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(Contract AID/NE-C-1701)

REPORT ON

SHORT-TERM STAFF ASSIGNMENT

AT THE

INSTITUTO UNIVERSITARIO DE TRAS-OS-MONTES E ALTO DOURO

VILA REAL, PORTUGAL

August 10-31, 1984
and
September 17 - October 16, 1984

Submitted by

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1. AREA OF CONSULTANCY

Quantitative genetics and statistics, Instituto Universitario de Tras-os-Montes e Alto Douro (IUTAD), Vila Real, Portugal.

2. SPECIFIC OBJECTIVES

a) Teach the course "Special Topics in Animal Sciences: Linear Statistical Models".

b) Teach the course "Special Topics in Animal Sciences: Statistical Aspects of Quantitative Genetics".

c) Implementation and supervision of research undertaken by faculty in the Department of Animal Production (Departamento de Zootecnia) of IUTAD - In particular, assistance in the development of doctoral theses being planned by their staff.

3. COUNTERPARTS

Drs. Jorge Antonio Colaco (Department of Animal Science) and Fernando Anibal Wolfango de Macedo (Department of Mathematics) provided intellectual, logistic, and personal support during the assignment. They were assigned full-time to the implementation of the objectives described in section 2 above.

4. ACCOMPLISHMENTS

A detailed itinerary and work schedule is given in Annex A. The outline of the course in Linear Statistical Models is in Annex B. The outline of the course in Statistical Aspects of Quantitative Genetics is in Annex C. The proposal developed for Dr. Jorge A. Colaco's thesis is in Annex D and the one for Dr. F. A. Wolfango de Macedo is in Annex E.

Course in Linear Models (See Annex B)

The course in Linear Statistical Models was taught between September 17 and September 28. Approximately 30 participants, including faculty, students and visitors from other institutions in Portugal were present the first day of class. However, only 12 completed all the requirements for the course (6 signed for Purdue credit and 7 were "auditors"). The large attrition was due to the following factors: 1) many participants were primarily casual attendants who soon realized that the course was taught at a level and at a speed which required full participation; 2) lack of familiarity with applications of matrix algebra. Most participants had a background in Linear Algebra, which is taught in Portugal at an abstract level, thus leaving a gap between theory and application; 3) insufficient training, from a qualitative viewpoint, on the interphase between experimental design and analysis, and estimation of parameters by least-squares or maximum likelihood. This occurs frequently at institutions where statistics is taught by agronomists or where classical texts (e.g., Steel and Torrie) are used. These texts tend to separate multiple regression from analysis of variance and covariance and pay little or no attention to the pervasive problem of unbalanced data, ever present in animal production experiments.

The course was taught at a good level (Searle, S. R. 1971. Linear models. Wiley), perhaps corresponding to that encountered in a first or second year graduate course in a Department of Statistics in an American University. Graduate students in animal breeding at the University of Illinois take a similar course, usually in the second or

third year of their program. The method of teaching consisted of formal lectures, usually in the mornings, with supplementary class notes distributed as needed. The class notes were translated into Portuguese by Drs. Macedo and Colaco, and the Insitute requested that a publication be made using these materials as a base. We will be working with the Portuguese colleagues in this endeavor, so as to include numerical examples and exercises. In this manner, the material used in the course would become the basic structure for the first text in linear statistical models ever written in Portugal. I was always available to respond to questions or to clarify matters. The requirements for the course were 80% attendance in classes, as a minimum, and active participation in class. Exercises were assigned but not collected.

Sections I, IV, V and VII were covered in considerable detail. Material in section II was introduced as needed. Most of the students in the course were unfamiliar with basic distribution theory, so section III was skipped and aspects requiring a thorough understanding of such theory (e.g., IX.2) were not presented. Section VII was taught by analogy with section VI. Because of lack of time, material in sections VIII and IX was touched upon sparingly. In section X, we covered variance component models, estimation with balanced data and Henderson's method 3 for unbalanced data. Other methods for unbalanced classifications were not dealt with either because of lack of time or due to lack of background in distribution theory.

The form of presenting the material, e.g., using matrix methods and emphasizing general results, was new in Portugal. At least in IUTAD, experimental design and regression models have been taught using

scalar algebra and the students appreciated a more general and powerful approach. The main difficulty was the insufficient amount of time and a lot of material was packaged into about 25-30 net hours of lectures. The course was taught in Spanish (a request of IUTAD'S authorities) and the strategy was very successful, as no time was lost in translating from English into Portugese.

Course in Quantitative Genetics (See Annex C)

The course in Statistical Aspects of Quantitative Genetics was taught between October 1 and 12. The prerequisite was the course in Linear Statistical Models. About 10-12 participants were present the first day of class, and 8 completed all requirements which were the same as for the course in Linear Models; 5 participants will receive credit from Purdue University. There was a researcher from the Department of Genetics, I.N.I.A., Spain, who came specifically for the purpose of the course.

Sections I, III, IV, VI and VII of the course outline were treated in detail. Section II was assumed known, and section V was regarded as a particular case of the developments presented in section IV. Sections VIII.3-VIII.8 and IX could not be covered because of time constraints. The method of teaching was as in the course for Linear Models, and a representative text of the level of coverage is Henderson, C. R. 1984. Applications of Linear Models in Animal Breeding, Guelph. However, we placed more emphasis on concepts and on derivations than on algorithmic aspects; the opposite occurs in the above mentioned text. The students participated actively, especially on the last day of class when they were asked to go to the blackboard and work

out specific genetic evaluation models, with and without genetic relationships between candidates for selection.

Classnotes were distributed and several sections were translated into Portuguese by Drs. Macedo and Colaco. At the request of IUTAD's authorities, we plan to make a more formal publication, in Portuguese.

Dr. Colaco thesis proposal (See Annex D)

The terms of reference called for the development of a research program for the faculty of IUTAD, with emphasis on prediction of breeding value and on simulation techniques. My viewpoint is that computer simulation should assist a broader program of research in animal breeding and not constitute a focal point. Animal breeding research in Portugal is virtually non-existent so there is a lack of a broader context within which computer simulation work could be inserted. Hence, encouragement was given to Dr. Colaco to identify meaningful data sets, suitable for application of modern prediction and estimation techniques.

We decided to use milk recording data from a program called "Contraste lacto-manteigueiro." There are approximately 70,000 records on milk and butterfat production of cows (registered and non-registered) from several hundred dairy herds all over Portugal. These data can be used to estimate basic parameters necessary for the development of meaningful breeding programs, and to obtain retrospective estimates of genetic and phenotypic change occurring in commercial dairy herds in Portugal.

Field data can be, of course, biased and they are not collected under the rigorous control exercised in research herds. However, they

have been successfully utilized for genetic research in the U.S. and in several European countries. In fact, the most important developments in animal breeding theory in the last 30 years have stemmed from work with field records. Also, a large proportion of the genetic change in milk yield in the U.S.A. in the last 15 years or so, can be attributed to the application to commercial herds of prediction methods where the parameters needed to calculate the predictions were obtained from field data. This type of research with field records would be expected to have the following importance in Portugal:

i) would contribute to the discussion on design of breeding programs that will hopefully occur in the next 5 or 10 years;

ii) will contribute directly to the development of the livestock sub-sector by increasing monetary returns accruing from more accurate selection decisions;

iii) will contribute to the formation of professionals trained in the application of advanced statistical and computing procedures to livestock data;

iv) will create research data files which could be used to conduct applied research and to monitor livestock development projects;

v) would help to characterize and quantify the effect of variables affecting milk or other productions.

The thesis proposal described in Annex D is considered feasible but will require careful and frequent supervision for a successful completion of the project.

Dr. Macedo's thesis proposal (see Annex E)

Animal breeding research conducted at IUTAD will depend, as it does in many institutions around the world, on the availability of scientific and technical support in statistical methods and computing. At present, there is no visible unit in IUTAD capable of delivering adequate service in statistical experimental design and analysis. The development of a capability in this area is of importance for all areas of research being carried out at IUTAD.

Jointly with Dr. Macedo, we developed a thesis proposal in the interphase between statistics and animal breeding. The thesis would consist of several parts, some requiring a critical review of statistical methods currently employed in animal breeding, and some making original contributions to the subject matter, particularly to the estimation of genetic parameters. The proposal, described in Annex E, will also require careful supervision.

5. IDENTIFICATION AND ANALYSIS OF PROBLEMS ENCOUNTERED

The objectives described in Section 2 above were fully achieved. Some of the problems encountered were described under "Accomplishments". The assignment was carried out on schedule and ample cooperation was received from the counterparts and from IUTAD's authorities.

From a broader perspective, the insufficient development of library and computing facilities at IUTAD can represent potential constraints for the development of activities such as the ones described in the present report.

6. FUTURE REQUIREMENTS AND PROPOSED ACTION

1) A successful implementation of the research project developed for Dr. Colaco (Annex D) will depend on the following:

a) Dr. Colaco should be released from teaching duties during the proposed period (10/15/84-10/1/87) so that he can work full-time in the research;

b) he should be allowed to undertake the bibliographic search at INIA, Spain between April and May, 1985;

c) technical support (mainly for data entry purposes) should be given to him to prepare the research files that will be used as data in the proposed thesis. Dr. Colaco will need to develop a liaison with the national registry of dairy cattle in order to obtain the pedigree information required to complete some of the analyses proposed;

d) he should take a short course in FORTRAN programming at some Portuguese institution. This will give him the background necessary to carry out the program of work outlined in (e) below;

e) due to the computational requirements of the statistical methods to be used in the research program, Dr. Colaco should be given the opportunity to spend 12-14 months at the University of Illinois at Urbana-Champaign. During this period, models and computing strategies would be developed and implemented, and the results would be interpreted. The computations cannot be carried out in Portugal and one year at Illinois would also enable Dr. Colaco to undertake some coursework which will directly support the thesis work.

f) a continuing mechanism of supervision of Dr. Colaco's thesis should be implemented. I propose that a <u>first</u> supervision

consisting of a 2-3 week visit of the U.S. advisor to Vila Real should occur between May-July 1985. At this time, progress would be reviewed and a decision would be made regarding whether or not Dr. Colaco would be ready to take full advantage of the proposed period of study in the U.S. If this is not the case, the timetable should be modified accordingly. A second (2-3 week) supervision would be conducted in March-April 1987; Dr. Colaco would have at this time a first draft of his thesis completed. A final supervision would then occur about October, 1987. This would consist of a thorough review of the thesis in its final form, and participation in the examination to be conducted at IUTAD.

2) In order to carry Dr. Macedo's thesis project to completion, the following action is needed:

   a) IUTAD should release Dr. Macedo from teaching duties during the proposed period (3/1/85-6/30/87);

   b) he should be permitted to use the already granted fellowship to go to INIA, Madrid, between March and June, 1985. This would enable him to complete the review of literature of his thesis. IUTAD's library is completely inadequate for this purpose;

   c) Dr. Macedo should write to the statisticians indicated in the list in Annex E in order to ascertain where it would be more profitable to undertake a year of study in Bayesian statistics. It is essential to develop a contact with a

statistical scientist who would be willing to take a personal interest in Dr. Macedo's research. We can offer that possibility at the University of Illinois.

d) Dr. Macedo should spend a year in a good U.S. university to acquire knowledge in Statistics currently not available in Portugal.

e) As in the case of Dr. Colaco, a mechanism of supervision would be required. We suggest similar calendar as in (2f) above.

3) From a longer term and broader perspective, it appears that IUTAD could benefit from developing a Biometrics or Applied Statistics Unit within some of the existing deparments, e.g. Animal Production. This unit would provide statistical services (e.g., design and analysis of experiments, statistical computing and teaching) to the whole of IUTAD. The unit could consist of one or two professors and some assistants. It is recommended that a short-term consultancy be conducted in order to study the need, requirements, feasibility and impact of developing such a unit.

4) IUTAD's library should be further strengthened in the areas of animal production and applied statistics. Several important journals such as Applied Statistics, Journal of the Royal Statistical Society, Zeitschrift fur Tierzuchtung und Zuchtungsbiologie are not available at present. Similarly, many important texts are not available in their current collection.

5) The computing center at IUTAD should be further strengthened. At present, their computer is a WANG model MVP with BASIC 2 as programming language. It has matrix commands, and a small statistical library. However, the equipment is outmoded and its capabilities will be clearly outgrown in view of the projected increase in IUTAD's enrollment. Further, available software is very limited. It is recommended that IUTAD study the upgrading of its computer facility, perhaps aiming towards a multi-user system, so that instruction in computing and computing services can be brought to a level concomitant with the needs of the institution.

6) The Department of Animal Production would benefit from a long-term advisor in the area of breeding and genetics. A total of 2 years of consultancy should be provided. The advisor (one man-year) would develop, jointly with the IUTAD faculty, an integrated program of animal breeding research including cross-breeding, methodology, systems of breeding, economic aspects and conservation. Also, this advisor could collaborate in the implementation of the proposed Biometrics unit in (3) above. The remaining man-year could be used in short-term consultancies aimed to support specific areas of the research program under development.

ANNEX A: ITINERARY AND WORK SCHEDULE

August 10: Departure from St. Louis Airport

August 11-12: Lisbon

August 13: Travel to Vila Real, by automobile. Arrived in Vila Real very late in the evening due to traffic congestion and construction on the road.

August 14: Visit with Rector and Vice-Rector. General tour of IUTAD, including Computing Center and Department of Animal Science. Discussion of present curriculum leading to the degree of "Engenheiro Zootecnista" (Engineer in Animal Production). Discussion of possible data bases available for research in Portugal including dairy records, swine confinement production units. Overview of the problem of conservation of native breeds.

August 15: Visit to Panoias and area of wine production in San Leonardo, Visit to Solar de Mateus and Village of Loureiro. Visit to Pedras Salgadas. Discussion of research and teaching activity and career in Portugal. Overview of the strategy consisting of developing "Teses de Doutoramento" (Doctoral theses) in the Portuguese context.

August 16-31: A) Tutorials with Drs Coleco and Macedo in the following areas: 1) Teaching materials in quantitative genetics; 2) use of computer simulation as a teaching device; 3) computer-based teaching programs available in the

U.S. (e.g., Iowa State University "cow game", SIMUMATE, MAXBULL); 4) limitations of BASIC (versus FORTRAN, for example) as a programming language; 5) role of Biometrics in a College of Agriculture; 6) selection indexes and their conceptual and computational difficulties; 7) formulation of linear models: location, dispersion and distributional aspects; 8) relation between selection indexes and linear models describing the records of production; 9) estimability of parametric functions in fixed and mixed models; 10) estimable functions in two-way classifications, with and without interaction; 11) construction of variance-covariance matrices in mixed models; 12) best linear unbiased estimation and the mixed model equations as an algorithm to implement it; 13) examples of simple sire evaluation models; 14) cow evaluation using mixed linear models: distinction between genetic and producing ability; 15) cow evaluation via best linear unbiased prediction versus selection indexes; 16) development of models with interactions between fixed factors and interactions between fixed and random factors; 17) discussion of best prediction and of best linear unbiased prediction and derivation of optimality properties; 18) derivation of best linear unbiased prediction and of its variance-covariance properties.

B) Development of projects of doctoral thesis for Drs. Colaco and Macedo. These are outlined in Annexes D and E.

Sepember 1-16: In France. Return to Vila Real on September 16.

September17-28: Course in Linear Statistical Models at IUTAD. See Annex B.

September 29-30: Visit to Polytechnic Institute at Braganca and performance testing station (Mirandesa breed) at Malhadas, near Miranda do Douro. Return to Vila Real.

October 1-12: Course in Statistical Aspects of Quantitative Genetics at IUTAD. See Annex C. Depart for Lisbon.

October 13-14: Lisbon

October 15: Lisbon-New York

October 16: New York-Champaign

ANNEX B: COURSE OUTLINE

LINEAR STATISTICAL MODELS

COURSE TAUGHT AT I.U.T.A.D.
Vila Real, Portugal, 1984

Dr. Daniel Gianola
University of Illinois, U.S.A.

OUTLINE

I. SETTING THE STAGE

I.1. Linear vs nonlinear models. Taxonomy of linear models
I.2. Fixed, random and mixed models
I.3. Statistical problems in linear models: estimation, prediction and hypothesis testing.

II. MATRIX ALGEBRA USEFUL IN LINEAR MODELS

II.1. Review of elementary operations
II.2. Algebraic rules
II.3. Quadratic and bilinear forms
II.4. Systems of equations and generalized inverses
II.5. Vector calculus and Lagrange multipliers
II.6. Numerical solution of large linear sparse systems

III. DISTRIBUTION THEORY USEFUL IN LINEAR MODELS

III.1. Univariate and multivariate distributions
III.2. Marginal and conditional distributions
III.3. Bayes theorem
III.4. Variances and covariances of random variables
III.5. Moments of conditional distributions
III.6. Changes of variable
III.7. The multivariate normal distribution
III.8. Variances and covariances of complex functions of random variables

IV. ESTIMATION OF PARAMETERS IN LINEAR MODELS

IV.1. General criteria
IV.2. Methods of estimation
- a) Least-squares and variations thereof
- b) Maximum likelihood
- c) Posterior estimates (Bayes)
- d) Minimum expected loss (MELO)
- e) Biased estimation

V. FIXED LINEAR MODELS OF FULL RANK

V.1. Estimation
V.2. Partitioning sums of squares
V.3. Analysis of variance
V.4. The general linear hypothesis
V.5. Miscellaneous topics in regression

VI. FIXED LINEAR MODELS OF INCOMPLETE RANK

VI.1. Solving the normal equations
VI.2. Generalized inverses of coefficient matrices
VI.3. Best linear unbiased estimation
VI.4. Partitioning of sums of squares and the analysis of variance
VI.5. G-inverses, restrictions, and constraints
VI.6. Reparameterizations and the "cell-means" model.

VII. SOME FIXED LINEAR MODELS

VII.1. The one-way classification
VII.2. The two-way nested classification
VII.3. The two-way crossed classification without interaction
VII.4. The two-way crossed classification with interaction
VII.5. Multiple classifications
VII.6. Complex layouts
VII.7. Computing aspects

VIII. THE ANALYSIS OF COVARIANCE

VIII.1. Motivation
VIII.2. Single and multiple covariates
VIII.3. Heterogeneous slopes
VIII.4. Computing aspects

IX. ESTIMATION, PREDICTION AND HYPOTHESIS TESTING IN MIXED MODELS

IX.1. The mixed model equations
IX.2. Relationship between maximum likelihood, generalized least-squares and Bayesian estimators
IX.3. Multivariate extensions

X. ESTIMATION OF VARIANCE AND COVARIANCE COMPONENTS

X.1. Variance component models: univariate and multivariate
X.2. Balanced data
X.3. Unbalanced data: random effects
X.4. Unbalanced data: mixed models
a) least-squares allied methods
b) MINQUE-allied method
c) likelihood based methods
X.5. Multivariate extensions

ANNEX C: COURSE OUTLINE

STATISTICAL ASPECTS OF QUANTITATIVE GENETICS

COURSE TAUGHT AT I.U.T.A.D.
Vila Real, Portugal, 1984

Dr. Daniel Gianola
University of Illinois, U.S.A.

OUTLINE

I. FACTORS AFFECTING RATE OF RESPONSE TO SELECTION

- I.1. Genetic progress and its components
- I.2. Relationship between selection intensity, accuracy and generation interval
- I.3. Optimal programs and replacement rates
- I.4. Age structure and overlapping generations
- I.5. Dissemination of genetic progress

II. RESEMBLANCE BETWEEN RELATIVES

- II.1. Orthogonal decomposition of genetic variance
- II.2. Correlation between relatives
- II.3. Factors affecting the correlation between relatives
  - a) Linkage
  - b) Sex-linkage and sex-dependence
  - c) Assortative mating
  - d) Maternal effects
  - e) Genotype of the conceptus

III. BEST PREDICTION

- III.1. The selection problem
- III.2. The best predictor
- III.3. Properties

IV. BEST LINEAR PREDICTION: GENERAL

- IV.1. Setting
- IV.2. Equal and unequal information
- IV.3. Properties of the best linear predictor
- IV.4. An algorithm to compute the best linear predictor
- IV.5. Some applications of best linear prediction
- IV.6. Multivariate normality

V. BEST LINEAR PREDICTION: SMITH-HAZEL THEORY

- V.1. Setting and solution
- V.2. Formulation in terms of correlations

V.3. Special cases
a) Single trait selection using information from relatives
b) Multiple trait selection using information from relatives
V.4. Expected response to index selection
V.5. Probability statements about candidates for selection
V.6. Retrospective and empirical indexes
V.7. Restricted indexes
V.8. Selection for maternal effects
V.9. Nonlinear merit functions
V.10. Limitations

VI. BEST LINEAR UNBIASED PREDICTION: GENERAL

VI.1. Derivation
VI.2. Properties
VI.3. The "mixed" model algorithm
VI.4. Properties of the mixed model equations
VI.5. Bayesian derivation of the mixed model equations

VII. BEST LINEAR UNBIASED PREDICTION: APPLICATIONS

VII.1. Individual models and maternal effects
VII.2. Sire evaluation models
VII.3. Use of relationships
VII.4. Repeated measures
VII.5. Evaluation of individuals without data
VII.6. Multiple trait models
VII.7. Restricted best linear unbiased prediction
VII.8. Prediction of nonadditive genetic merit

VIII. GENERAL FRAMEWORK FOR PREDICTION OF BREEDING VALUE

VIII.1. Optimality criteria
VIII.2. A problem in conditional inference: the best predictor
VIII.3. Properties of the best predictor
VIII.4. Translation invariant rules
VIII.5. Multivariate normality
VIII.6. Discrete responses
VIII.7. Longitudinal information (growth, lactation)
VIII.8. Generalization of generalized linear models

IX. PREDICTION OF BREEDING VALUE IN POPULATIONS UNDERGOING SELECTION

IX.1. Genetic trend and its measure
IX.2. Biases stemming from genetic trend
IX.3. Optimal predictors under selection
IX.4. Henderson's selection model
IX.5. Monte-Carlo results
IX.6. Grouping: an ad-hoc procedure to reduce bias

ANNEX D: "Methods of genetic evaluation of animals and their application to dairy cattle improvement in Portugal", a thesis proposal submitted by Dr. Jorge A. Colaco, IUTAD.

TABLE OF CONTENTS

I. General introduction

II. Review of literature

A. Methods of genetic evaluation

1) contemporary comparison; herdmate comparison; cumulative differences; variations

2) best prediction, best linear prediction, best linear unbiased prediction (univariate and multivariate)

3) non-linear methods for categorical and censored data

4) applications in different countries

B. Estimation of variance and covariance components

1) balanced data

2) Henderson's methods

3) MINQUE theory

4) maximum and restricted maximum likelihood

5) Bayesian methods

6) multivariate procedures

III. Analysis of field records from Portugal

A. Data: milk and butterfat production, fat test and intercalving intervals vrom "Contraste lacto-manteigueiro" (1974-present, if possible)

B. Analyses: Estimation of variance and covariance components between and within herds (first and all records); estimation of correlations between successive records (intra-cow); estimation

of age correction factors (age, parity, duration of lactation); prediction of productive and genetic ability of cows; estimation of genetic parameters (if the sires of the cows can be identified); assessment of trends in producing ability.

IV. Conclusions

REQUIREMENTS

I. Scientific supervision

. Prof. Dr. J. Lima Pereira (IUTAD)

. Prof. Dr. L. S. Monteiro (PORTO)

. Prof. Dr. D. Gianola (ILLINOIS)

II. Bibliographic search: to be conducted at the Department of Quantitative Genetics, I.N.I.A., Madrid, Spain under the supervision of Dr. Fernando Orozco and his team. Two-month fellowship granted by the Government of Spain.

III. A short course in FORTRAN programming, perhaps at the University of Minho (Braga)

IV. Computing, data analysis and interpretation of research to be carried out at the University of Illinois (U.S.A.) with selected postgraduate courses which will support the thesis. Duration of stay: 12-14 months.

TIMETABLE

October 15, 1984 - April 1, 1985:	Completion of Part II.A at IUTAD. Preparation of research files for part III, AT IUTAD.
April 1, 1985 - May 31, 1985:	Completion of Part II.B at INIA, Madrid.
June 1, 1985 - July 31, 1985:	Preparation of research files continued.
July, 1985:	Two-three week supervision of work by Prof. Gianola at IUTAD.
August 25, 1985 - August 30 or September 30, 1985:	Analysis, interpretation of data and supporting course work at the University of Illinois, U.S.A.
March - April, 1987:	Two-three week supervision by Prof. Gianola at IUTAD.
October 1, 1986 - October 1, 1987:	Writing and presentation of thesis, IUTAD.

ANNEX E: "Contribution to Bayesian statistical methods in animal genetics", a thesis proposal submitted by Dr. F. A. Wolfango de Macedo, IUTAD.

TABLE OF CONTENTS

I. General introduction

A. Classical statistical methods as used in animal production

B. Problems of difficult resolution by classical approaches

C. Possibilities of resolution via Bayesian methods

II. Bayesian statistics

A. Foundations

B. Work of Bayes, Jeffreys, Savage, DeFinetti, Lindley

C. Bayesian solution to

1) linear models

2) multivariate analyses

3) transformations

4) other problems

III. Bayesian methods used in animal production

A. Identification of carriers

B. Selection indexes

C. Best linear unbiased prediction

D. Estimation of genetic value using non-linear models

E. Estimation of genetic parameters

IV. Bayesian estimation of variance components

A. Simple models: prior and posterior densities

B. Estimation of functions of parameters

C. Estimators of Lindley and Smith

D. Simulation studies

V. Conclusions

REQUIREMENTS

I. Scientific supervision

. Prof. Dr. Francisco da Costa Durao (Mathematics)

. Prof. Dr. Joaquim Lima Pereira (Applications in Animal Genetics)

. Prof. Dr. Daniel Gianola (general supervision)

. Consultant specializing in Bayesian statistics, who, jointly with Prof. Gianola, will evaluate part IV of the thesis, hopefully an original contribution to the subject matter.

II. Bibliographic search: to be conducted at the Instituto Nacional de Investigaciones Agropecuarias (I.N.I.A.), Madrid. Four-month fellowship granted by the Government of Spain.

III. Short visits: Biometrics Laboratory, I.N.R.A., Toulouse, France (Drs. Bruno Goffinet and Sotan IM). Also, attendance to relevant meetings of statistical nature which might be conducted at the European level.

IV. Specialized courses in Bayesian Statistics: The following contacts should be pursued

i) Dr. David Harville, Deparment of Statistics, Iowa State University, U.S.A.

ii) Dr. Daniel Solomon, Department of Experimental Statistics, North Carolina State University, Raleigh, North Carolina, U.S.A.

iii) Dr. John Marden, Division of Statistics, University of Illinois at Urbana-Champaign, U.S.A.

iv) Dr. G. E. P. Box, Department of Statistics, University of Wisconsin, Madison, Wisconsin.

v) Dr. Arnold Zellner, Department of Statistics, University of Chicago

TIMETABLE

March 1 - June 31, 1985:	Review of literature (parts, I, II, III of thesis) carried out at I.N.I.A.
July, 1985:	Two-three week supervision of work by Prof. Gianola at IUTAD
August 25, 1985 - August 30 or September 30, 1986:	Support courses and research work in U.S.A., primarily in relation to parts III and IV of thesis
March - April, 1987:	Two-three week supervision by Prof. Gianola at IUTAD.
October 1, 1986 - June 30, 1987	Writing and presentation of thesis, IUTAD.