

Power investigation for John Lowery's denitrification experiment

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For starters, the following fixed effects model was fit

$$\mu_{ijkl|t} = \mu + \alpha_i + \gamma_j + \alpha\gamma_{ij} + \beta_t t + \alpha_i \beta_{t2} t^2 + \alpha_i$$

where  $i, j, k, l = 1, 2$  denote levels of fertilizer, location, chamber and day, respectively:

$$\begin{aligned} i &= \begin{cases} 1 & \text{unfertilized} \\ 2 & \text{fertilized} \end{cases} \\ j &= \begin{cases} 1 & \text{fairway} \\ 2 & \text{rough} \end{cases} \\ k &= \begin{cases} 1 & \text{day 1} \\ 2 & \text{day 2} \end{cases} \\ l &= \begin{cases} 1 & \text{1}^{st} \text{ chamber} \\ 2 & \text{2}^{nd} \text{ chamber} \end{cases} \\ t &= \text{time} \end{aligned}$$

In this simplistic fixed effects analysis, in which each observation is treated as independent, the fertilizer effect and the location effect are significant, and the fertilizer effect appears to vary significantly by location. There is also a linear time effect. There may be some curvature in the association with time: the  $p$ -value for adding a quadratic term to the model is  $p = 0.09$ . The fitted model and analysis of variance appear on the next page. The 5 (or 6) regression parameters are estimated by setting  $\alpha_2 = \gamma_2 = \alpha\gamma_{12} = \alpha\gamma_{21} = \alpha\gamma_{22} = 0$ .

## The GLM Procedure

## Class Level Information

Class	Levels	Values
fert	2	1 2
location	2	1 2

Number of observations 76

Dependent Variable: y

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	2193651559	438730312	41.42	<.0001
Error	70	741389603	10591280		
Corrected Total	75	2935041162			

R-Square	Coeff Var	Root MSE	y Mean
0.747401	38.39755	3254.425	8475.605

Source	DF	Type I SS	Mean Square	F Value	Pr > F
fert	1	1778061853	1778061853	167.88	<.0001
location	1	206903400	206903400	19.54	<.0001
fert*location	1	111397476	111397476	10.52	0.0018
txf	1	66543767	66543767	6.28	0.0145
txf2	1	30745063	30745063	2.90	0.0929

Source	DF	Type III SS	Mean Square	F Value	Pr > F
fert	1	12521416.2	12521416.2	1.18	0.2806
location	1	220083782.8	220083782.8	20.78	<.0001
fert*location	1	121242621.7	121242621.7	11.45	0.0012
txf	1	48847572.0	48847572.0	4.61	0.0352
txf2	1	30745063.1	30745063.1	2.90	0.0929

Parameter	Estimate	Standard Error	t Value	Pr >  t
Intercept	3572.592067 B	2707.982069	1.32	0.1914
fert 1	-373.171014 B	2809.021659	-0.13	0.8947
location 1	5937.967632 B	1058.875878	5.61	<.0001
fert*location 1 1	-5059.388685 B	1495.356048	-3.38	0.0012
txf	4239.931983	1974.293085	2.15	0.0352
txf2	-545.434869	320.132252	-1.70	0.0929

### Estimation of variance components

A more appropriate model allows for the possibility of correlation among observations taken from the same chamber. To this end, a random chamber effect,  $C_l \sim N(0, \sigma_C^2)$  was added to the model, which was fit using PROC MIXED in SAS. The analysis does not indicate any evidence of intrachamber correlation. (The estimate of the chamber variance component is  $\hat{\sigma}_C^2 = 0$ .) This estimate will not be useful for subsequent power and sample size computations. Additionally, the possibility of intraday correlation was investigated by including a random day effect,  $D_k \sim N(0, \sigma_D^2)$ . Again, no evidence of a day effect was exhibited. The code and output used to address these questions is attached.