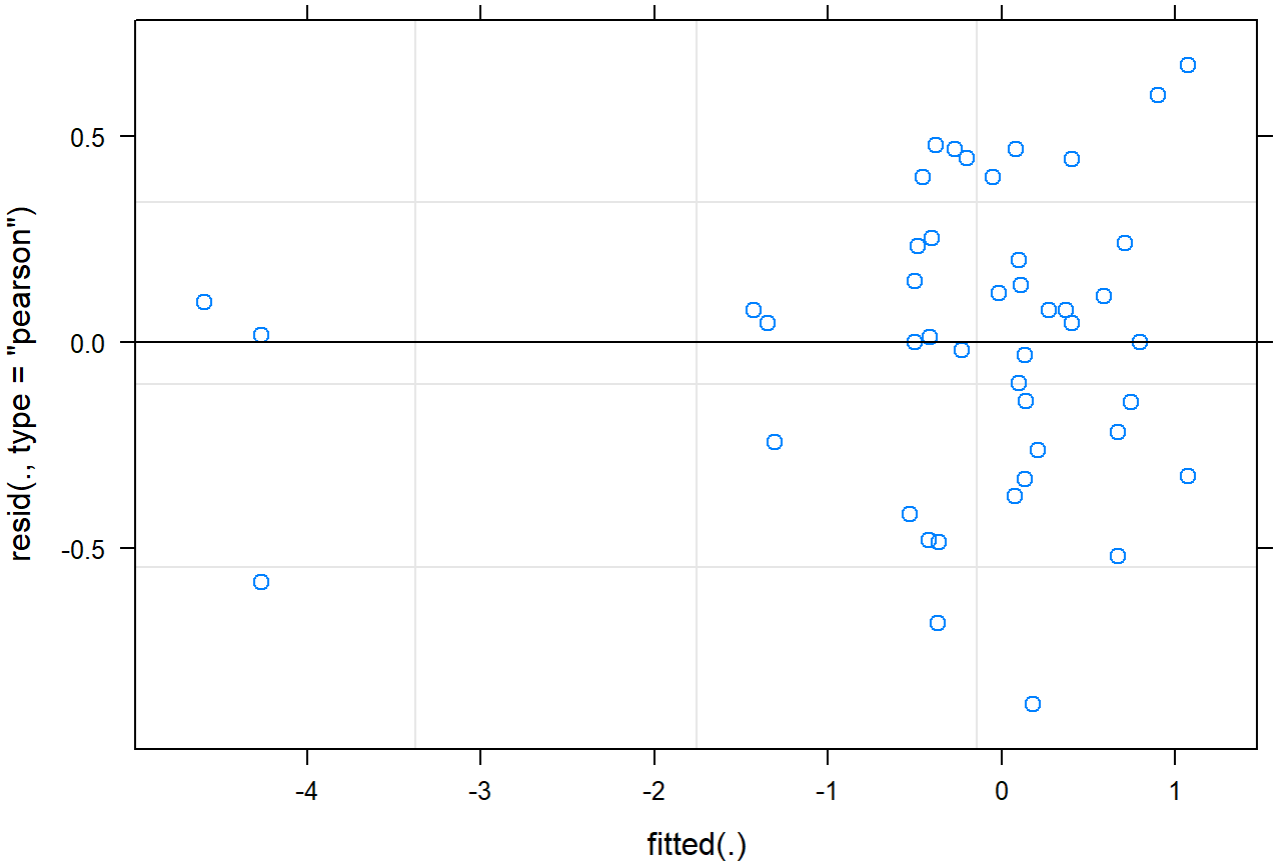
```
## $emmeans
##  Plot_type emmean    SE df lower.CL upper.CL
##  MS        -0.403 0.616 12    -1.75    0.940
```

```
##  PC         0.170 0.616 12    -1.17    1.513
##  ST        -0.620 0.616 12    -1.96    0.723
##
## Results are averaged over the levels of: Date
## Degrees-of-freedom method: kenward-roger
## Confidence level used: 0.95
##
## $contrasts
##  contrast estimate    SE df t.ratio p.value
##  MS - PC    -0.573 0.872 12 -0.658  0.7916
##  MS - ST     0.217 0.872 12  0.249  0.9666
##  PC - ST     0.790 0.872 12  0.906  0.6468
##
## Results are averaged over the levels of: Date
## P value adjustment: tukey method for comparing a family of 3 estimates
```

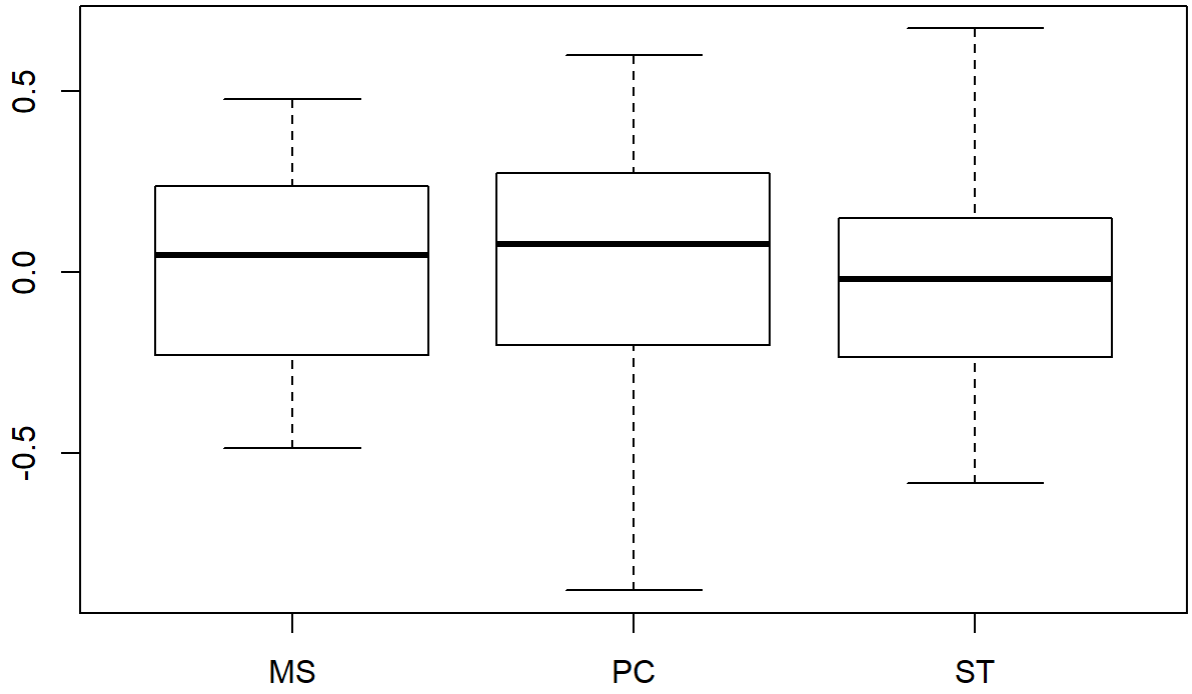
```
sumYA2015September[c(4:6),c(2:7)] <- summary(em)$emmeans

ggqqplot(residuals(mod))
```



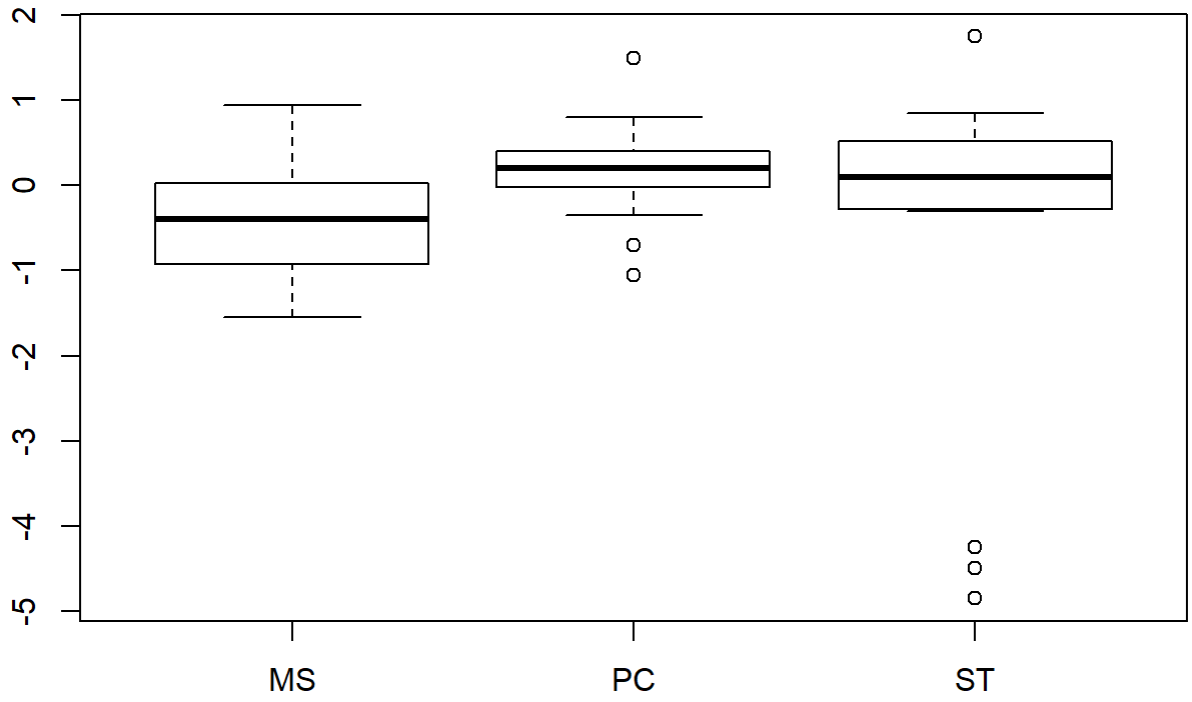

```
plot(mod)
```



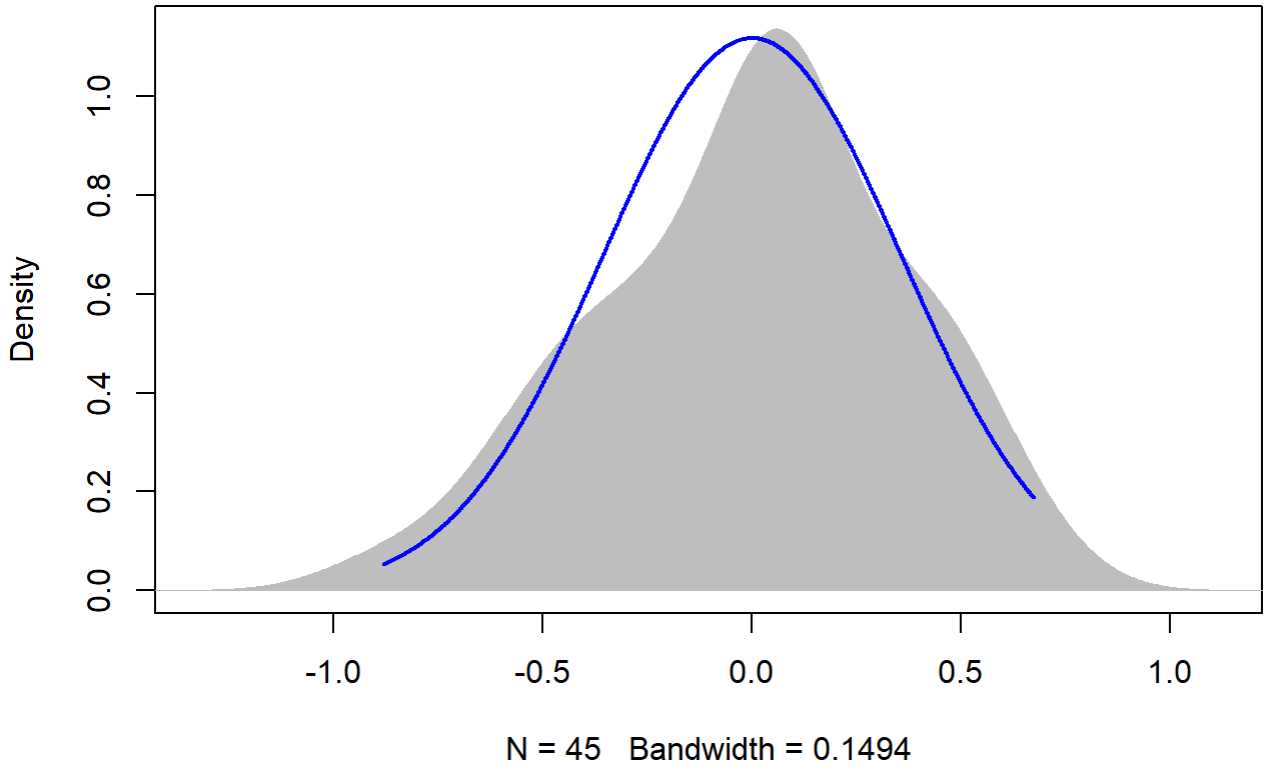

```
boxplot(residuals(mod) ~ TV14$Plot_type)
```




```
boxplot(TV14$AvgMout~ TV14$Plot_type)
```




```
plotNormalDensity(resid(mod))
```



16

```
TV16 <- filter(TV, Flight_hour == "16")

mod <-lmer(AvgMout ~ Plot_type * Date + (1|Plot_id), data = TV16)

anova(mod, ddf="Kenward-Roger")
```

```
## Type III Analysis of Variance Table with Kenward-Roger's method
##                  Sum Sq Mean Sq NumDF DenDF F value Pr(>F)
## Plot_type      0.73987 0.36993     2    12  1.2304 0.3265
## Date           0.72044 0.36022     2    24  1.1981 0.3192
## Plot_type:Date 0.60556 0.15139     4    24  0.5035 0.7335
```

```
em <-emmeans(mod, pairwise ~ Plot_type, adjust = "Tukey")
```

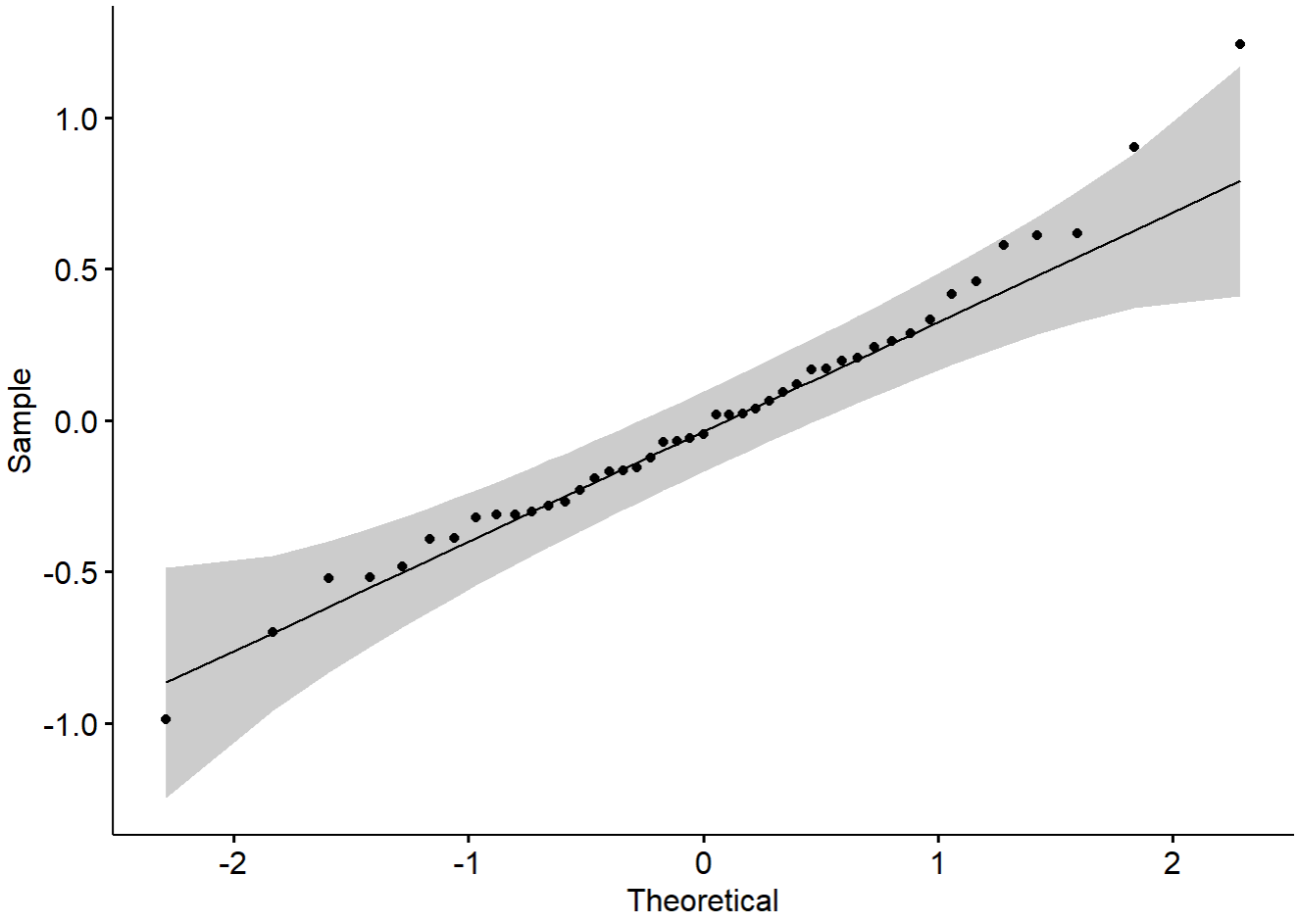
```
## NOTE: Results may be misleading due to involvement in interactions
```

```
em
```

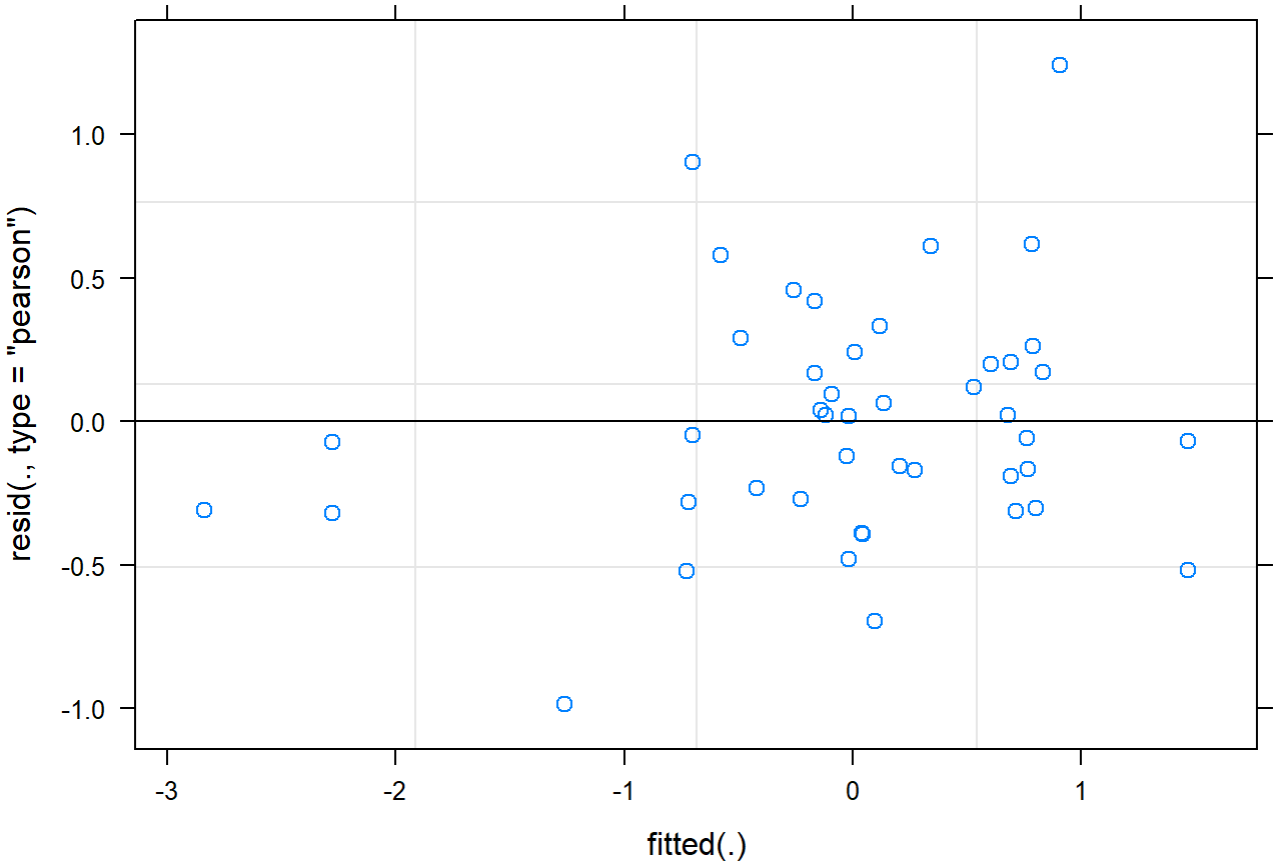
```
## $emmeans
##  Plot_type  emmean    SE df lower.CL upper.CL
##  MS         0.0767 0.431 12   -0.862    1.015
```

```
##  PC          0.4167 0.431 12   -0.522    1.355
##  ST         -0.5267 0.431 12   -1.465    0.412
##
## Results are averaged over the levels of: Date
## Degrees-of-freedom method: kenward-roger
## Confidence level used: 0.95
##
## $contrasts
##  contrast estimate    SE df t.ratio p.value
##  MS - PC    -0.340 0.609 12 -0.558  0.8443
##  MS - ST     0.603 0.609 12  0.991  0.5964
##  PC - ST     0.943 0.609 12  1.549  0.3042
##
## Results are averaged over the levels of: Date
## P value adjustment: tukey method for comparing a family of 3 estimates
```

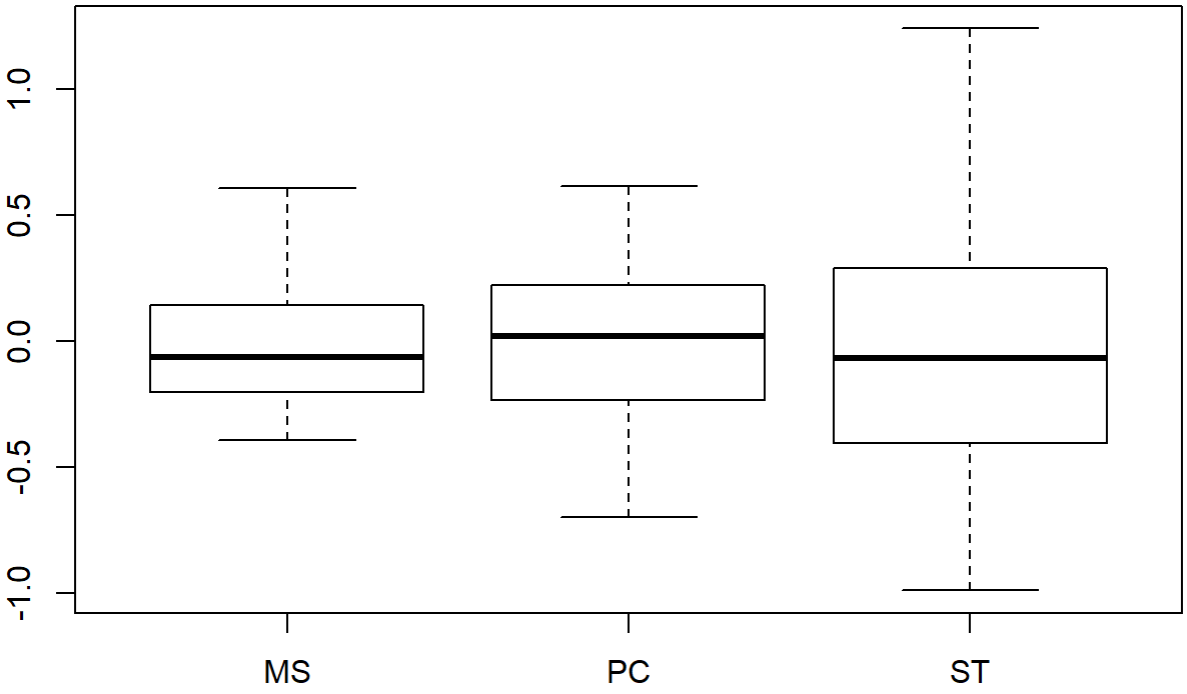
```
sumYA2015September[c(7:9),c(2:7)] <- summary(em)$emmeans

ggqqplot(residuals(mod))
```



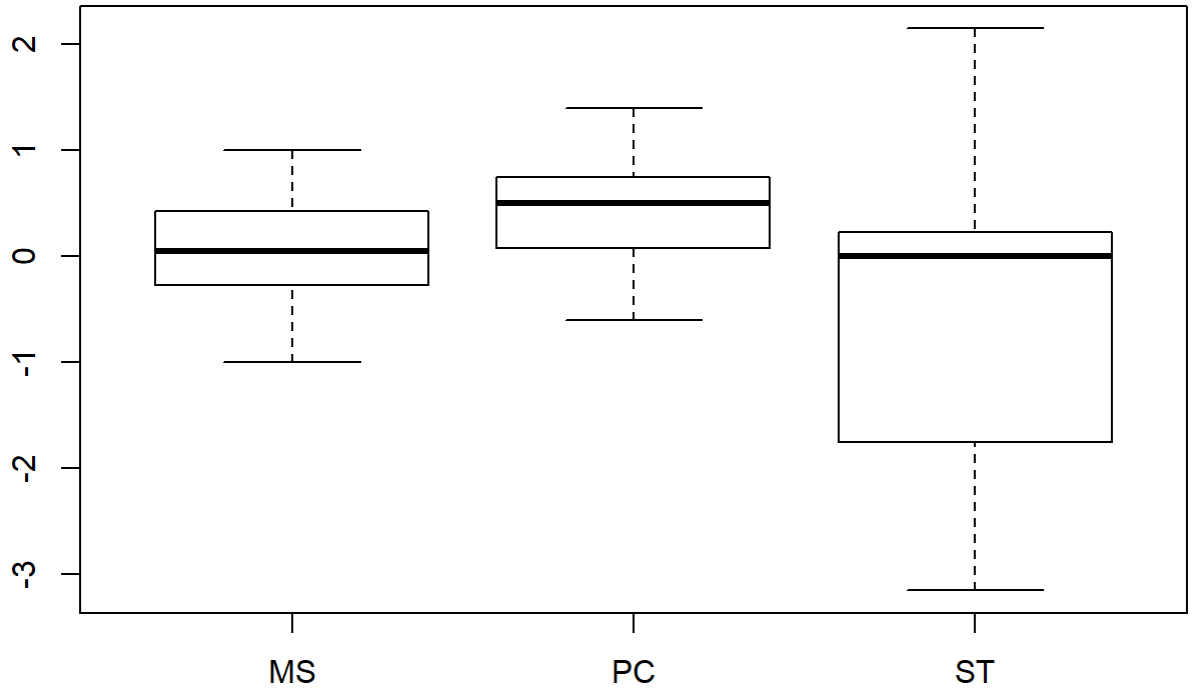

```
plot(mod)
```



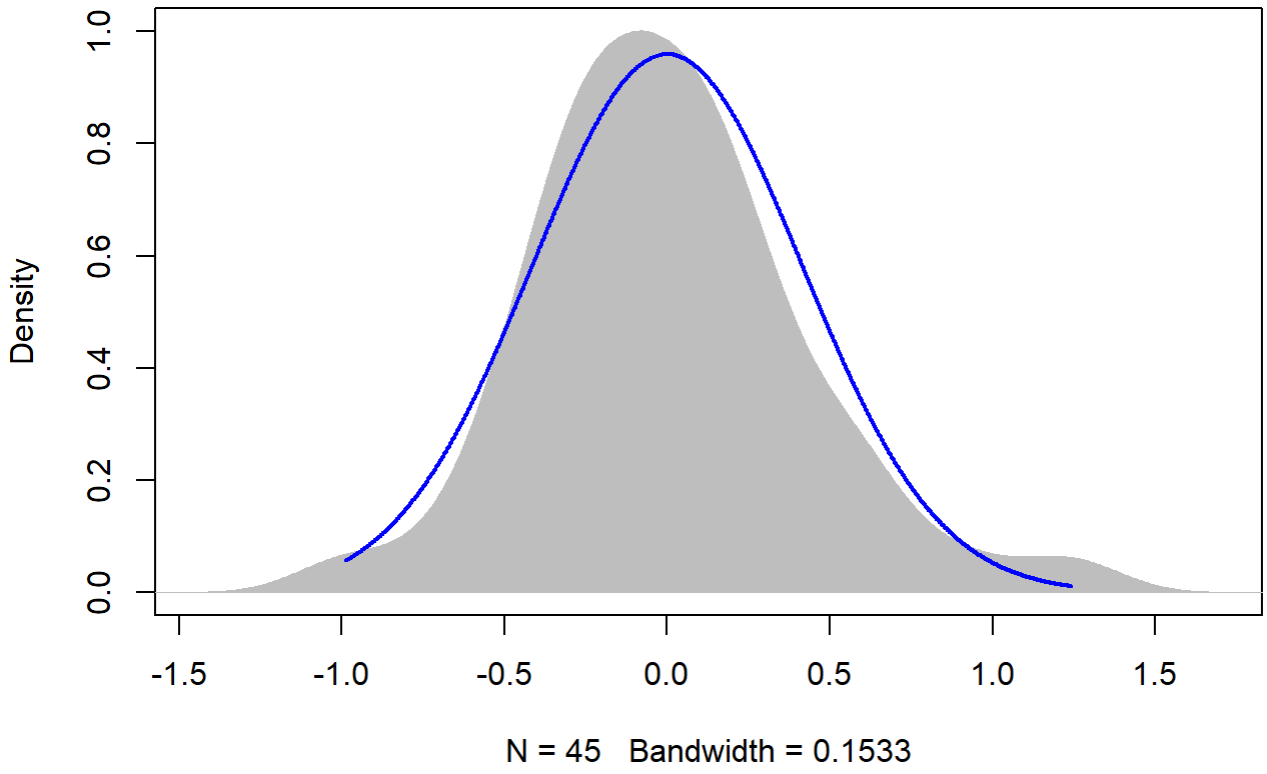

```
boxplot(residuals(mod) ~ TV16$Plot_type)
```




```
boxplot(TV16$AvgMout~ TV16$Plot_type)
```




```
plotNormalDensity(resid(mod))
```



20

```
sumYA2015September[c(10:12),c(2:7)] <- NA
```

Graph over time - 2015 Reforestation September - NORMALIZED

```
sumYA2015September[,'Plot_type']<-factor(sumYA2015September[,'Plot_type'])

tiff("YA2015September.tiff", width = 7, height = 4, units = 'in', res = 100)

pd <- position_dodge(0.3)

ggplot(sumYA2015September, aes(x=Flight_hour, y=emmeans, colour=Plot_type)) +
  geom_errorbar(aes(ymin=lower.CL, ymax=Upper.cl), width=.3, position=position_dodge(width=0.3
)) +
  geom_point(position=pd, size=3, shape=21, fill="white") +
  geom_line(position=pd, linetype = "dashed") +
  xlab("Time of day (24-hr format)") +
  ylab(expression("Norm. EM Mean Surface Net-Temperature   " (  degree*C))) +
  scale_colour_manual(values = c("#9449CC", "#C5433A", "#008C91"), name="Plot type",
                      breaks=c("1", "2", "3"),
                      labels=c("Spray-and-Mow Control", "Passive Control", "Topsoil Recipient"
)) +
  expand_limits(y=c(-4,4)) +
  scale_y_continuous(breaks=c(-4, -2, 0, 2, 4)) +
  scale_x_continuous(breaks=c(12,14,16,18,20)) +
```

```
  theme_bw() +
  theme(legend.position=c(0.8,0.2), legend.title = element_text(size = 12, face = "bold"),
        legend.text = element_text(size = 12), text = element_text(size=12), axis.text = eleme
nt_text(color = "black", size=12.5), axis.title.x=element_text(size=12.3), axis.title.y=elemen
t_text(size=12.5)) +
  annotate(geom="label",x = 12.2,  y = 2.5,
           label = "p = 0.578\n(6, 3)", fontface = "plain", col ="black", size = 3.5, fill = "
white") +
  annotate(geom="label",x = 14,  y = 2.5,
           label ="p = 0.653\n(6, 3)", fontface = "plain", col ="black", size = 3.5, fill = "w
hite") +
  annotate(geom="label",x = 16,  y = 2.5,
           label = "p = 0.326\n(6, 3)", fontface = "plain", col ="black", size = 3.5, fill = "
white") +
annotate(geom="label",x = 12,  y = 3.8,
           label = "B", fontface = "bold", col ="black", size = 4)
```

```
## Warning: Removed 3 rows containing missing values (geom_point).
```

```
## Warning: Removed 3 row(s) containing missing values (geom_path).
```

```
dev.off()
```

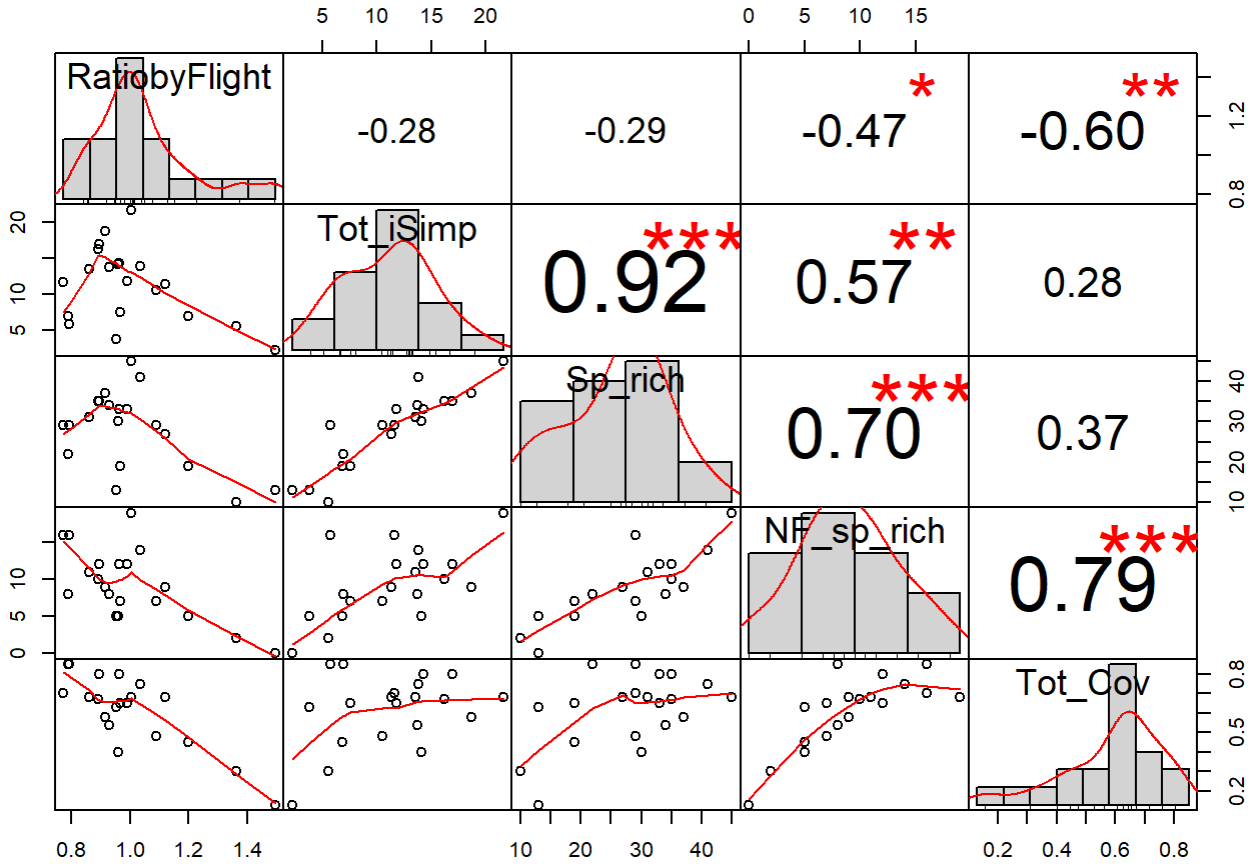
```
## png
##   2
```

4.3.2 Surface temperature response and vegetation characteristics

4.3.2.1. Correlations of temperature and vegetation characteristics within fields

Correlations Gravel Pit July - 12-4

```
GravelJulyDay <-read.csv("GravelJulyDayFocus.csv")

c <- as.matrix(GravelJulyDay[,-c(1:4)])

chart.Correlation(c, histogram=TRUE, pch=19, method = "spearman") #only to check for normality
 (some not normal)
```




```
res <- rcorr(c, type = "spearman")

rcorr.adjust(c)
```

```
##
##  Pearson correlations:
##               RatiobyFlight Tot_iSimp Sp_rich NF_sp_rich Tot_Cov
## RatiobyFlight        1.0000   -0.4071 -0.5076    -0.6509 -0.8195
## Tot_iSimp           -0.4071    1.0000  0.9011     0.6041  0.3564
## Sp_rich             -0.5076    0.9011  1.0000     0.7793  0.5149
## NF_sp_rich          -0.6509    0.6041  0.7793     1.0000  0.7676
## Tot_Cov             -0.8195    0.3564  0.5149     0.7676  1.0000
##
##  Number of observations: 20
##
##  Pairwise two-sided p-values:
##               RatiobyFlight Tot_iSimp Sp_rich NF_sp_rich Tot_Cov
## RatiobyFlight               0.0748    0.0223  0.0019     <.0001
## Tot_iSimp     0.0748                  <.0001  0.0048     0.1230
## Sp_rich       0.0223        <.0001            <.0001     0.0202
## NF_sp_rich    0.0019        0.0048    <.0001             <.0001
## Tot_Cov       <.0001        0.1230    0.0202  <.0001
##
##  Adjusted p-values (Holm's method)
##               RatiobyFlight Tot_iSimp Sp_rich NF_sp_rich Tot_Cov
```

```
## RatiobyFlight              0.1497    0.0807  0.0113     <.0001
## Tot_iSimp     0.1497                 <.0001  0.0240     0.1497
## Sp_rich       0.0807       <.0001            0.0004     0.0807
## NF_sp_rich    0.0113       0.0240    0.0004             0.0005
## Tot_Cov       <.0001       0.1497    0.0807  0.0005
```

```
attr(res$r, "dimnames")
```

```
## [[1]]
## [1] "RatiobyFlight" "Tot_iSimp"     "Sp_rich"       "NF_sp_rich"
## [5] "Tot_Cov"
##
## [[2]]
## [1] "RatiobyFlight" "Tot_iSimp"     "Sp_rich"       "NF_sp_rich"
## [5] "Tot_Cov"
```

```
name <- list(c("Temp. norm.", "Sp. diversity",  "Sp. rich.",
               "NF sp. rich.",
               "% ground cover"))
attr(res$r, 'dimnames') <- c(name, name)
attr(res$P, 'dimnames') <- c(name, name)

tiff("CorrGravel.tiff", width = 7, height = 5, units = 'in', res = 100)

ggcorrplot(res$r, hc.order = FALSE,
           type = "upper", p.mat = res$P, colors = c("olivedrab3", "white", "orange"), lab = T
RUE, sig.level = 0.05,
           insig = "pch", pch = 4, pch.col = "red", pch.cex = 10) +
  theme(axis.text=element_text(colour="black"))


dev.off()
```

```
## png
##   2
```

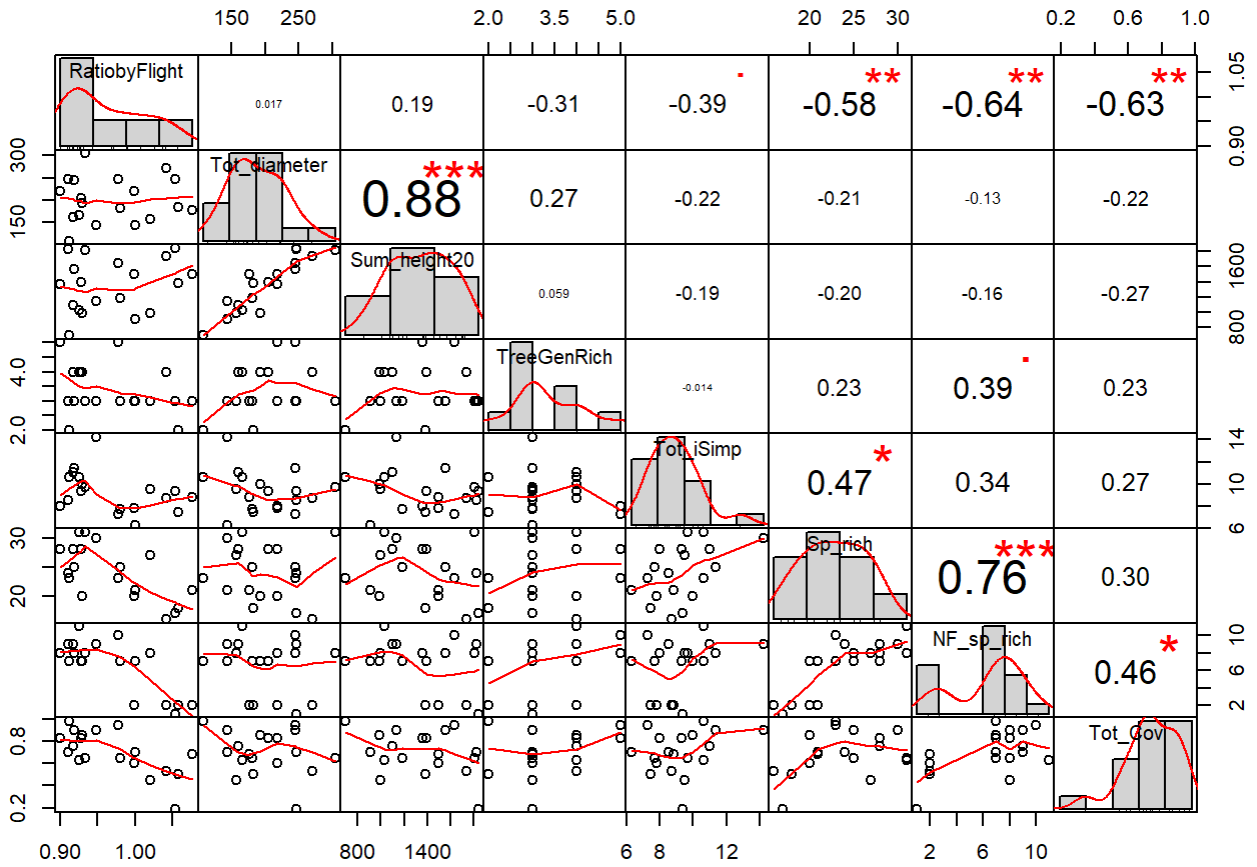
```
partialc <- as.matrix(GravelJulyDay[,-c(1:4, 6, 8)])

partial.cor(partialc, tests=TRUE, use=c("complete.obs", "pairwise.complete.obs"))
```

```
##
##  Partial correlations:
##               RatiobyFlight  Sp_rich  Tot_Cov
## RatiobyFlight       0.00000 -0.17434 -0.75561
## Sp_rich            -0.17434  0.00000  0.20035
## Tot_Cov            -0.75561  0.20035  0.00000
##
##  Number of observations: 20
##
##  Pairwise two-sided p-values:
```

```
##                RatiobyFlight Sp_rich Tot_Cov
## RatiobyFlight                 0.4753  0.0002
## Sp_rich        0.4753                 0.4108
## Tot_Cov        0.0002         0.4108
##
##  Adjusted p-values (Holm's method)
##                RatiobyFlight Sp_rich Tot_Cov
## RatiobyFlight                 0.8217  0.0005
## Sp_rich        0.8217                 0.8217
## Tot_Cov        0.0005         0.8217
```

Correlations 2016 Reforestation July - 12-4

```
TV2016JulyDay <-read.csv("TV_2016JulyDayno25DSFocus.csv")

c <- as.matrix(TV2016JulyDay[,-c(1:4)])

chart.Correlation(c, histogram=TRUE, pch=19, method = "spearman") #only to check for normality
 (some not normal)
```




```
res <- rcorr(c, type = "spearman")
res$P
```

```
##                RatiobyFlight Tot_diameter Sum_height20 TreeGenRich
## RatiobyFlight             NA 9.459370e-01 4.415495e-01   0.1966590
```

```
## Tot_diameter    0.945937003           NA 7.166067e-07   0.2566913
## Sum_height20    0.441549502 7.166067e-07           NA   0.8118940
## TreeGenRich     0.196658988 2.566913e-01 8.118940e-01          NA
## Tot_iSimp       0.097653060 3.605109e-01 4.329028e-01   0.9533718
## Sp_rich         0.009052493 3.823818e-01 4.097878e-01   0.3430536
## NF_sp_rich      0.003242020 5.884624e-01 5.030367e-01   0.0970484
## Tot_Cov         0.003772274 3.674862e-01 2.688946e-01   0.3493573
##                Tot_iSimp      Sp_rich   NF_sp_rich     Tot_Cov
## RatiobyFlight 0.09765306 0.0090524928 0.0032420198 0.003772274
## Tot_diameter  0.36051093 0.3823818104 0.5884623764 0.367486152
## Sum_height20  0.43290282 0.4097878214 0.5030367093 0.268894571
## TreeGenRich   0.95337176 0.3430536365 0.0970483982 0.349357334
## Tot_iSimp             NA 0.0417243634 0.1521281033 0.272176760
## Sp_rich       0.04172436           NA 0.0001512877 0.216401811
## NF_sp_rich    0.15212810 0.0001512877           NA 0.049893663
## Tot_Cov       0.27217676 0.2164018111 0.0498936629          NA
```

```
attr(res$r, "dimnames")
```

```
## [[1]]
## [1] "RatiobyFlight" "Tot_diameter"  "Sum_height20"  "TreeGenRich"
## [5] "Tot_iSimp"     "Sp_rich"       "NF_sp_rich"    "Tot_Cov"
##
## [[2]]
## [1] "RatiobyFlight" "Tot_diameter"  "Sum_height20"  "TreeGenRich"
## [5] "Tot_iSimp"     "Sp_rich"       "NF_sp_rich"    "Tot_Cov"
```

```
name <- list(c("Temp. norm.","Tree diameter", "Tree height",  "Tree gen. rich.", "Sp. diversit
y",   "Sp. rich.",
               "NF sp. rich.",
               "% ground cover"))
attr(res$r, 'dimnames') <- c(name, name)
attr(res$P, 'dimnames') <- c(name, name)

tiff("Corr2016.tiff", width = 7, height = 5, units = 'in', res = 100)

ggcorrplot(res$r, hc.order = FALSE,
           type = "upper", p.mat = res$P, colors = c("olivedrab3", "white", "orange"), lab = T
RUE, sig.level = 0.05,
           insig = "pch", pch = 4, pch.col = "red", pch.cex = 10) +
  theme(axis.text=element_text(colour="black"))

dev.off()
```

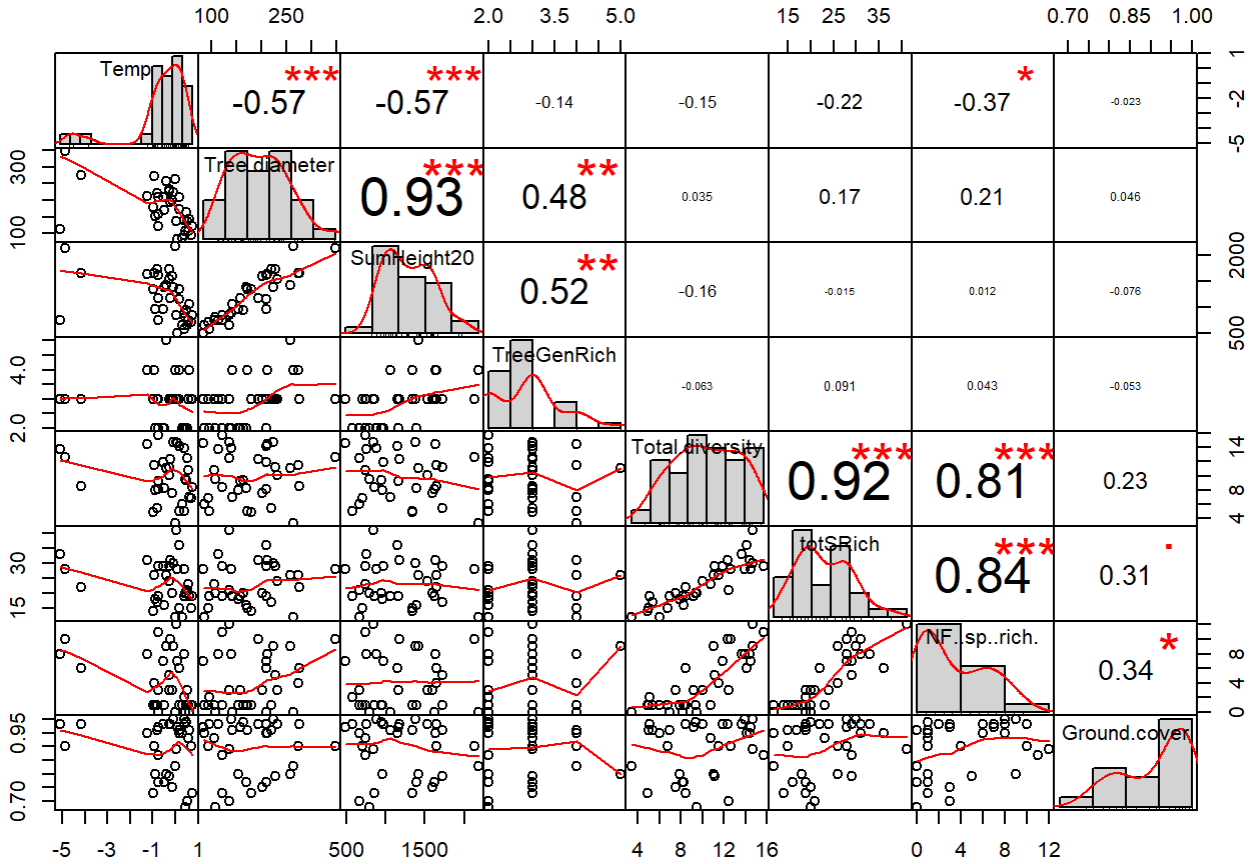
```
## png
##   2
```

```
partialc <- as.matrix(TV2016JulyDay[,-c(1:5,7, 9:11)])

partial.cor(partialc, tests=TRUE, use=c("complete.obs", "pairwise.complete.obs"))
```

```
##
##  Partial correlations:
##              Tot_diameter TreeGenRich  Tot_Cov
## Tot_diameter      0.00000     0.38865 -0.34387
## TreeGenRich       0.38865     0.00000  0.36022
## Tot_Cov          -0.34387     0.36022  0.00000
##
##  Number of observations: 19
##
##  Pairwise two-sided p-values:
##              Tot_diameter TreeGenRich Tot_Cov
## Tot_diameter              0.1110      0.1624
## TreeGenRich  0.1110                   0.1420
## Tot_Cov      0.1624       0.1420
##
##  Adjusted p-values (Holm's method)
##              Tot_diameter TreeGenRich Tot_Cov
## Tot_diameter              0.3329      0.3329
## TreeGenRich  0.3329                   0.3329
## Tot_Cov      0.3329       0.3329
```

Correlations 2015 Reforestation July - 12-4

```
TV2015JulyDay <-read.csv("TV_2015JulyDayFocus.csv")

c <- as.matrix(TV2015JulyDay[,-c(1:4)])

chart.Correlation(c, histogram=TRUE, pch=19, method = "spearman") #only to check for normality
 (some not normal)
```




```
res <- rcorr(c, type = "spearman")
attr(res$r, "dimnames")
```

```
## [[1]]
## [1] "Temp"            "Tree.diameter"   "SumHeight20"     "TreeGenRich"
## [5] "Total.diversity" "totSRich"        "NF..sp..rich."   "Ground.cover"
##
## [[2]]
## [1] "Temp"            "Tree.diameter"   "SumHeight20"     "TreeGenRich"
## [5] "Total.diversity" "totSRich"        "NF..sp..rich."   "Ground.cover"
```

```
name <- list(c("Temp. norm.","Tree diameter", "Tree height",  "Tree gen. rich.", "Sp. diversit
y",   "Sp. rich.",
               "NF sp. rich.",
               "% ground cover"))
attr(res$r, 'dimnames') <- c(name, name)
attr(res$P, 'dimnames') <- c(name, name)

tiff("Corr2015.tiff", width = 7, height = 5, units = 'in', res = 100)

ggcorrplot(res$r, hc.order = FALSE,
           type = "upper", p.mat = res$P, colors = c("olivedrab3", "white", "orange"), lab = T
RUE, sig.level = 0.05,
           insig = "pch", pch = 4, pch.col = "red", pch.cex = 10) +
  theme(axis.text=element_text(colour="black"))
```

```
dev.off()
```

```
## png
##   2
```

4.3.2.2 Variation in ecological attributes

```
#ground cover
AllS <-read.csv("AllSites.csv")

ex1 <- AllS %>%
  group_by(Field) %>%
  summarise(test = mean(Ground.cover), sd(Ground.cover), var(Ground.cover))
head(ex1)
```

```
## # A tibble: 3 x 4
##   Field   test `sd(Ground.cover)` `var(Ground.cover)`
##   <fct>  <dbl>              <dbl>               <dbl>
## 1 PE     0.614              0.186              0.0345
## 2 YA2015 0.891              0.100              0.0101
## 3 YA2016 0.698              0.195              0.0381
```

```
DT <- data.table(AllS)
DT[, .(W = shapiro.test(Ground.cover)$statistic, P.value = shapiro.test(Ground.cover)$p.value)
,
   by = .(Field)]
```

```
##     Field         W      P.value
## 1:     PE 0.9163575 0.0843313495
## 2: YA2015 0.8601087 0.0004748873
## 3: YA2016 0.9479709 0.3647906701
```

```
leveneTest(AllS$Ground.cover ~ AllS$Field)
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value  Pr(>F)
## group  2  2.6877 0.07506 .
##       70
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
kruskal.test(Ground.cover ~ Field, data = AllS)
```

```
##
##  Kruskal-Wallis rank sum test
##
```

```
## data:  Ground.cover by Field
## Kruskal-Wallis chi-squared = 32.454, df = 2, p-value = 8.967e-08
```

```
dunnTest(Ground.cover ~ Field, data = AllS)
```

```
## Dunn (1964) Kruskal-Wallis multiple comparison
```

```
##   p-values adjusted with the Holm method.
```

```
##        Comparison         Z      P.unadj        P.adj
## 1     PE - YA2015 -5.329041 9.873253e-08 2.961976e-07
## 2     PE - YA2016 -1.274667 2.024270e-01 2.024270e-01
## 3 YA2015 - YA2016  3.817220 1.349638e-04 2.699277e-04
```

```
#sp rich
ex1 <- AllS %>%
  group_by(Field) %>%
  summarise(test = mean(totSRich), sd(totSRich), var(totSRich))
head(ex1)
```

```
## # A tibble: 3 x 4
##   Field   test `sd(totSRich)` `var(totSRich)`
##   <fct>  <dbl>          <dbl>           <dbl>
## 1 PE      28.2           9.49            90.1
## 2 YA2015  23.2           7.06            49.8
## 3 YA2016  24             4.68            21.9
```

```
TFC <- read.csv('TreeFieldComp.csv')
#Total diameter by field
ex1 <- TFC %>%
  group_by(Field) %>%
  summarise(mean(Sum_diam), sd(Sum_diam), var(Sum_diam))
head(ex1)
```

```
## # A tibble: 2 x 4
##   Field  `mean(Sum_diam)` `sd(Sum_diam)` `var(Sum_diam)`
##   <fct>             <dbl>          <dbl>           <dbl>
## 1 YA2015             174.           66.1           4367.
## 2 YA2016             201            50.4           2545.
```

```
TFC$Sum_diam <- as.numeric(TFC$Sum_diam)

DT <- data.table(TFC)
DT[, .(W = shapiro.test(Sum_diam)$statistic, P.value = shapiro.test(Sum_diam)$p.value),
   by = .(Field)]
```

```
##     Field         W   P.value
```

```
## 1: YA2015 0.9725223 0.5161859
## 2: YA2016 0.9766085 0.8961827
```

```
leveneTest(TFC$Sum_diam ~ TFC$Field)
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value Pr(>F)
## group  1  1.7338 0.1937
##       52
```

```
anova(lm(Sum_diam ~ Field, data = TFC))
```

```
## Analysis of Variance Table
##
## Response: Sum_diam
##           Df Sum Sq Mean Sq F value Pr(>F)
## Field      1   9130  9130.1  2.4437 0.1241
## Residuals 52 194284  3736.2
```

```
#Total height by field
ex1 <- TFC %>%
  group_by(Field) %>%
  summarise(mean(Sum_height20), sd(Sum_height20), var(Sum_height20))
head(ex1)
```

```
## # A tibble: 2 x 4
##   Field  `mean(Sum_height20)` `sd(Sum_height20)` `var(Sum_height20)`
##   <fct>                <dbl>              <dbl>               <dbl>
## 1 YA2015               1167.               463.             213974.
## 2 YA2016               1347.               344.             118642.
```

```
DT <- data.table(TFC)
DT[, .(W = shapiro.test(Sum_height20)$statistic, P.value = shapiro.test(Sum_height20)$p.value)
,
   by = .(Field)]
```

```
##     Field         W   P.value
## 1: YA2015 0.9582667 0.2027580
## 2: YA2016 0.9538131 0.4576183
```

```
leveneTest(TFC$Sum_height20 ~ TFC$Field)
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value Pr(>F)
## group  1  2.7401 0.1039
##       52
```

```
anova(lm(Sum_height20 ~ Field, data = TFC))
```

```
## Analysis of Variance Table
##
## Response: Sum_height20
##           Df  Sum Sq Mean Sq F value Pr(>F)
## Field      1  402796  402796  2.2257 0.1418
## Residuals 52 9410691  180975
```

```
#Tree genus richness
ex1 <- TFC %>%
  group_by(Field) %>%
  summarise(mean(TreeGenusRich), sd(TreeGenusRich), var(TreeGenusRich))
head(ex1)
```

```
## # A tibble: 2 x 4
##   Field  `mean(TreeGenusRich)` `sd(TreeGenusRich)` `var(TreeGenusRich)`
##   <fct>                  <dbl>               <dbl>                <dbl>
## 1 YA2015                  2.86               0.772                0.597
## 2 YA2016                  3.37               0.831                0.690
```

```
DT <- data.table(TFC)
DT[, .(W = shapiro.test(TreeGenusRich)$statistic, P.value = shapiro.test(TreeGenusRich)$p.valu
e),
   by = .(Field)]
```

```
##     Field         W      P.value
## 1: YA2015 0.8208962 5.385962e-05
## 2: YA2016 0.8553458 8.206216e-03
```

```
leveneTest(TFC$TreeGenusRich ~ TFC$Field)
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value Pr(>F)
## group  1  0.0432 0.8362
##       52
```

```
anova(lm(TreeGenusRich ~ Field, data = TFC))
```

```
## Analysis of Variance Table
##
## Response: TreeGenusRich
##           Df Sum Sq Mean Sq F value  Pr(>F)
## Field      1  3.219  3.2192  5.1181 0.02788 *
## Residuals 52 32.707  0.6290
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```