Presentation of Analysis of Variance Results and Graphical Data

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Several issues related to presenting statistical results in articles published in *HortTechnology, HortScience,* and the *Journal of the American Society for Horticultural Science* were discussed at a recent meeting of ASHS associate editors. Previous reviews of statistical procedures (Chew, 1976; Peterson, 1977; Swallow, 1984) have dealt with some of those issues, such as misuse of multiple comparison procedures, and when to apply quantitative analyses. However, several issues dealing with analysis of variance (ANOVA) and graphical presentation of data remain. In this Viewpoint, we address several common practices that have been adopted by many authors as space-saving devices for summarizing complex results, and then suggest guidelines for improved presentation of data in ASHS journals.

Presentation of error bars on line plots

Graphical results of regression analyses often are plotted using error bars derived separately for each value of the independent variable. Because error bars can represent standard deviation (SD), standard error (SE), or confidence interval (CI), such figures may be misleading for the reader. In most cases, our preference would be to show the SE of the means, and to identify clearly the statistics being presented. More important from a statistical viewpoint, in most cases, all data points presented in a single graph belong to a single, planned experiment, and separation of error variance on the basis of the value of the independent variable is inappropriate. In some cases, when error values differ for different values of the independent variable, the model assumptions are violated and interpretation of the regression results is suspect. However, if heterogeneity of variance existed in the experiment, weighted least squares could be used for the analysis, resulting in different error bars for the plotted means.

Although many commonly available graphing programs for computers permit calculating and presenting error bars in any combination, it may be better to show a single error bar-calculated using the pooled error for the experiment-for the whole graph. The pooled estimate of error also will have smaller variance itself, being based on more data, and will have more degrees of freedom. Another alternative is to present the 95% confidence limit as bands around the regression curve. In any case, the statistic presented (i.e., SD, SE, CI) should be clearly identified.

Presentation of ANOVA and regression results

Many authors include regression equations, significance levels for F ratios, and r^2 values in plots of their raw data or in tables summarizing treatment means. In most research articles, an ANOVA table that details the actual tests performed also should be included. A more complete presentation of methods and statistical outcomes would permit readers to make their own conclusions regarding the statistical significance and horticultural importance of the experimental results. In any case, the experiment design should be described adequately in the methods section.

When significance tests are based on complex models (e.g., mixed models or multilevel split plots), an ANOVA table that includes expected mean squares also may be appropriate. Many quantitative studies would be improved by including complete ANOVA tables. The ANOVA table has the additional benefit of allowing future reanalysis of experiments published in light of new findings or in combination with other related experiments as part of a review, or for meta analysis.

Presentation of summary statistics

A third issue, derived in part from the above discussion, concerns appropriate presentation of summary statistics. We encourage the inclusion of means, sample sizes, and SES of treatment means (rather than SDS) based on the model used in the analysis. The model should be explained in the methods section. The practices of publishing means with the results of mean-separation tests (i.e., placing a common letter next to means that do not differ significantly) and adding error bars to plots or bar graphs do not provide equivalent information.

If horticultural scientists are to make effective use of research results in their discipline, they must be able to summarize results of previously published studies. Procedures that allow quantitative summarization of results across studies are available (meta analysis), and their power to provide research insight not available within individual studies is becoming well recognized (see Hedges and Olkin, 1985). Synthesis of research results requires that authors provide good summary statistics, and we recommend that approach as a standard for publication in ASHS journals.

We recognize that the above recommendations will increase the size of individual publications. Each manuscript will differ; authors and editors will need to use common sense as well as compromise. However, it is our contention that the efforts to minimize individual manuscript length have unacceptably reduced the information content of many articles.

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l *Editor's note: The* suggestions expressed in this Viewpoint may lead to changes in policy for ASHS publications. Therefore, authors are encouraged to submit a "Letter to the Editor" expressing their opinions, pro or con, on this issue. Submit your comments now, *before* policy decisions are made. Send your letter, to arrive no later than 1 Sept. 1994, to Werner J. Lipton, *HortScience* Science Editor, P.O. Box 5558, Fresno, CA 93755-5558,USA.