A Survey of the Applications of main Biometrical methodologies and relative Informatics tools applied in agricultural research.

Vissarion Gousios[1], StergiosTzortzios[2]

[1] University of Thessaly, School of Agricultural Sciences, Laboratory of Biometry, Fytokou Street - Nea Ionia, Volos, Greece, email: vgousios@uth.gr
[2] University of Thessaly, School of Agricultural Sciences, Laboratory of Biometry, Fytokou Street - Nea Ionia, Volos, Greece, email: stzortz@uth.gr

Abstract: Today, that the collection of biological data has been increasing at explosive rate, the right processing of these data is something more than a necessity. Fisher's work (1925) in conjunction with the vast increases in computer power that were implemented after the 1960s, have made possible much more efficient and exciting methods of data analysis (Curnow, 1984), thus opening the "bag of Aeolus" for the application of modern statistical techniques in agricultural experimentation and research. This study mainly seeks to survey biometrical methodologies that have been applied in the agricultural research, emphasizing in the segregation of the agriculture in six separate scientific fields.

Keywords: Biometrical methodologies, Agriculture, Research, Applications

1. Introduction

Many scientists have indicated the importance of statistical research in agriculture (Fisher 1925; Box 1976; Finney 1978; Riley 1998; Wilson 1999). Biometry moves towards this direction as it is implied from its various definitions: a branch of biology that studies biological phenomena and observations by means of statistical analysis (http://www.wordnetweb.princeton.edu/perl/ webwn), the measurement of quantities in the living world (Source: *Oxford Dictionary of Statistics*), the application of statistical methods to the analysis of continuous variation in biological systems (http://www.expertglossary.com/ science) and others.

Some interesting concepts for the work that has been done in the field of Biometry come from several authors. According to Box (1976) "Fisher's work gradually made clear that the statistician's job did not begin when all the work was over -it began long before it was started". Preece (1984), Sadasivan (1982) and Fielding (1990) summarized the poor quality of data collection and trial design together with the ritualistic approach to data analysis, as main disadvantages in biological research. Camacho and Carbonell (1993) reviewed the quality of statistics in agricultural research in Costa Rica and concluded that there were weak links

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between agriculturalists and researchers. Riley and Onwueme (1996) concluded in their work that level of biometric knowledge of Agricultural researchers in ACP countries is poor. Onwueme et al. (1996) suggested that lack of access to computer and statistical software have seriously hampered the teaching, learning and using of biometry in developing countries. Akoroda (1996) believes that the poor and inefficient use of biometrical methods in applied agricultural research can be attributed to cultural background, school schedules, teachers orientation limited resources a. o.

Towards this direction, a brief survey in the papers referring to agriculture in the past conferences of the International Biometric Society (I.B.S.) has shown that the rate of these papers is about 8% of the total papers submitted (Gousios and Tzortzios, 2011).

The aim of this paper is to make a survey of the biometrical methodologies and relative informatics tools applied in agricultural research as well as the classification of these methodologies in different agricultural fields and the detection of possible trends in their application. An extended survey of the biometrical methodologies could lead to the best exploitation of the biological material.

2. Methodology

The general methodology followed for the implementation of this study is consisted of four parts.

Initially, a personal survey was made in well known electronic scientific databases (Elsevier, Wiley and Science Direct) for papers referred to applications of biometrical methodologies in agriculture. To this purpose, we search for terms as "statistical/biometric methodologies", "statistical/biometric applications" and "biometrics" which were included in the abstract, title or keyword of the papers. We also restricted the research in the subject "agricultural and biological sciences" for all the years that it was possible.

After this, we limited the results in journals relative with agricultural fields of interest (Biotechnology, Crop Protection, Crop Production, Animal Production, Food Science and Technology, Natural Resources Management). Totally, a number of about 700 papers including the above criteria were reviewed to comprise the backbone of this study. Furthermore, a classification of the surveying biometrical methodologies has been made according to their applications in the above six different agricultural fields.

Meanwhile, a questionnaire was constructed to help the survey of biometrical methodologies and relative informatics tools applied in agriculture. The questionnaire was addressed to researchers and scientists of Greek Agricultural Institutes and Research Centers. Each one of the interviewed scientists belongs to one of the six different agricultural fields, thus the results of the questionnaires were classified per field.

Finally, an evaluation of the biometrical methodologies has been made, according to the total number of their applications in the different fields of agriculture and a comparison of the results between the bibliographical research and

the answers in the questionnaires.

3. Results and Discussion

In the **Biotechnology** field the survey showed that twelve methodologies have been applied in the past (fig. 1). The most commonly used ones are:

Cluster Analysis with applications such as in the determination of groupings in the genotypes or in the environments (Mungomery *et al.* 1974; Byth *et al.* 1976; Lin and Thompson 1975; Lin 1982; Fox and Rosielle 1982; Ramey and Rosielle 1983 and Ghaderi et al. 1982) and the classification of locations on the basis of a single trait for screening superior breeding lines (Campbell and Lafever 1980; Ghaderi et al. 1980; Fox and Rosielle 1982; Baenziger et al. 1985; Yau et al. 1991; Collaku 1991; Van Oosterom et al. 1993; Abdalla et al. 1996; Trethowan et al. 2001). **Regression analysis** with applications such as in the explanation of Genotype x Environment interactions (Cruz et al. 1989; Eberhart and Russel 1966; Finlay and Wilkinson 1963; Freeman and Perkins 1971; Perkins and Jinks 1968; Shukla 1972; Silva 1995, 1998; Silva and Barreto 1985; Toler 1990; Toler and Burrows 1998; Verman et al. 1978) and the examination of yield stability of various genotypes (Finlay and Wilkinson 1963; Eberhart and Russell 1966). **Discriminant Analysis** also shows a wide range of applications in this field such as in the identification of cultivars with specific characteristics (Ebdon et al. 1998), in the determination of genetic variation in populations (Nelson 2001; McElroy et al. 2002; Ilarslan et al. 2002), in the assessment of the impact of a transgenic crop on soil environment (Park et al. 2006) and the identification of appropriate parents and top crosses in corn for future breeding and genetics program (Aydin et al. 2007).

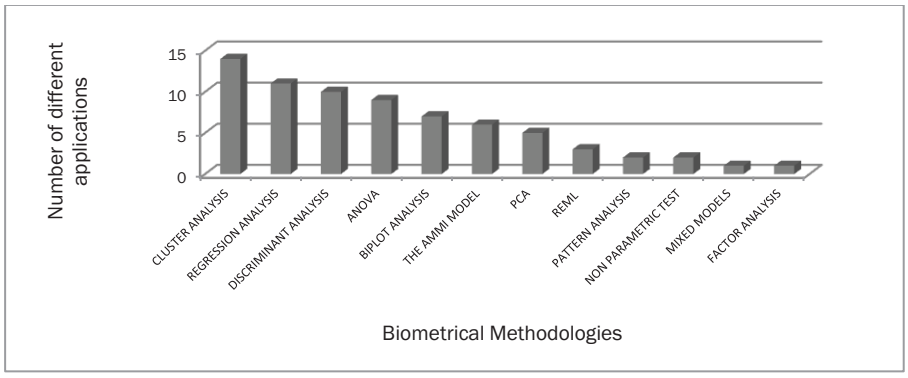

Fig 1. Number of different applications of Biometrical methodologies in Biotechnology.

In the **Crop Protection** field nineteen methodologies have been applied (Fig. 2), while in this field Analysis of Variance methodology appears many applications,

which is rather a consequence of the nature of the specific field. More specifically, the most commonly applied methodologies in the **Crop Protection** field are:

Analysis of Variance with applications in the evaluation of different insecticides/fungicides against pests/fungi in field crops (Bi et al. 2002; Obanor et al. 2008), field evaluation of the resistance of different genotypes to parasitic weeds (Abbes et al. 2007) and study of the influence of water and fertilization on biology of insects / fungi in field crops and greenhouses (Archer et al. 1995; Jauset et al. 2000; Simoglou et al. 2006). **Regression Analysis** with applications such as in the study of the effect of pesticides application in crop sequences on associated weed composition, richness and diversity over five years (Puricelli, 2005), study of the correlation of insect infestation in cultivars with abiotic and biotic factors (Vayssieres et al. 2009), determination of the critical dates of cumulative catches of Andean potato weevils and carabids in two potato rotation systems (Kroschel et al. 2009). **General Linear Models** with applications in the estimation of the dynamic future populations of Diaprepes Abbreviatus in terms of time and space (Li et al. 2007), study of the performance of wheat cultivars and cultivar mixtures in the presence of Cephalosporium stripe (Mundt, 2002) and study of the influence of the different herbicide strategies on barley yields (Barroso et al. 2009).

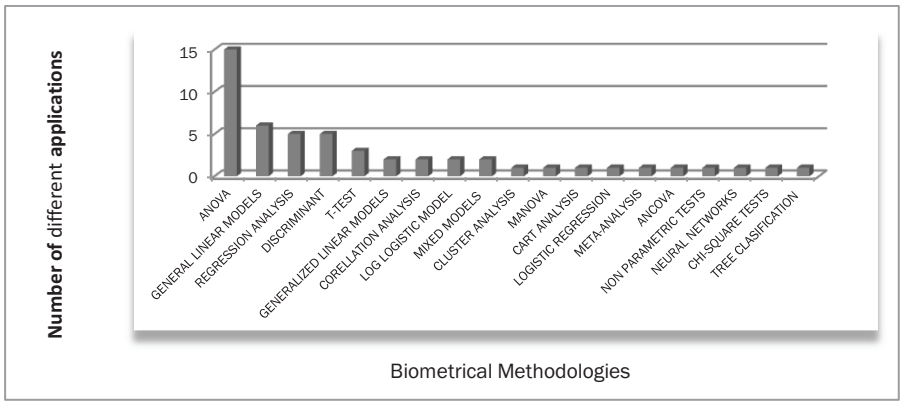

Fig 2. Number of different Applications of Biometrical methodologies in Plant Protection.

In the **Food Science and Technology** field the survey showed fifteen biometrical methodologies to be applied (fig.3), most of them with many applications. Some of the common methodologies in the **Food Science and Technology** field are:

Principal Components Analysis which has been applied for determination of the combined effects of pressure, temperature, and co-solutes on Lactococcus lactis (Killiman *et al*. 2006), classification of agricultural products according their genotype/ physical properties/ origin (Campbell *et al*. 2000; Goodner *et al*. 2001; Maeztu *et al*. 2001; Kallithraka *et a*l. 2001; Bertelli *et al*. 2007), quality assessment in grain/vegetables (Autran *et al.* 1986; Porretta, 1994). **Discriminant Analysis** with applications in the determination of anthocyanins, flavonoids and colour parameters in wines (Gomes – Cordoves et al. 1995), determination of mineral nutrients and

toxic elements in coffee (Éder José dos Santos *et al.* 2001) and detection of seed oil adulteration in virgin olive oils in combination with spectroscopy (Vigli *et al.* 2003). **Survival Analysis** with applications in studying sensory shelf life of foods (Hough *et al.* 2003; Calle *et al.* 2003), determination of the affection of environmental conditions to growth/no growth of typical spoilage yeasts (Evans *et al.* 2004), estimation of optimum concentrations of a food ingredient (Gartita *et al.* 2006), studying of optimum ripening time of fruits according to consumer data (Garitta *et al.* 2008).

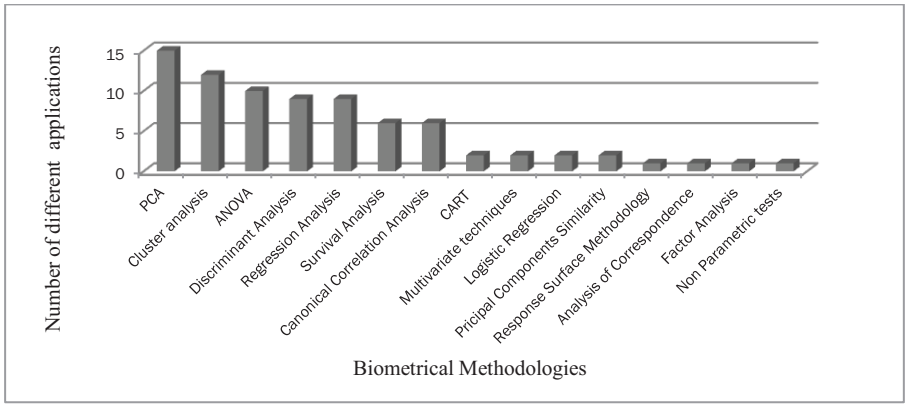

Fig 3. Number of different Applications of Biometrical methodologies in Food Science and Technology.

In the **Natural Resources Management and Agricultural Engineering** Field sixteen methodologies have been applied (fig. 4) while applications of most common methodologies in the specific field are:

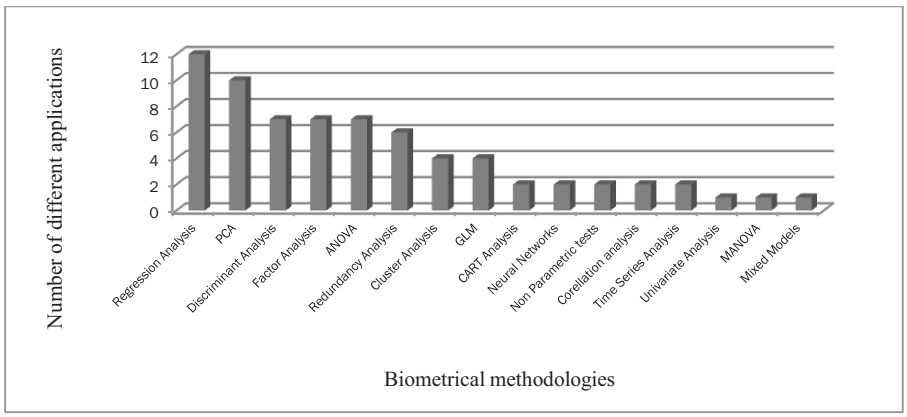

Fig 4. Number of different Applications of Biometrical methodologies in Natural Resources Management.

Principal Components Analysis with applications in: the examination of crops' yields according to fertilizer applications (Willson and Freeman 1970), the evaluation of variation in biological, chemical and physical soil properties (Stenberg et al. 1998), the determination of management effects on soil parameters (Sena *et al.* 2002) and the evaluation of microbial indices of soil fertility (Suzuki *et al.* 2005). **Discriminant Analysis** with applications in: the determination of soil chemical properties according to the presence of Azotobacter in soil (Cox and Martin 1937), hard classifications in soil science (Hughes and Lindley 1955; Caroll *et al*. 2005) and the determination of relationships between identified and measured soil nutrient properties on fields (Splechtna and Klinka 2001). **Factor Analysis** with applications in: Soil Quality Indexes identification and/ or interpretation. (Bachmann and Kinzel 1992; Wander and Bollero 1999; Brejda *et al*. 2000a,b; Andews *et al.* 2002; Shukla *et al*. 2004a;2006), investigation of groundwater contamination (Grande *et al*. 1996; Subbarao *et al*. 1995; Abu-Jaber *et al*. 1997; Jeong 2001), determination of management discriminant properties in soils (Quiroga *et al.* 1998) and identification of sources of soil pollutants (Carlosena *et al.* 1998).

In the **Animal Production** field the survey showed that eighteen methodologies have been applied in the past and (fig. 5). Some of the most commonly used methodologies in the **Animal Production** field are:

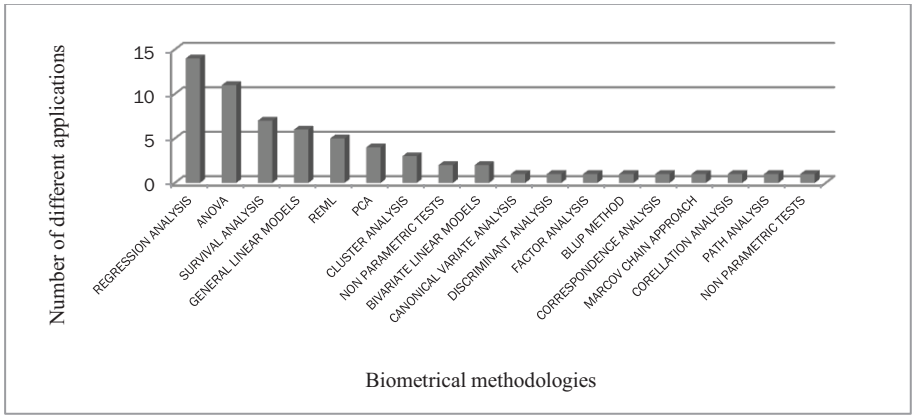

Fig 5. Number of different Applications of Biometrical methodologies in Animal Production Field.

The **REML method** with applications in: the examination of the effects of level of fish oil inclusion in the diet on rumen digestion and fermentation parameters in cattle offered grass silage based diets (Keady and Mayne 1999), estimation of genotypic and phenotypic correlations in conjunction with specialized software packages (Berry *et al.* 2002; Gilmour *et al.* 1999; Persson and Andersson 2003; Conington *et al.* 2001; Legarra and Ugarte 2001; Neumaier and Groeneveld 1998; Boldman *et al*. 1993; Bureau *et al.* 2001; Zhu and Weir 1996) and study of the

gestation length in Danish Holsteins (Hansen *et al*. 2004). The **Survival Analysis** with applications in: Genetic Evaluation (Cox 1972; Cox and Oaks 1984; Ducrocq *et al.* 1998), comparison of different dairy cow breeds on a seasonal grass-based system of milk production (Dilloe *et al.* 2003), determination of factors affecting culling early in the productive life of Holstein-Friesian cattle (Ojango *et al.* 2005) and estimation of effects on longevity of beef cows (Szabó *et al.* 2009). The **General Linear Models** with applications in: examination of relationship between level of milk production and estrous behavior of lactating dairy cows (Lopez *et al.* 2003), effect of dietary phosphorus concentration on estrous behavior of lactating dairy cows (Lopez *et al.* 2003) and investigation of the effects of maceration of rice straw on voluntary intake and performance of growing beef cattle fed rice straw-based rations (Nader *et al.* 2008).

In the **Plant Production** field the survey showed that fifteen methodologies have been applied in the past and some of the most commonly used ones are:

Cart Analysis with applications such as in the detection of temporal and spatial variability in crop yields (Perez-Quezada *et al.* 2003), the determination of

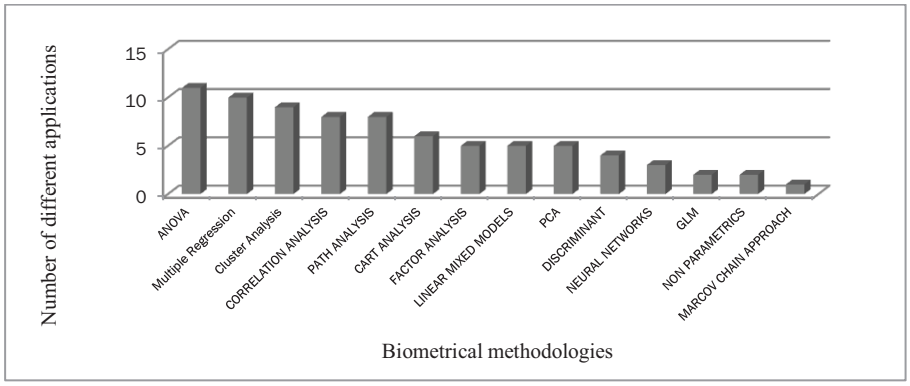

Fig 6. Number of different Applications of Biometrical methodologies in Crop Production Field.

relationships and interactions between soybean yields and a suite of soil and agronomic variables (Zheng *et al.* 2009) and the examination of the primary associations between environmental, agronomic and weed management variables to crop and weed dependent variables (Williams *et al.* 2009). **Cluster Analysis** with applications in: classification of varieties according to their genetic similarity (Murphy *et al.* 1986), study the relationship between wheat grain yield and its components under drought conditions (Leilah *et al.* 2005), determination of metals in plants cultivated during the process of conversion from conventional to organic agriculture (dos Santos *et al.* 2009) and study of the adjustment of modern rice varieties in high-altitude regions (Steele *et al*. 2009). **Multiple Regression** with application such as in: development of empirical models from large data sets, as has been done for a number of canopy-level crop condition parameters (Shibayama and Akiyama 1991; Osborne *et al*. 2002), identification of the relationship between rice

grain yields and soil mineralizable nitrogen (Tsujimoto *et al*. 2009) and study of the cover cropping effects on yield and weed control of potato in transitional systems (Campiglia *et al.* 2009).

In addition to the bibliographic survey, a questionnaire was constructed, addressed to researchers and scientists in Greek Agricultural Institutes and Research Centers. Its role was to survey the utilization of the biometrical methodologies and relative informatics tools by scientists in the different fields of agriculture.

The whole procedure was implemented via personal interviews and each scientist could answer the questions based on a five grade scale. This five grade scale contains symbols *, 1, 2, 3, 4. The "*" means that somebody is not familiar with the method, "1" means that the asking person simply doesn't need that methodology, "2" means that the asking person use this methodology in a rate 30% of his work, "3" means that the asking person use this methodology in a rate 30-70% of his work and "4" means that the asking person use the methodology in a rate greater than 70% of his work. The total number of the questionnaires completed was 102 and the survey which began in 2009 is still in progress. (The results probably must be indexed as preliminary). Finally, data from the questionnaires were compared with data from the survey in the bibliography.

The results of the questionnaires so far, are presented below:

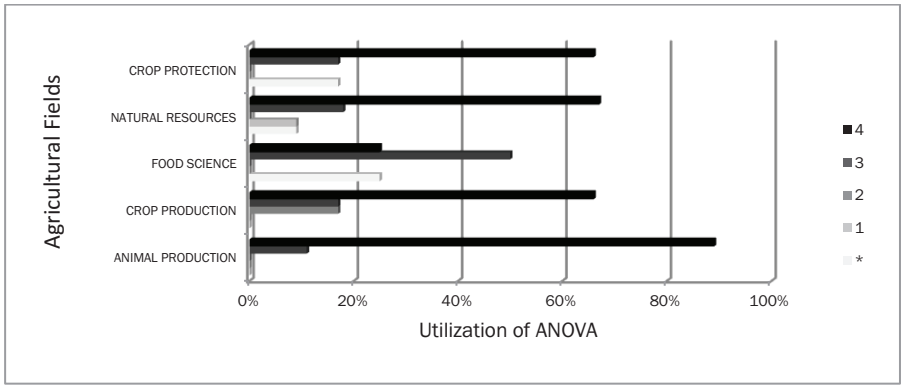

Fig 7. Utilization of ANOVA in agricultural fields (Questionnaires)

Undoubtedly, ANOVA is a methodology very familiar to users from every agricultural field. This condition is being confirmed from the fact that the rates of scientists which apply ANOVA in their work range from 75-100% (fig.8), while only a 9% in the Natural Resources field is not familiar with the method. Having in mind the survey in the databases for ANOVA, this rate is justified because we have found many applications of this methodology in each agricultural field (fig 1-6).

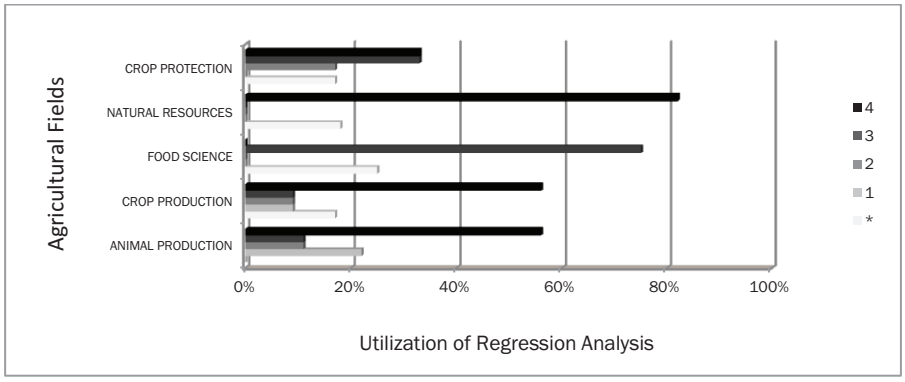

Fig 8. Utilization of Regression Analysis in agricultural fields (Questionnaires)

Regression Analysis is also a method with many applications in Agriculture, as we have already seen from the survey. Figure 8 confirms this condition since its use is very common within scientists in all agricultural fields with percentages ranging from 75 to 85%. The utilization of this methodology is especially high in the Natural Resources field, where the 85% of the researchers apply Regression Analysis in a percentage larger than 75% of their work. The percentage of researchers in all agricultural fields which are not familiar with that method ranges from 17 to 25%.

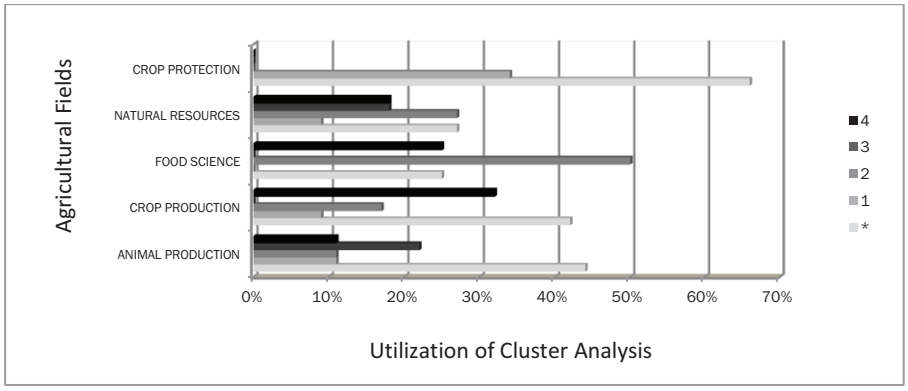

Fig 9. Utilization of Cluster Analysis in agricultural fields (Questionnaires)

The results of the survey in literature have showed that Cluster Analysis is a method with many applications in all the agricultural fields except possibly from the Crop Protection field. This fact is also being confirmed in fig. 9. Furthermore, scientists in the Crop Production field, have to give more attention in this methodology because of the great number of recorded applications (fig. 6). In

general, Cluster Analysis doesn't seem to be well adopted from scientists in Crop Protection (100%), Crop Production (51%) and Animal Production (55%).

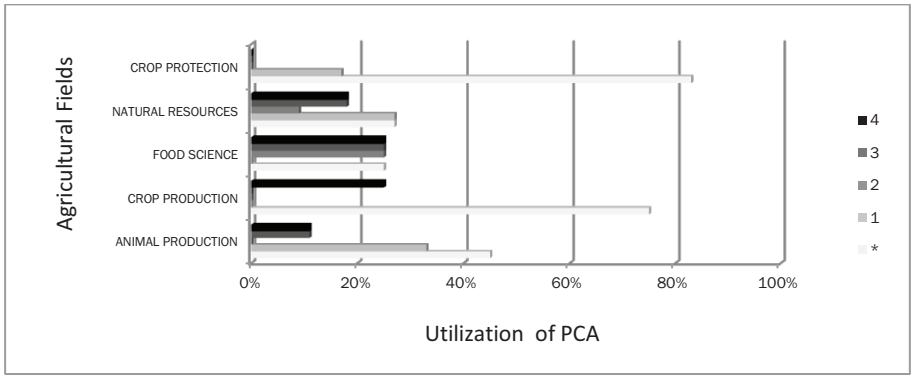

Fig 10. Utilization of Principal Components Analysis in agricultural fields (Questionnaires).

For Principal Components Analysis the survey has shown that there are many applications in Natural Resources Field and Food Science and Technology field. The questionnaires (fig. 10) seem to confirm this view (Natural Resources: 45%, Food Science: 75%), but still there are capabilities for a more extended application of this methodology in these two fields. In Crop Production, Crop Protection and Animal Production Fields there is a definite hysteresis in the use of this methodology, since 75%, 100% and 78% of the researchers are not familiar with Principal Components Analysis.

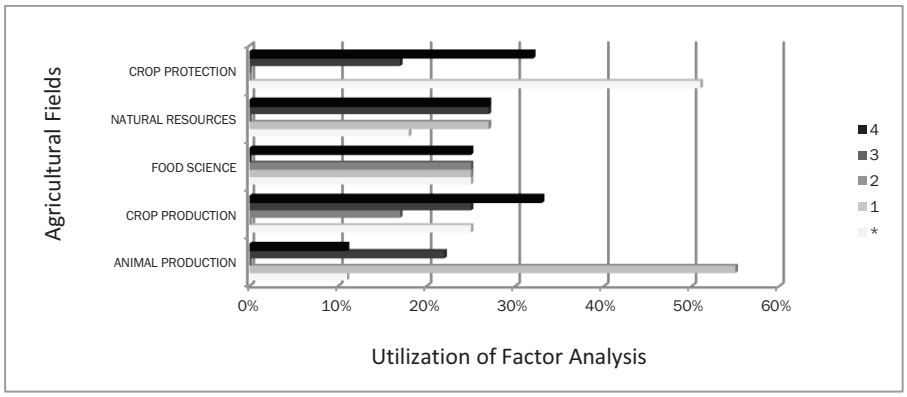

Fig 11. Utilization of Factor Analysis in agricultural fields

The survey showed that Factor Analysis has many applications especially in Crop Production and Natural Resources fields. Results from the questionnaires show

that this methodology is being used in a medium percentage (value from 33% to 58 %) in all the scientific fields from Greek scientists. It is also obvious that scientists from Animal Production (65%) and Food Science (75%) fields don't prefer or don't have the knowledge to use this methodology in their work.

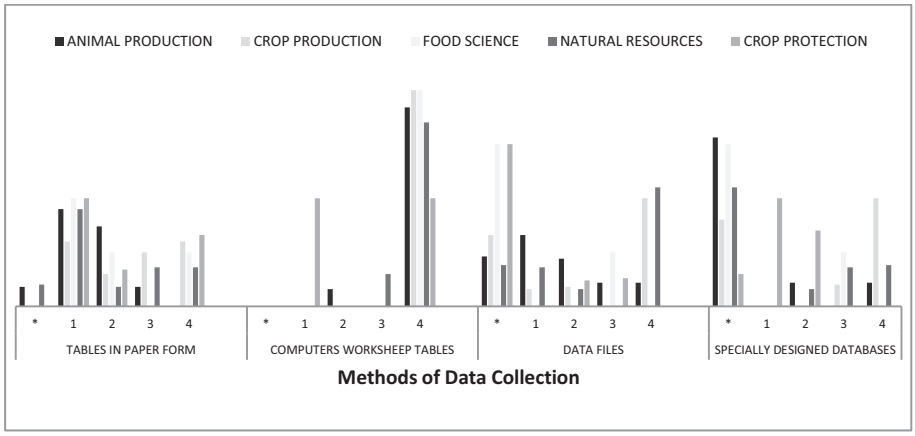

Fig 12. Methods of Data Collection in agricultural fields (Questionnaires)

Regarding the data collection methods, in Animal Production field the 92% of the researchers use worksheet tables, 33% use data files and only an 11% use specially designed databases to store their data. In Crop Production field 100% use worksheet tables, 50% use data files and 60% used specially designed database. In Food Science field 100% use worksheet tables while just 25% use data files and specially designed databases. All scientists from Natural Resources field use worksheet tables, 55% of them use data files and 37% prefer specially designed databases. Finally, half of the scientists in Crop Protection field use worksheet tables whereas only 15% make use of data files (fig. 12).

As far as the informatics tools are concerned, in Animal Production field 56% of the researchers use ACCESS, 90% use SPSS and only 33% use a programming language. In Crop Production field, 30% use Access and in general there is an adequate knowledge in statistical packages. In addition, 15% of scientists in Crop Protection use Visual basic and 8% use Pascal while 50 % of the scientists in food science use Access, 75% use SPSS, 50% use STATISTICA and only 25% use Visual basic. Scientists from Natural Resources field use ACCESS to a significant extent (85%) and have a good knowledge of statistical packages. It is impressive that 70% of them use FORTRAN. Finally, 35% of scientists in Crop Protection field use ACCESS while 60% of them use SPSS and are familiar with programming languages in rates from 15 to 30% (fig. 13).

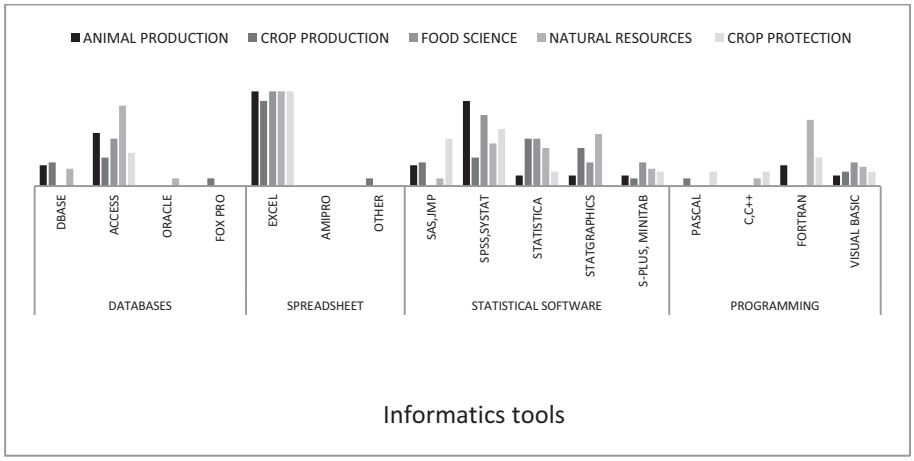

Fig 13. Informatics tools used in agricultural fields (Questionnaires).

4. Conclusions

The biometrical methodologies which are mostly applied, according to the survey in databases/journals are:

- In the **Biotechnology** field: Cluster Analysis > Regression Analysis > Discriminant Analysis > Biplot analysis >AMMI model.
- In the **Crop Protection** field: ANOVA > General Linear Models > Regression Analysis > Discriminant Analysis.
- In the **Food Science and Technology** field: PCA > Cluster Analysis > Discriminant Analysis > Regression Analysis > Survival Analysis > Canonical Correlation Analysis.
- In the **Natural Resources** field: Regression Analysis > PCA > Discriminant Analysis > Factor Analysis > ANOVA > Redundancy Analysis.
- In the **Animal Production** field: Regression Analysis > Survival Analysis > General Linear Models > ANOVA > REML.
- In the **Plant Production** field: ANOVA > Regression Analysis > Cluster Analysis > Correlation Analysis > PATH analysis > CART Analysis.

According to the Questionnaires completed the most common methodologies are:

- In the **Plant Protection** field ANOVA and Regression.
- In the **Natural Resources** field ANOVA, Regression and Factor Analysis.
- In the **Food Science and Technology** field ANOVA, Regression and Principal Component Analysis.
- In the **Crop Production** field ANOVA, Regression and Factor Analysis.
- In the **Animal Production** field Regression Analysis and ANOVA.

In the present study there is a definite hysteresis in the application of most methodologies from Greek scientists, except for ANOVA, Regression and PCA.

Agricultural researchers could use the material described above in order to have better results in their work.

Regarding the use of informatics tools it is a general fact that at least 30% of scientists use Access whereas the vast majority of them (90%) use Excel. The highest rates regarding the use of the statistical packages come from Animal Production (90% use SPSS), Food Science (75% use SPSS), Crop Protection (60% use SPSS), and Natural Resources (55% use Statgraphics). As for the Programming languages, it is indicated by the questionnaires that Fortran is the most widely used one, since 70% of Natural Resources Field Scientists opt for it.

REFERENCES

Akoroda O.M. (1996) Anatomy of problems facing users of statistical tools in agricultural research: a Nigerian perspective. Proceedings of a CTA/University of Hohenheim Workshop, Hohenheim, Germany 7-9 October 1996.

Box G. E. P. (1976) Science and statistics. Journal of the American Statistical Association, 71, p. 791-799.

Curnow, N.R. (1984) Present Position and Potentional Developments: Some Personal Views, Statistics in Biometry and Agriculture. *Journal of Royal Statistical Society*, 147 (2), p 349-358.

Ebdon JS, Petrovic AM, Schwager SJ. (1998) Evaluation of discriminant analysis in identification of low-and highwater use Kentucky Bluegrass cultivars. Crop Science 38: 152-157.

Evans, G., Everis, K. and Betts, D., (2004) Use of survival analysis and Classification and Regression Trees to model the growth/no growth boundary of spoilage yeasts as affected by alcohol, pH, sucrose, sorbate and temperature. International Journal of Food Microbiology, 92, p. 55– 67.

Finney J. (1978) Statistics and Statisticians in Agricultural Research. Journal of Agricultural Science, 91, p. 653-659.

Garitta, L., Serrat, C., Hough, G. and Curia, A., (2006) Determination of optimum concentrations of a food ingredient using survival analysis statistics. Journal of Food Science 71, p. 526–532.

Goodner, K., Rouseff, R. and Hofsommer, H., (2001) Orange, mandarin, and hybrid classification using multivariate statistics based on carotenoid profiles. Journal of Agricultural and Food Chemistry, 49, 1146–1150.

Jauset, A., Sarasu, M., Avilla, H and Albajes, R. (2000) Effect of nitrogen fertilization level applied to tomato on the greenhouse whitefly. Crop Protection, 19, p. 255-261.

Keady, T. and Mayne, C., (1999) The effects of level of fish oil inclusion in the diet on rumen digestion and fermentation parameters in cattle offered grass silage based diets. Animal Feed Science and Technology, 81, p. 57±68.

McElroy, S., Walker, R.H. and Santen, E.V. (2002) Patterns of Variation in Poa annua populations as Revealed by Canonical Discriminant analysis of Life History Traits. Crop Science, 42, p. 513-517.

Obanor, F., Jaspers, M., Jones E. and Walter, M. (2008) Greenhouse and field evaluation of fungicides for control of olive leaf spot in New Zealand. Crop Protection, 27, p. 1335– 1342.

Ojango, J., Ducrocq, V. and Pollot G. (2005) Survival Analysis to factors affecting culling early in the productive life of Holstein-Friesian cattle in Kenya. Livestock Production Science, 92, p. 317-322.

Perkins, J. and Jinks, J. (1968) Environmental and genotype-environmental components of variability. IV. Non-linear interactions for multiple inbred lines. Heredity, 23, 525-535.

Preece, A.D. (1984). Biometry in the third world: Science not ritual. Biometrics, 40, p. 519-523.

Puricelli, E. and Tuesca, D. (2005) Weed density and diversity under glyphosate-resistant crop sequences. Crop Protection, 24, p.533–542.

Riley, J. (1998). Strengthening biometry and statistics in agricultural research. Study Report. (CTA) Technical Centre for Agricultural and Rural Cooperation. Wageningen, The Netherlands. 27 pp.

Sena, M., Frighetto, R., Valarini, P., Tokeshi, H. and Poppi, R. (2002) Discrimination of management effects on soil parameters by using principal component analysis: a multivariate analysis case study. Soil and Tillage Research, 67, p. 171–181.

Stenberg, B., Pell, M. and Torstensson L. (1998) Integrated evaluation of variation in biological, chemical and physical soil properties, Ambio*,*27, p. 9–15.

Szabó, F. and Dákay, I. (2009) Estimation of some productive and reproductive effects on longevity of beef cows using survival analysis**.** Livestock Scienc*e*, 122 (2-3), p. 271-275**.**

Toler, J. E. and. Burrows, P.M. (1998). Genotype performance over environmental arrays: a non-linear grouping protocol. Journal of Applied Statistics, [S.l.], 25, p. 131-143.

Vigli, G., Philippidis, A., Spyros, Apostolos, and Dais, P. (2003) Classification of edible oils by employing 31P and 1H NMR spectroscopy in combination with multivariate statistical analysis. A proposal for the detection of seed oil adulteration in virgin olive oils. Journal of Agricultural and Food Chemistry, 51, p. 5715–5722.

Wander, M.M. and Bollero, G.A. (1999). Soil quality assessment of tillage impacts in Illinois. Soil Science Society of America Journal*,* 63, p. 961–971.

Wilson, R.S. (1999). Evolution and Biometry. Biometrics, 55, p 333-337.

Zhu J. and Weir B.S. (1996) Mixed model approaches for diallel analysis based on a bio-model. Genetic Resolution (Cambridge), 68:233–240