CodingChallenge7_LinearModel_SK

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Q1: Reading the data

```
# Load required libraries
library(tidyverse)
```

```
## -- Attaching core tidyverse packages ------------------------ tidyverse 2.0.0 --
## v dplyr     1.1.4     v readr     2.1.5
## v forcats   1.0.0     v stringr   1.5.1
## v ggplot2   3.5.1     v tibble    3.2.1
## v lubridate 1.9.3     v tidyr     1.3.1
## v purrr     1.0.2
## -- Conflicts ------------------------------------------ tidyverse_conflicts() --
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()
## i Use the conflicted package (<http://conflicted.r-lib.org/>) to force all conflicts to become errors
```

```
library(lme4)
```

```
## Loading required package: Matrix
##
## Attaching package: 'Matrix'
##
## The following objects are masked from 'package:tidyr':
##
##     expand, pack, unpack
```

```
library(emmeans)
```

```
## Welcome to emmeans.
## Caution: You lose important information if you filter this package's results.
## See '? untidy'
```

```
library(multcomp)
```

```
## Loading required package: mvtnorm
## Loading required package: survival
## Loading required package: TH.data
## Loading required package: MASS
```

```
##
## Attaching package: 'MASS'
##
## The following object is masked from 'package:dplyr':
##
##     select
##
##
## Attaching package: 'TH.data'
##
## The following object is masked from 'package:MASS':
##
##     geyser
```

```r
library(multcompView)

# Read in the data
PlantEmergence <- read.csv("PlantEmergence.csv")

# Convert columns to factors
PlantEmergence$Treatment <- as.factor(PlantEmergence$Treatment)
PlantEmergence$DaysAfterPlanting <- as.factor(PlantEmergence$DaysAfterPlanting)
PlantEmergence$Rep <- as.factor(PlantEmergence$Rep)
```

Q2: Fitting the linear model with Treatment, DaysAfterPlanting, and their interaction.

```r
# Fit the linear model with interaction
lm_emergence <- lm(Emergence ~ Treatment * DaysAfterPlanting, data = PlantEmergence)

# View the summary of the linear model
summary(lm_emergence)
```

```
##
## Call:
## lm(formula = Emergence ~ Treatment * DaysAfterPlanting, data = PlantEmergence)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -21.250  -6.062  -0.875   6.750  21.875
##
## Coefficients:
##                                Estimate Std. Error t value Pr(>|t|)
## (Intercept)                   1.823e+02  5.324e+00  34.229   <2e-16 ***
## Treatment2                   -1.365e+02  7.530e+00 -18.128   <2e-16 ***
## Treatment3                    1.112e+01  7.530e+00   1.477    0.142
## Treatment4                    2.500e+00  7.530e+00   0.332    0.741
## Treatment5                    8.750e+00  7.530e+00   1.162    0.248
## Treatment6                    7.000e+00  7.530e+00   0.930    0.355
## Treatment7                   -1.250e-01  7.530e+00  -0.017    0.987
## Treatment8                    9.125e+00  7.530e+00   1.212    0.228
```

```
## Treatment9                       2.375e+00  7.530e+00   0.315    0.753
## DaysAfterPlanting14              1.000e+01  7.530e+00   1.328    0.187
## DaysAfterPlanting21              1.062e+01  7.530e+00   1.411    0.161
## DaysAfterPlanting28              1.100e+01  7.530e+00   1.461    0.147
## Treatment2:DaysAfterPlanting14   1.625e+00  1.065e+01   0.153    0.879
## Treatment3:DaysAfterPlanting14  -2.625e+00  1.065e+01  -0.247    0.806
## Treatment4:DaysAfterPlanting14  -6.250e-01  1.065e+01  -0.059    0.953
## Treatment5:DaysAfterPlanting14   2.500e+00  1.065e+01   0.235    0.815
## Treatment6:DaysAfterPlanting14   1.000e+00  1.065e+01   0.094    0.925
## Treatment7:DaysAfterPlanting14  -2.500e+00  1.065e+01  -0.235    0.815
## Treatment8:DaysAfterPlanting14  -2.500e+00  1.065e+01  -0.235    0.815
## Treatment9:DaysAfterPlanting14   6.250e-01  1.065e+01   0.059    0.953
## Treatment2:DaysAfterPlanting21   3.500e+00  1.065e+01   0.329    0.743
## Treatment3:DaysAfterPlanting21  -1.000e+00  1.065e+01  -0.094    0.925
## Treatment4:DaysAfterPlanting21   1.500e+00  1.065e+01   0.141    0.888
## Treatment5:DaysAfterPlanting21   2.875e+00  1.065e+01   0.270    0.788
## Treatment6:DaysAfterPlanting21   4.125e+00  1.065e+01   0.387    0.699
## Treatment7:DaysAfterPlanting21  -2.125e+00  1.065e+01  -0.200    0.842
## Treatment8:DaysAfterPlanting21  -1.500e+00  1.065e+01  -0.141    0.888
## Treatment9:DaysAfterPlanting21  -1.250e+00  1.065e+01  -0.117    0.907
## Treatment2:DaysAfterPlanting28   2.750e+00  1.065e+01   0.258    0.797
## Treatment3:DaysAfterPlanting28  -1.875e+00  1.065e+01  -0.176    0.861
## Treatment4:DaysAfterPlanting28   3.264e-13  1.065e+01   0.000    1.000
## Treatment5:DaysAfterPlanting28   2.500e+00  1.065e+01   0.235    0.815
## Treatment6:DaysAfterPlanting28   2.125e+00  1.065e+01   0.200    0.842
## Treatment7:DaysAfterPlanting28  -3.625e+00  1.065e+01  -0.340    0.734
## Treatment8:DaysAfterPlanting28  -1.500e+00  1.065e+01  -0.141    0.888
## Treatment9:DaysAfterPlanting28  -8.750e-01  1.065e+01  -0.082    0.935
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 10.65 on 108 degrees of freedom
## Multiple R-squared:  0.9585, Adjusted R-squared:  0.945
## F-statistic: 71.21 on 35 and 108 DF,  p-value: < 2.2e-16
```

```r
# View the ANOVA table
anova(lm_emergence)
```

```
## Analysis of Variance Table
##
## Response: Emergence
##                              Df Sum Sq Mean Sq  F value    Pr(>F)
## Treatment                     8 279366   34921 307.9516 < 2.2e-16 ***
## DaysAfterPlanting             3   3116    1039   9.1603 1.877e-05 ***
## Treatment:DaysAfterPlanting  24    142       6   0.0522         1
## Residuals                   108  12247     113
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Q3:

Based on the ANOVA results, the interaction between Treatment and DaysAfterPlanting is not significant ($p = 1.000$), so we do not need to include it in the model. A simplified model with only the main effects of

Treatment and DaysAfterPlanting is sufficient.

Step1: fit simplified linear model

```
# Fit simplified linear model with only main effects
lm_simple <- lm(Emergence ~ Treatment + DaysAfterPlanting, data = PlantEmergence)

# Summary of the linear model
summary(lm_simple)
```

```
##
## Call:
## lm(formula = Emergence ~ Treatment + DaysAfterPlanting, data = PlantEmergence)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -21.1632  -6.1536  -0.8542   6.1823  21.3958
##
## Coefficients:
##                     Estimate Std. Error t value Pr(>|t|)
## (Intercept)          182.163      2.797  65.136  < 2e-16 ***
## Treatment2          -134.531      3.425 -39.277  < 2e-16 ***
## Treatment3             9.750      3.425   2.847  0.00513 **
## Treatment4             2.719      3.425   0.794  0.42876
## Treatment5            10.719      3.425   3.129  0.00216 **
## Treatment6             8.812      3.425   2.573  0.01119 *
## Treatment7            -2.188      3.425  -0.639  0.52416
## Treatment8             7.750      3.425   2.263  0.02529 *
## Treatment9             2.000      3.425   0.584  0.56028
## DaysAfterPlanting14    9.722      2.283   4.258 3.89e-05 ***
## DaysAfterPlanting21   11.306      2.283   4.951 2.21e-06 ***
## DaysAfterPlanting28   10.944      2.283   4.793 4.36e-06 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 9.688 on 132 degrees of freedom
## Multiple R-squared:  0.958,  Adjusted R-squared:  0.9545
## F-statistic: 273.6 on 11 and 132 DF,  p-value: < 2.2e-16
```

```
# ANOVA table for the model
anova(lm_simple)
```

```
## Analysis of Variance Table
##
## Response: Emergence
##                     Df Sum Sq Mean Sq F value    Pr(>F)
## Treatment            8 279366   34921 372.070 < 2.2e-16 ***
## DaysAfterPlanting    3   3116    1039  11.068 1.575e-06 ***
## Residuals          132  12389      94
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Step2: Interpretation

The simplified model with excluding the interaction term fits the data very well (Adjusted $R^2 = 0.9545$). Both Treatment and DaysAfterPlanting are significant predictors of Emergence. The intercept (182.16) represents average emergence for Treatment 1 at baseline planting day. The Treatment2 coefficient (-134.53) indicates that, all else equal, Treatment 2 results in a massive and statistically significant reduction in emergence.

Q4: calculating least square means (LS means) for Treatment, performing Tukey's post-hoc test, and interpreting the Compact Letter Display (CLD) using the emmeans and cld() functions.

```
# Load emmeans and multcompView if not already loaded
library(emmeans)
library(multcompView)

# Calculate LS means (estimated marginal means) for Treatment
treatment_lsmeans <- emmeans(lm_simple, ~ Treatment)

# Tukey post-hoc test with compact letter display
treatment_cld <- cld(treatment_lsmeans, alpha = 0.05, Letters = letters, reversed = TRUE)

# View results
treatment_cld
```

```
##  Treatment emmean   SE  df lower.CL upper.CL .group
##  5          200.9 2.42 132    196.1    205.7  a
##  3          199.9 2.42 132    195.1    204.7  a
##  6          199.0 2.42 132    194.2    203.8  a
##  8          197.9 2.42 132    193.1    202.7  ab
##  4          192.9 2.42 132    188.1    197.7  ab
##  9          192.2 2.42 132    187.4    196.9  ab
##  1          190.2 2.42 132    185.4    194.9  ab
##  7          188.0 2.42 132    183.2    192.8   b
##  2           55.6 2.42 132     50.8     60.4    c
##
## Results are averaged over the levels of: DaysAfterPlanting
## Confidence level used: 0.95
## P value adjustment: tukey method for comparing a family of 9 estimates
## significance level used: alpha = 0.05
## NOTE: If two or more means share the same grouping symbol,
##       then we cannot show them to be different.
##       But we also did not show them to be the same.
```

Conclusion:

Treatments 3, 5, and 6 had the highest and statistically similar emergence. Treatment 2 is significantly worse than all others and should likely be avoided. Intermediate treatments (like 4, 8, 9, 1) may perform acceptably but are not clearly top-tier.

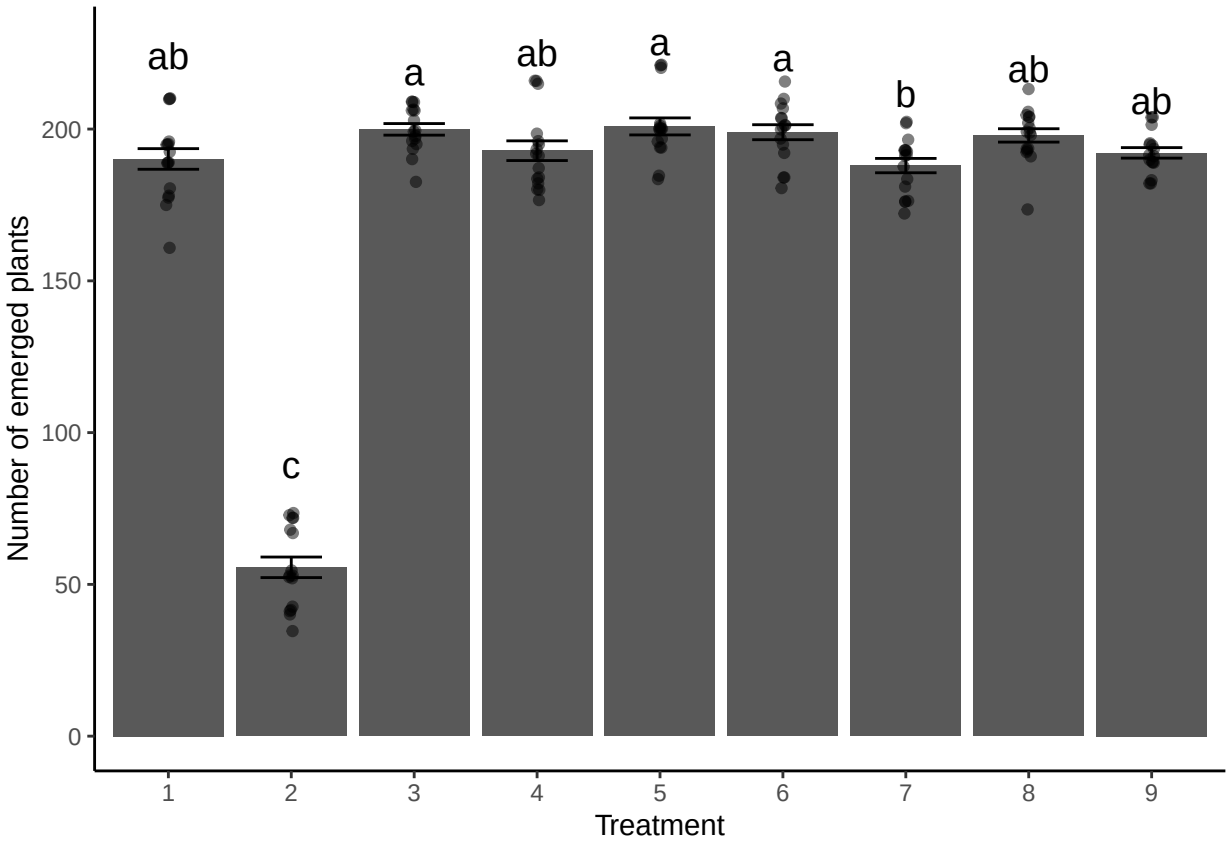
Q5: Making a plot using the provided function

Step1: Running the full function definition

```
plot_cldbars_onefactor <- function(lm_model, factor) {
  data <- lm_model$model
  variables <- colnames(lm_model$model)
  dependent_var <- variables[1]
  independent_var <- variables[2:length(variables)]

  lsmeans <- emmeans(lm_model, as.formula(paste("~", factor))) # estimate lsmeans
  Results_lsmeans <- cld(lsmeans, alpha = 0.05, reversed = TRUE, details = TRUE, Letters = letters) # c

  # Extracting the letters for the bars
  sig.diff.letters <- data.frame(Results_lsmeans$emmeans[,1],
                                 str_trim(Results_lsmeans$emmeans[,7]))
  colnames(sig.diff.letters) <- c(factor, "Letters")

  # for plotting with letters from significance test
  ave_stand2 <- lm_model$model %>%
    group_by(!!sym(factor)) %>%
    dplyr::summarize(
      ave.emerge = mean(.data[[dependent_var]], na.rm = TRUE),
      se = sd(.data[[dependent_var]]) / sqrt(n())
    ) %>%
    left_join(sig.diff.letters, by = factor) %>%
    mutate(letter_position = ave.emerge + 10 * se)

  plot <- ggplot(data, aes(x = !! sym(factor), y = !! sym(dependent_var))) +
    stat_summary(fun = mean, geom = "bar") +
    stat_summary(fun.data = mean_se, geom = "errorbar", width = 0.5) +
    ylab("Number of emerged plants") +
    geom_jitter(width = 0.02, alpha = 0.5) +
    geom_text(data = ave_stand2, aes(label = Letters, y = letter_position), size = 5) +
    xlab(as.character(factor)) +
    theme_classic()

  return(plot)
}
```

Make the plot

```
plot_cldbars_onefactor(lm_simple, "Treatment")
```



Link to my GitHub

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