

A SECOND glance at Reynolds data on node survival
Jason A. Osborne, Dept. of Statistics, NCSU, October 2002

In the initial analysis, the experimental unit was taken as replication. Instead of a sum of node mortality ($x/30$) for all 15 2-node stolons together, the individual stolons are used in this second analysis. Because 15 stolons were measured for each replication, and replications are viewed as randomly sampled from a population, there is the possibility of intra-replication correlation, or correlation among two stolons from the same rep. The response for a given stolon was dichotomized into categories of survival or no-survival. The model used for the analysis has a 6×4 fixed-effect factorial design with a random effect for replication, nested in the fixed effect treatment combination. If p_{ijk} denotes the chance of at least one node surviving for cultivar i , temperature j and replication k within cultivar \times temp ij , and $R_{k(ij)}$ denotes the normally distributed random effect for replication k , the **generalized linear mixed model** for survivorship, given the replication effect, is

$$\log\left(\frac{p_{ijk}}{1-p_{ijk}}\right) = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + R_{k(ij)}$$

The SAS procedure GENMOD (code attached) is used to estimate model parameters using generalized estimating equations (GEE). Type 3 tests for the fixed effects of TEMPERATURE, CULTIVAR and their interaction TEMPERATURE \times CULTIVAR are based on likelihood ratios after including other terms in the model. This second analysis yields the same conclusion as the first: there is no evidence of a TEMPERATURE \times CULTIVAR interaction, but there is strong evidence a monotonic association between survivorship and temperature. The survivorship differences among cultivars is not significant.

Score Statistics For Type 3 GEE Analysis

Source	DF	Chi-Square	Pr > ChiSq
Temp	2	11.14	0.0038
cultivar	5	1.90	0.8630
Temp*cultivar	10	13.79	0.1829

In the following output, the last level of each fixed effect is taken as a “baseline” by default. For example, to estimate the mean survival for the three temperatures, for the “tifway” cultivar, use

$$\begin{aligned} \hat{p}_{16} &= (1 + \exp\{-0.2683 + 4.3458\})^{-1} \\ &= 0.983 \\ \hat{p}_{26} &= (1 + \exp\{-0.2683 + 2.0029\})^{-1} \\ &= 0.849 \\ \hat{p}_{36} &= (1 + \exp\{-0.2683\})^{-1} \\ &= 0.433 \end{aligned}$$

The SAS System

The GENMOD Procedure

Model Information

Data Set	WORK.CASEY
Distribution	Binomial
Link Function	Logit
Dependent Variable	surv
Observations Used	1080

Class Level Information

Class	Levels	Values
Temp	3	1 2 3
cultivar	6	GN1 NB QS Tifsport Tifton Tifway
Rep	4	1 2 3 4

Response Profile

Ordered Value	surv	Total Frequency
1	1	830
2	0	250

PROC GENMOD is modeling the probability that surv='1'.

Criteria For Assessing Goodness Of Fit

Criterion	DF	Value	Value/DF
Deviance	1062	950.4059	0.8949
Scaled Deviance	1062	950.4059	0.8949
Pearson Chi-Square	1062	1079.9999	1.0169
Scaled Pearson X2	1062	1079.9999	1.0169
Log Likelihood		-475.2029	

GEE Model Information

Correlation Structure	Exchangeable
Subject Effect	Rep(Temp*cultivar) (72 levels)
Number of Clusters	72
Correlation Matrix Dimension	15
Maximum Cluster Size	15
Minimum Cluster Size	15

Analysis Of GEE Parameter Estimates
Empirical Standard Error Estimates

Parameter		Estimate	Standard Error	95% Confidence Limits		Z	Pr > Z
Intercept		-0.2683	0.7086	-1.6571	1.1206	-0.38	0.7050
Temp	1	4.3458	1.1304	2.1303	6.5613	3.84	0.0001
Temp	2	2.0029	0.7410	0.5505	3.4553	2.70	0.0069
Temp	3	0.0000	0.0000	0.0000	0.0000	.	.
cultivar	GN1	-0.0682	0.7434	-1.5253	1.3889	-0.09	0.9269
cultivar	NB	0.3350	0.8160	-1.2644	1.9343	0.41	0.6814
cultivar	QS	0.6737	1.0066	-1.2993	2.6467	0.67	0.5033
cultivar	Tifsport	1.7622	0.8570	0.0825	3.4419	2.06	0.0398
cultivar	Tifton	0.4018	0.7396	-1.0478	1.8513	0.54	0.5869
cultivar	Tifway	0.0000	0.0000	0.0000	0.0000	.	.
Temp*cultivar	1 GN1	-1.0649	1.4695	-3.9450	1.8152	-0.72	0.4687
Temp*cultivar	1 NB	-2.2153	1.2700	-4.7045	0.2739	-1.74	0.0811
Temp*cultivar	1 QS	-2.3534	1.3508	-5.0009	0.2942	-1.74	0.0815
Temp*cultivar	1 Tifsport	-3.2007	1.5398	-6.2187	-0.1826	-2.08	0.0377
Temp*cultivar	1 Tifton	-1.8403	1.2687	-4.3269	0.6463	-1.45	0.1469
Temp*cultivar	1 Tifway	0.0000	0.0000	0.0000	0.0000	.	.
Temp*cultivar	2 GN1	-1.3299	0.8517	-2.9993	0.3395	-1.56	0.1184
Temp*cultivar	2 NB	0.5695	0.9254	-1.2442	2.3832	0.62	0.5383
Temp*cultivar	2 QS	-0.5365	1.0497	-2.5940	1.5209	-0.51	0.6093
Temp*cultivar	2 Tifsport	-2.0029	1.0666	-4.0934	0.0877	-1.88	0.0604
Temp*cultivar	2 Tifton	-0.4018	0.8819	-2.1302	1.3266	-0.46	0.6487
Temp*cultivar	2 Tifway	0.0000	0.0000	0.0000	0.0000	.	.
Temp*cultivar	3 GN1	0.0000	0.0000	0.0000	0.0000	.	.
Temp*cultivar	3 NB	0.0000	0.0000	0.0000	0.0000	.	.
Temp*cultivar	3 QS	0.0000	0.0000	0.0000	0.0000	.	.
Temp*cultivar	3 Tifsport	0.0000	0.0000	0.0000	0.0000	.	.
Temp*cultivar	3 Tifton	0.0000	0.0000	0.0000	0.0000	.	.
Temp*cultivar	3 Tifway	0.0000	0.0000	0.0000	0.0000	.	.

Score Statistics For Type 3 GEE Analysis

Source	DF	Chi-Square	Pr > ChiSq
Temp	2	11.14	0.0038
cultivar	5	1.90	0.8630
Temp*cultivar	10	13.79	0.1829

Least Squares Means

Effect	Temp	cultivar	Estimate	Standard Error	DF	Chi-Square	Pr > ChiSq
Temp*cultivar	1	GN1	2.9444	0.9116	1	10.43	0.0012
Temp*cultivar	1	NB	2.1972	0.4141	1	28.16	<.0001
Temp*cultivar	1	QS	2.3979	0.1890	1	161.05	<.0001
Temp*cultivar	1	Tifsport	2.6391	0.9279	1	8.09	0.0045
Temp*cultivar	1	Tifton	2.6391	0.5357	1	24.27	<.0001
Temp*cultivar	1	Tifway	4.0775	0.8807	1	21.44	<.0001
Temp*cultivar	2	GN1	0.3365	0.3547	1	0.90	0.3428
Temp*cultivar	2	NB	2.6391	0.3788	1	48.54	<.0001
Temp*cultivar	2	QS	1.8718	0.2040	1	84.21	<.0001
Temp*cultivar	2	Tifsport	1.4939	0.5969	1	6.26	0.0123
Temp*cultivar	2	Tifton	1.7346	0.4286	1	16.38	<.0001
Temp*cultivar	2	Tifway	1.7346	0.2168	1	64.03	<.0001
Temp*cultivar	3	GN1	-0.3365	0.2248	1	2.24	0.1345
Temp*cultivar	3	NB	0.0667	0.4046	1	0.03	0.8691
Temp*cultivar	3	QS	0.4055	0.7150	1	0.32	0.5706
Temp*cultivar	3	Tifsport	1.4939	0.4820	1	9.61	0.0019
Temp*cultivar	3	Tifton	0.1335	0.2118	1	0.40	0.5283
Temp*cultivar	3	Tifway	-0.2683	0.7086	1	0.14	0.7050

```
/* SAS CODE */
```

```
options ls=105 ps=300;
```

```
proc format;
  value cvfmt 1='Tifsport' 2='Tifway' 3='GN1' 4='QS' 5='NB' 6='Tifton';
run;
```

```
data casey;
  format cultivar cvfmt.;
  infile "casey.dat" firstobs=3;
  input Rep Cultivar $ Temp Nodes;
  if nodes>=1 then surv=1; else surv=0;
  if temp<4;
run;
```

```
proc genmod descending;
  class temp cultivar rep;
  model surv=temp|cultivar/ dist=bin type3;
  repeated subject=rep(temp*cultivar)/ type=exch corrw;
  lsmeans temp*cultivar;
run;
```

The estimated intra-replication correlation coefficient is small, $\hat{\rho} = 0.07$.