J. Ind. Soc. Agril. Statist.
61(2), 2007 : 147-155

Fitting Cumulative Size Mechanistic Models to Insect Population Data: A Nonlinear Mixed Effects Model Analysis

James H. Matis, Lan Zhou, Thomas R. Kiffe[1] and Timothy I. Matis[2]
Department of Statistics, Texas A&M University, College Station, TX, 77843-3143, USA

SUMMARY

Recently a new class of mechanistic models for insect population size has been developed. The death rate in the new models is a function of the cumulative size of past generations. Prajneshu (1998) developed the first such model and others have followed. The models have been shown to fit data from diverse aphid populations well. This paper shows that the nonlinear regression model solution for aphid population size may be used as a basis for a nonlinear mixed effects model analysis of designed experiments. The experiment analyzed in this paper consists of a 3×3 factorial, of Water by Nitrogen levels, applied in a randomized block design, repeated two years. The fixed Water treatments are statistically significant in one year and the fixed Nitrogen treatments in the other. The paper outlines possible generalizations.

Key words : Aphids, Logistic models, Nonlinear least squares.

1. INTRODUCTION

A new class of mechanistic models based on a cumulative size concept has recently been developed to describe the growth of insect populations. In Section 2, this paper first establishes an ecological foundation for the new models by reviewing the well-known logistic models. The new models based on cumulative size are then presented. The simplest of these models has a concise analytical solution which serves as a regression model for data. The regression model and some of its properties are given. In Section 3, we note that the new regression model fits diverse aphid population data well. Data for a 3×3 factorial experiment investigating the effects of water and nitrogen on cotton aphids are presented. In Section 4, the nonlinear regression model is used as the basis for a nonlinear mixed effects model analysis using the nlme software for the R package. The analysis indicates that there are significant Water and Nitrogen main effects in the data. In Section 5, the results from the nlme analysis are compared to results obtained by fitting the individual curves using nonlinear least squares. The results are shown to be similar qualitatively.

Concluding remarks, including possibilities for generalizing both the underlying model and the accompanying statistical analysis, are given in Section 6. In brief, the paper suggests that the new models, combined with the nlme analysis, have broad appeal for describing and analyzing data on local insect populations that collapse in size. Such data are widespread in agriculture.

2. MODEL DEVELOPMENT

2.1 Logistic Models Based on Current Size

In his classic book on ecology, Andrewartha (1951) describes several types of curves for describing the growth of 'local populations'. One class of curves is of the logistic type which increases monotonically in size with an asymptotic equilibrium value called a 'carrying capacity'. Andrewartha suggests that such curves may be "generally true of any local population whose numbers are determined by the stock of some non-expendable resource; non-expendable in the sense that the amount

[1] *Department of Mathematics, Texas A&M University, College Station, TX, 77843-3368, USA*

[2] *Department of Industrial Engineering, Texas Tech University, Lubbock, TX, 79409-3061, USA*