

ROUTINE STATISTICAL ANALYSES OF FIELD EXPERIMENTS BY USING AN EXCEL® EXTENSION

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Summary

This paper wishes to bring to the attention of readers a new EXCEL® VBA macro add-in, which may be useful as a support for teaching statistics or to perform statistically sound analyses of routine agriculture experiments. The code was progressively developed over the years to support the intensive field research activity that is carried out at the author's institution and has been specifically thought to address all the peculiarities of routine field experiments, with particular reference to agronomy and plant protection. A very user-friendly interface has been developed to be used by people (mainly students and technicians) with a limited background in statistics and computer programming.

Starting from experimental data, users may easily perform 23 different types of Analyses of Variance (ANOVA), including one-way balanced or unbalanced designs and two to four way balanced designs. Fully randomised, randomised block, latin square, factorial and split-plot designs may be analysed, as well as multi-location and/or multi-year experiments with one or two experimental factors, considering annual and perennial crops. A series of diagnostic tools have been implemented for one-way experiments, to verify whether basic assumptions for ANOVA are met (i.e. Tukey's test for non-additivity, Bartlett's and Levene's tests for homogeneity of variances), to seek for possible outliers and to select the most appropriate transformation of data. Several multiple comparison tests have been as well implemented, to cover all the most common types of routine analysis for field experiments. Users can also calculate correlation matrices, perform simple and multiple linear regression analyses and compare regression lines. DSAASTAT has been extensively tested and validated; it is freeware and can be easily downloaded from the author's web-site.

Introduction

Agriculture applied research in agronomy and plant protection has traditionally made an extensive use of field experiments, that have a number of peculiarities regarding the statistical approach to data analyses. In brief: (1) the randomised block is the most widespread design to account for soil heterogeneity; (2) it is very common to repeat experiments across environments and/or locations, to comply with a very high environmental variability; (3) factorial split-plot designs are very common especially when one experimental factor requires big plot sizes; (4) multiple comparison procedures are frequently used to rank experimental treatments in order of effectiveness; (5) data are commonly affected by problems of eteroschedasticity, non-additivity or by the presence of outliers.

Although basic methods have been clearly established long ago, statistical analyses still represent a 'nightmare' for field experimenters who would like to have their results published. Indeed, it must be recognised that agriculture students do not have a big background in statistics and computer science and so they have difficulties in 'statistical thinking' when they begin working. Furthermore, there is a big lack of standardisation and no protocols have ever been established as a guidance to correct statistical analyses of routine field trials. For example, the European Good Laboratory Practice (GLP; directive 91/414/EEC) requires full and detailed documentation during the execution of experiments, whereas appropriate statistical analyses are described in far less detail.

Other problems relate to commercial statistical software, which tends to be rather expensive, difficult to master and, generally, not specifically thought for field experiments, so that users pay a lot of redundant features and are forced to some programming.

All the above problems are particularly evident when experiments are carried out either in small private research Institutions or in developing countries, where access to information or statistical software is restrained.

It is thus very important to overcome the gap between agricultural sciences on one side and statistics on the other side, both through education and software availability, in order to make statistical methods more readily applicable and user-friendly. Considering the software, two main roads are practicable: the open-source software (such as the R-environment) and the extension to existing widespread commercial software. As spreadsheet programmes are among the most commonly used and as most of the people (including first-year students) have experience with them and possibly use them for data-entry, it becomes relevant to build add-ins for those spreadsheets, to provide users with the required output, without the need for a long statistical and computer training.

The objective of this work was to develop a new EXCEL® VBA add-in (DAASTAT), that would address all the peculiarities of agriculture applied research, particularly in the subjects of agronomy and plant protection, and that would be aimed at students, field technicians and other users with limited background in statistics and computer programming, which is often the case in agriculture.

General features and usage

The add-in was written in the VBA language and implemented in EXCEL® 97; it has been tested under EXCEL XP and 2003. It is freeware, virus-free and can be downloaded from the INTERNET (<http://www.unipg.it/~onofri>), where users can also find examples and detailed explanations. At the moment, the last update is 1.018 and it comes as a single file (DAASTAT.XLS) which can be opened as a normal Excel spreadsheet; on loading (make sure macros are enabled in Excel!), five new entries are added to the tools menu (Diagnostic tools, ANOVA, Multiple comparison tests, Correlation matrices, Regression analyses), which can be used to start the calculations.

First of all, the user is prompted to select an input dataset, that has to be organised as a normal database, with observations in rows, and variables in columns; the first row is reserved for variable names (Fig. 1).

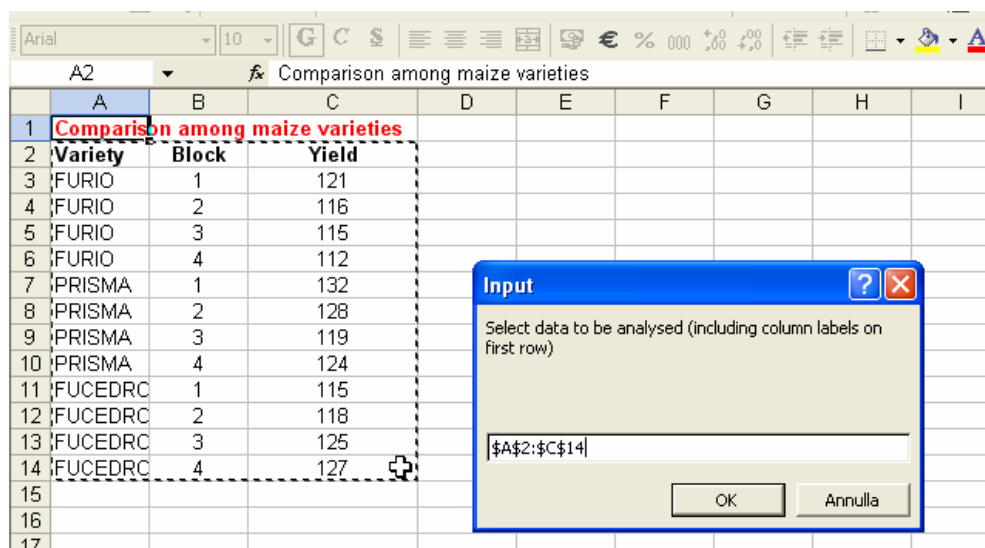


Figure 1. Example of data selection.

Basically, one column variable plus one or more explanatory variables are required, coding for each effect included in the ANOVA or regression model. The response variable must be numeric and measured on a continuous scale while explanatory variables may be either numeric or string. Numeric variables are obviously required for correlation or regression analyses, though when more curves have to be compared, they can be coded by a string variable. The selection of variables is made by drop-down list controls (Fig. 2).

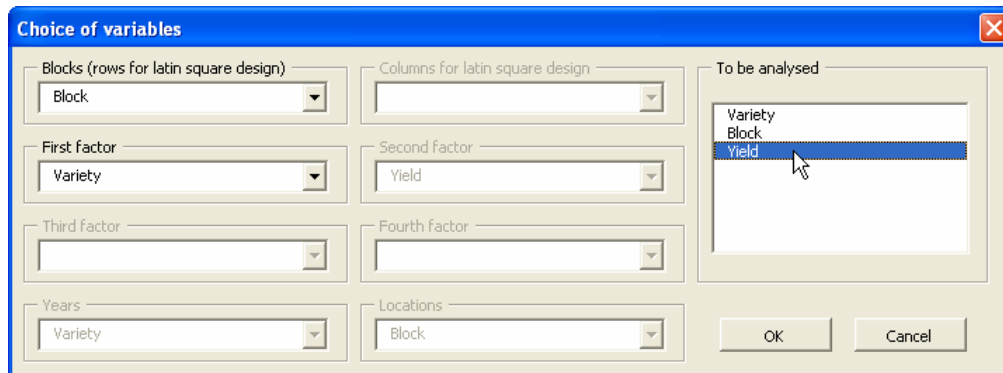


Figure 2. Example of the user-interface for variable selection

Specifications

All the algorithms behind the interface are clear and understood by statisticians and details will not be given; readers are referred to the original literature for detail. The innovation here is that all those algorithms have been made available under the spreadsheet EXCEL.

A brief list of tasks performed by DSAASTAT is hereby given so that users may understand whether this add-in fits their needs. More explanation can be found on the original papers or on the author's web page.

Diagnostic tools.

The first step on data analysis should always be a good exploration of data to identify and remove possible problems related to the presence of heteroscedasticity, removable non-additivity or outliers. These latter are detected by a graphical and numerical inspection of residuals (Anscombe and Tukey, 1963) with a 'premium' of 2.5% (see original paper for information). Multiple outliers are detected by a recursive procedure: the first outlier is corrected (Leclerg et al., 1963), then residuals are recomputed and inspected again until no more outliers can be found. The user obtains a scatterplot 'expected vs. residuals' and a list of outliers plus suggested values for correction.

On randomised block designs, non-additivity is tested by using the Tukey's procedure, while the homogeneity of variances is tested by using the Bartlett's and the Levene's tests (Snedecor and Cochran, 1991). The user obtains respectively a F-value for non-additivity, a χ^2 -value for Bartlett's test and a F-value for Levene's test, with corresponding probability levels.

To help the user in finding possible correcting transformations, the procedure proposed by Box and Cox (1964) has been implemented, as described by Draper and Smith (1981). A table helps the user to select the type of transformation that better suits his needs, on the basis of a maximum likelihood λ value, with confidence limits.

Analysis of Variance

DSAASTAT performs the ANOVA for 23 different types of designs, covering a main part of the needs of field experimenters (LeClerg *et al.*, 1962). It considers experiments with up to four explanatory variables (five, including the block effect), with fully randomised and randomised block designs. Latin square designs are considered with one-way ANOVA, while

fully factorial and split plot designs are considered with multi-way ANOVA. One-way and two way multi-year (with same or different randomisation each year) and/or multi-location experiments (same or different locations for multi-year-location experiments) are considered; years and locations may be considered fixed or random factors. Designs must be naturally balanced, which is absolutely normal with field experiments. However, one-level completely randomised unbalanced designs may be as well analysed, to meet the requirements of simple greenhouse or laboratory experiments.

Multiple comparison tests

Fisher's LSD, Duncan's MRT, Newman-Keuls's test, Tukey's multiple range test, Tukey's HSD, Sheffe's method, Dunnet's test for a two sided comparison with a control, Scott-Knott's cluster procedure have all been implemented, while the Waller Duncan's bayesian LSD is currently being developed. Readers are referred to Chew (1976) for description and comparisons of procedures.

Correlation matrices and linear regression analyses

DSAASAT allows the users to calculate correlation matrices and performs linear regression analysis (up to 4th order polynomial). The user may select the parameters he wants to include/exclude in/from the model. Multiple regression may as well be easily performed. These functions are already implemented in EXCEL, but DSAASAT adds more flexibility and a user friendly interface to define the model.

It is also possible to compare regression lines in order to verify whether they may be considered similar (not statistically different) or whether they may have similar slopes or intercepts, on the basis of consecutive F-tests (Draper and Smith, 1981).

Conclusions

Work carried out during previous years and the intensive use of DSAASAT by users with any kind of statistic and computer backgrounds (students, technicians and researchers) has shown that this tool has the flexibility and the simplicity to accomplish the main needs of field experimenters or statistic teachers. This software does not do anything particularly innovative, but does it quickly and easily: the advantage over other free statistical software is that EXCEL users may perform statistical analyses with no cost, no programming and without the need for learning any other software tools, which is

Aknowledgements

The author thanks Dino and Raffaele Alberati, Euro Pannacci (University of Perugia), Annuai Adthalungrong (Horticulture Research Institute, Thailand), Simone Bellinazzo for their help in testing and developing the macro.

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