

Discussion Solution: Guinea Grass Growth with Native Plants

I do not show any of the details of the analyses here; if you have questions about them, ask.

General Approaches

Various approaches could be taken to the analysis of these data, as summarized below. **This does not mean all or several of the approaches should be used.** Redundant analyses addressing the same question should not be reported. Instead you should select the approach which is most appropriate and effective and use it.

H1: growth will be inversely related to the number of native species

This hypothesis could be addressed in at least two different ways, which differ subtly in the nature of the replication they use and thus of the scope of their conclusions:

- ANOVA followed by one or more pre-planned contrasts, or
- regression of **treatment means** against the number of native species.

In the ANOVA–contrast method, the observations (individual guinea grass plants) are the replication. The strength of any observed pattern — of differences in means related to the number of native species — would be evaluated relative to the variation among these observations, *i.e.* among plants growing with the same set of competitors. The conclusions would apply to these particular native species and combinations of native species. This approach also is more flexible than regression in terms of the hypothesized relationship of guinea grass mass to native species diversity: it does not assume a linear relationship.

In the regression approach, in contrast, the treatment groups are the replication. The observed pattern — the slope of the decrease in guinea grass mass with increasing native diversity — would be evaluated relative to variation among the different treatments. If the species and combinations used in this study could be viewed as a random sample of native species, the conclusions could then apply to all native species, giving a much more general conclusion than the ANOVA approach. In this study, however, the native species cannot be regarded as random representatives of native species in general: the three species were selected specifically to represent different growth forms. The scope of the conclusions that could be drawn from this approach therefore is unclear.

In short, the ANOVA–contrast method would probably be more powerful (has more “observations”) and a narrower but clearer scope of inference. I feel it is the better approach.

The seemingly obvious approach of regressing individual observations against the number of native species would not be valid because the replicate observations for a given treatment are not independent replication of that number of native species. This is why a regression would need to be done on the treatment-group means instead.

H2: growth will be greater when grown alone than with native species

vs.

H3: growth will be less when grown alone than with native species

These hypotheses are best addressed by ANOVA followed by a pre-planned contrast comparing the mean of the guinea-grass-only treatment to the average of the other 10 treatment means.

Dunnett's multiple comparisons between the guinea-grass-only treatment and each of the other treatments could be used instead of the contrast, but would be less powerful and would address the hypotheses in a piecemeal way. Tukey's multiple comparisons among all the treatment means would waste power by including many comparisons which are not relevant to these hypotheses, though this would be useful for the more general purpose of determining which treatments are most effective at suppressing guinea grass.

It would not be appropriate to use both Dunnett's and Tukey's comparisons, or both a preplanned contrast and either kind of unplanned multiple comparison.

Recommended Approach: Contrasts following ANOVA

ANOVA assumptions all are reasonable for these data: the observations are independent (unless treatments are pooled); the standard deviations satisfy the 2-fold guideline despite the groups being so small, and so many; the residuals are close to Normally distributed and there are no outliers.

The omnibus ANOVA is highly significant ($F_{10, 33} = 8.58$, $P < 0.0005$), but that doesn't address any of the hypotheses.

H2 and H3:

H2 and H3 can be addressed by a single pre-planned contrast, comparing the mean of the UUUU treatment to the average of the other treatments' means. The null hypothesis would be that there is no difference, with H2 and H3 then representing competing alternative hypotheses, *i.e.* the test would be two-sided and these two hypotheses would be the two sides of H_a . The conclusion from the contrast is that there is no significant evidence against the null hypothesis ($t_{33} = 0.0935$, $P = 0.926$), so neither of H2 or H3 is supported by the data.

H1:

Because there are several levels of the number of native species, a wide variety of preplanned contrasts could be used to analyze H1. A first decision is whether to include the UUUU treatment in these analyses, in which case the contrast in the preceding paragraph is relevant. I feel, though, that the 0-native treatment should not be included in this analysis; H3 indicates that there are biological reasons why the effect of an absence of native species might not follow whatever trend is seen in relation to number of native species when at least one is present.

One reasonable pair of independent contrasts would compare, first, the average of the 1-native treatments to the average of the 2- and 3-native treatments, and second the average of the 2-native treatments to the 3-native treatment; one-sided tests would be appropriate. The first of these contrasts is highly statistically significant ($t_{33} = 4.947$, $P < 0.0001$), while the second is not ($t_{33} = -0.04$, $P = 0.516$). Alternatively, the first contrast could compare the average of the 1- and 2-native treatments to the 3-native treatment, followed by a comparison between the averages of the 1-native and 2-native treatments. The first of these contrasts is not statistically significant ($t_{33} = 1.178$, $P = 0.124$) while the second is highly statistically significant ($t_{33} = 5.455$, $P < 0.0005$).

Conclusions

There is no evidence supporting either H2 or H3: while there is considerable variation among the treatments with different native species and species combinations, there is no statistical significant overall effect of the presence of native species on growth of guinea grass.

There is strong support for at least a partial version of H1: on average, guinea grass grew substantially more when competing with only one native species than when with two or more native species. There is no evidence, though, that adding a third native species reduces guinea grass more than does the average two species mix.

All these conclusions are specific to these three native species and combinations of them.

Alternative Approaches, Inferior but Valid

Dunnett's Comparisons to Address H2 and H3:

The means of three treatments with native species were significantly different (at "family" $\alpha = 0.05$) from that for the guinea-grass-only treatment: guinea grass grew more when competing with only *Plumbago* or only *Dodonea* and grew less when competing with two *Myoporum* and one *Dodonea*; the other treatments did not differ significantly from guinea grass alone.

Taken as a whole, these results do not support either H2 or H3 as general statements about these three native species. In this sense the conclusion is the same as from the contrast described above.

These comparisons do, though, indicate that H3 may apply for some of the native species, at least when only one native species is present. The fact that the two treatments with growth significant higher than for guinea grass alone had only one native species, and the one treatment with significantly lower growth had two native species, also could be taken as weak support for the same partial version of H1 supported by the contrasts described above: that having at least two of these native species suppresses guinea grass better than (at least some) treatments with only one native species.

Regression on Treatment Means to Address H1

With so few observations, it is difficult to assess regression assumptions, particularly evenness of spread and Normality of residuals. The crucial assumption of a linear relationship, though, is highly dubious: the value for the one 3-natives treatment is slightly larger than the average of the six values for combinations with two native species, and nearly twice what it would be predicted to be if a linear trend from 1-native to 2-natives continued in a linear fashion. Some nonlinear model with a decreasing effect of adding more native species, or a linear model relating guinea grass growth to a transformation of species number (*e.g.* log) would be a better fit, but still not a good fit, given the essentially flat pattern seen between 2-natives and 3-natives.

Using a linear regression (on untransformed variables) as a very rough model for the relationship, the analysis does not give convincing evidence of a linear trend ($t_8 = -1.74$, $P = 0.12$).

This analysis produces a seemingly different conclusion than does the preplanned contrast described above, which shows a highly significant decrease in guinea grass growth when competing with two or three native species than when competing with only one native species. There are two reasons for this. The most important, and obvious, is that the regression models the effect of native-species diversity as a linear trend, while the contrast does not, and as noted above, there does not appear to be a decrease in guinea grass growth from two native species to three, let alone a linear continuation of the decrease seen from one to two native species. In other words, the regression model does not fit the data as well as does the less specific contrast.

In addition, as discussed on the first page, these two analyses have different sorts of replication. The regression evaluated the significance of the trend in relation to the quite

substantial variability seen among treatments with the same number of native species, *i.e.* among species and species combinations, while the ANOVA and associate contrast evaluated the difference in relation to the considerably smaller variation among observations of the same treatment.