Deutscher Tropentag 1999 in Berlin
Session: Sustainable Technology Development in Crop Production

Statistical analysis of ratio-variables in agriculture

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Keywords: Ratios, bias, precision, ANOVA, weighting

Introduction

A problem in calculating means for ratios of variables is illustrated by the German unemployment rate. Calculating the average between 8.5% in the western states and 17.6% in eastern states results in 13.1% for the whole country. The official statistics of Germany, however, amounts to 10.3% only. This relative discrepancy of about 30% is due to unequal population numbers in eastern and western states. Thus the overall unemployment has to be calculated by weighted means of ratios, i.e. by dividing the total number of unemployed people by the total number of the labour force.
In agriculture, means of ratios are commonly computed unweighted which is more convenient. For isometric relationships between numerator and divisor of the ratio variable (straight line through the origin) weighted and unweighted means are equal because the ratio is constant for all divisor values. For allometric relationships, however, as for example a higher harvest index (HI) with increasing total plant dry weight, weighting is necessary for calculating the average HI of several samples from a field or from a plant population.

Objectives

Quantification of the bias between unweighted and weighted means of common ratios in agriculture.
To asses the impact of weighting on statistical precision and normal distribution in ANOVA.

Data analysis

A sample of 1080 treatments comprising raw data from field experiments and data from publications that presented ratios, numerator and divisor means were analysed for twelve major agronomic ratios. With the exception of the land equivalent ratio (LER), the ratio of means was statistically analysed by weighting plot data by the denominator in standard ANOVA programmes and by MANOVA with numerator and divisor as dependent variables. The LER, which is a linear combination of ratios, was calculated by standardising component crop yields from intercropping mixtures by a constant, the average of each treatment from all blocks (replications).

Results

The results of weighted means differed moderately from the conventional, unweighted means. The average bias was less than 10% relative to the unweighted mean and the bias for 90% of the treatments (90%-quantile) was less than 20%. Two exceptions were nutrient use

efficiency (average bias of 18%) and shoot:root ratio (27% bias of the 90%-quantile). Weighting reduced the experimental error in the mean of 66 statistical analyses for six variables by 13%, whereas MANOVA results were inconsistent. Departure from normality of residuals was significant ($p \leq 0.05$) in only 13-14% of the tests irrespective of the ANOVA method.

Conclusion

Weighting by the divisor is a relatively simple technique for avoiding any bias and for improving precision in ANOVA of major agronomic ratio variables.