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Biometrical applications in biological sciences-A review on the agony for their practical efficiency-Problems and perspectives

Abstract

The effect of the three biological sciences- agriculture, environment and medicine in the people's life is of the greatest importance. The chain of the influence of the environment to the form and quality of the agricultural production and the effect of both of them to the people's health and welfare consists in an integrated system that is the basic substance of the human life. Agriculture has a great importance in the World's economy; however, the available resources for research and technology development are limited. Moreover, the environmental and productive conditions are very different from one country to another, restricting the generalized transferring of technology. The statistical methods should play a paramount role to insure both the objectivity of the results of agricultural research as well as the optimum usage of the limited resources. An inadequate or improper use of statistical methods may result in wrong conclusions and in misuse of the available resources with important scientific and economic consequences. Many times, Statistics is used as a basis to justify conclusions of research work without considering in advance the suitability of the statistical methods to be used. The obvious question is: What importance do biological researchers give to the statistical methods? The answer is out of any doubt and the fact that most of the results published in specialized journals includes statistical considerations, confirms its importance. However, the ultimate question is: are the statistical methods properly used? This review undertakes an attempt to present the case history with special reference to the developing and underdeveloped countries, the problems and the possible perspectives.

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A General introduction

It is rather a very well known feeling in the teaching statistics rooms the common students' anxiety for their inability to make clear the practical applications of the theoretical statistics on real biological research matters. Of course, it could be considered somehow reasonable some decades ago, as then there were not so many data available, neither computers in the lectures rooms and surely not any statistical software for the proper data organization, manipulation and analysis. Neither the students nor the researchers were of a diminished intelligence, but the lack of the proper tools available today was the reason of their inability to understand well the theory and make it applicable to practical matters. Frank Yates an enthusiastic user of computers writing used to say. to be a good theoretical statistician one must also compute, and must therefore have the best computing aids.

This exact need of making the theoretical statistics applicable to biological phenomena raised the appearance of the scientific field of Biometry. According to the very philosophical reality on which the main law of the International Biometric Society's (IBS) bylaws was based, it should not probably allowed to the biometricians to be proud when they talk about statistics from the theoretical point of view, but only if it refers to the sense of "bios" (meaning life). What was the result achieved up to resent years is presented in the following review.

A brief review of the biometrical applications in biological sciences presented as papers in biometrics and other journals

Stergios Tzortzios[1] reported that if one goes through the papers presented in the IBS conferences and the publications in the IBS journals he shall realize that in the Practical Applications of Statistics in the biological research, and more particularly in the fields of agriculture and environment, are not more than 50% of the total, although-according to the IBS bylaws they should be nearly to 100%. In the journal of "Biometrics" it is much lower. It is very strange that it is a similar case particularly in regards to the journal of JABES -which was created on the purpose of giving the solution to the problem of "Biometrics" after all those comments and suggestions made by many IBS members since some decades ago.

Having said that in apparent and real defense of our mathematically oriented members, I do agree (Billard[2]-1996- notes) and sympathize with our members who are primarily trained in biology or agriculture or the like but who depend on statistical procedures as the primary tool in the design and hence the analysis and interpretation of experiments in their substantive field. Their contentious complaint is that in recent years Biometrics papers are far too mathematical to be read, and that furthermore they appear to be written solely from a theoretical standpoint, with the authors subsequently casting around

for an example to which the theory can be applied after it has been developed. Let's quote from CI Bliss[3] in his 1958 account of the first decade of the Biometric Society and in particular his review of the role of Biometrics:

One of the periodic complaints of our biological members is that the journal is becoming too 'high brow' statistically for them to understand, and the counter-complaint of the Editor that good biological, less technical manuscripts are hard to come by, despite numerous pleas for material. It is very well known the important works published by Riley among whom she surveyed aquaculture journals which contained a large proportion of papers from developing countries. They found that, of 180 papers, only a very few could be seen to have used and presented statistical methods and results correctly. The reasons for this were attributed to poor training and inadequate description of presentational requirements in the journals.

In order to help in achieving an improvement an agreement was reached in 1993 to move ahead with plans for a new journal called the Journal of Agricultural, Biological, and Environmental Statistics (JABES). As the name suggests, the journal:… emphasizes applications of statistics in agriculture, biological, and environmental sciences…. articles of immediate and practical value to the applied workers in these fields ... to develop the interface between statistics and the biological sciences ... only applied papers will be considered [note the specific exclusion of theoretically focused papers] ... expository, review and survey articles addressing broad-based statistical issues in the biological sciences will be valuable.

However, questions arise whether the today's performance of the IBS organization as an International Society offers the best possible contribution to the biological research globally. But the various calls for help in research collaboration from all the developing countries don't support this. On the contrary, urgent ascertainments on the need for changes in the methodology of teaching biometry – as applied research methods and statistics in scientific sectors - and on the collaboration in the practice, are quite often outputs in IBS conferences, especially in those of the IBS Regions and Groups of the developing countries.

In the following an attempt is presented to get an idea about the research done in all the countries in the field of the three sciences: agriculture, environment, and health-medicine, through their publications in the period from 1996 to 2013 (using SJR[4]), in order to show the gap between the developed and developing countries and the lack of the cooperation required Tzortzios.[5]

A brief presentation of the publications presented in journals for all the countries in the world

In the subject area of "Agricultural and Biological Sciences-miscellaneous" the number of publications range from 85.076 (for USA) down to 1 or 2 and up to 50 in the 110 developing countries (out of 220 in total), with the respective number of Citations per document ranging from 29 to 0 or 1 up to 5, and the H-Index from 287 to 0 or 1 up to 10. In the subject area of "Environmental Sciences Miscellaneous" the number of publications range from 54000 (for USA) and around 10000-20000 for five more developed countries down to 1- 10 in 140 developing countries (out of 214 in total), with the respective citations per document from some thousands or hundreds for the developed countries down to 0 or single digit numbers for developing countries.

In the subject area of "Health Professions Miscellaneous" the number of publications range from some hundreds to the most developed 23 countries down to 0- 50 for the rest of the 126 countries presented No comments for the citations.

A comparison between the continents for their published research

In the field of Agricultural research published documents (Figure 1)

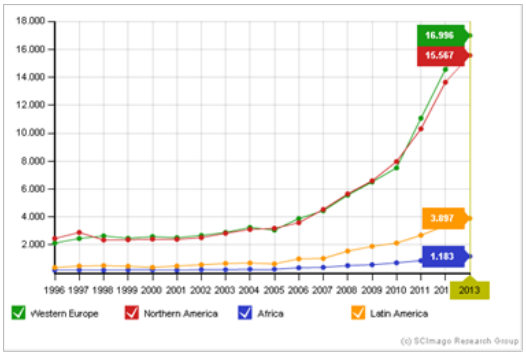

Figure 1 Comparison W Europe-N America-Africa-Latin America for published documents.

In the field of Environmental research published documents (Figure 2)

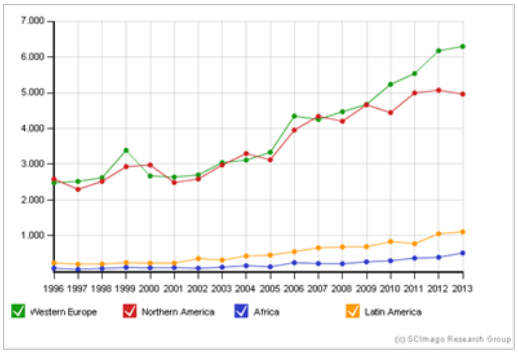

Figure 2 Comparison W Europe-N America-Africa-Latin America for published documents.

In the field of Health research published documents (Figure 3) (Figure 4)

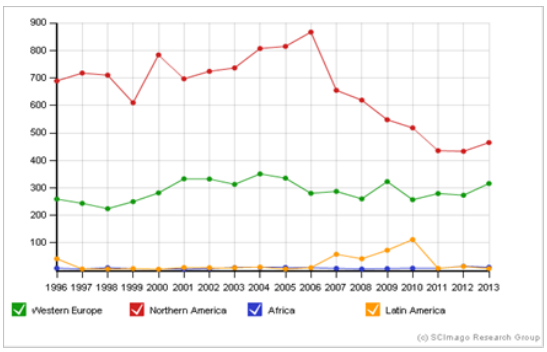

Figure 3 Comparison W Europe-N America-Africa-Latin America for published documents.

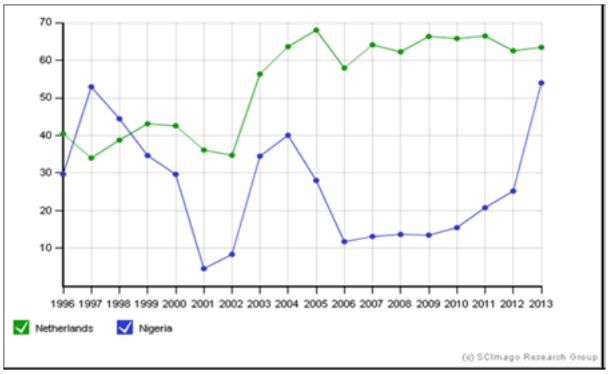

Figure 4 A Comparison between Netherlands- Nigeria for their International Collaboration (in percent of documents with more than one country).

The above figures show the great difference between the continents and more particularly between the developed and developing countries in the number of publications and their H-Index which means the quantity and the quality of the research. However, it can be emphasized that there is an increasing interest in the developing world in their collaboration with colleagues from other counties in order to increase the quantity and quality of their biological research.

Olelekam et al.[6] reported an effort to assess the profile and determinants of health research productivity in Africa since the onset of the new millennium.

They identified 107 662 publications, with a median of 727 per country (range 25–31757). Three countries (South Africa, Nigeria and Kenya) contributed 52% of the publications. The number of publications increased from 3623 in 2000 to 12709 in 2014 (relative growth 251%). Similarly, the per cent share of worldwide research publications per year increased from 0.7% in 2000 to 1.3% in 2014. The trend analysis was also significant to confirm a continuous increase in health research publications from Africa, with productivity increasing by 10.3% per year.

An effort to evaluate the biometric efficiency in the real practical situation:

The misuse of biometrical methodologies

Regardless everyone's assessment of the as above presented review of the historical papers presentation it is worthwhile an effort to undertake an evaluation of the real practical situation in the agricultural industry as a whole, e.g. education-research-production.

Rilley[7] reported that the literature has demonstrated in recent years that deficiencies exist in biometric approaches in developing countries. Suggestions for the improvement of biometrical services in these countries, statistics training schemes and for the supply of equipment were outlined by many authors including Nokoe,[8] Lauckner,[9] and others, although the need for appropriate technology was also heavily stressed as inappropriate donations of aid can actually be detrimental.

To get an idea about the biometric deficiencies in the Greek agricultural industry Tzortzios S.[10] has attempted a project on the "Survey and evaluation of biometric approaches in the field of agriculture" in Greece at first stage and in collaboration with other countries. A first remarkable conclusion seemed to be the notable differences between the various basic sectors of agriculture in broad sense (e.g. plant science and production, animal science and production, food technology, engineering and natural recourses, forestry, agricultural economics and management) on the following main biometrical approaches: (a) ways of Data Management, Collection, Organization and Manipulation; (b) Methods of Statistical Analysis-processing; (c) the Experimental designs used; (d) the computer equipment-Software used. It was rather expectable due to the natural differences in their subject and material from basic points of view.

Problems in the design of the experiments

The objectives of the research should condition all the research process and mainly the design of the experiment. The objectives in an experiment are many and variable but a common one is the optimum use of resources, obtaining the maximum of information and precision from the available resources; in short, efficiency.

Usually there is a tendency to copy the designs used by other colleagues and published in prestigious journals without critically revising the experimental conditions where those experiments were carried out. Lauckner[9] in an analysis of 510 papers found that 41% used the randomized complete block design and 27% the split-plot design, in the remaining 22% the method was not even clearly described.

Problems in the field and the data recording

A very important aspect, often forgotten in mathematically oriented textbooks is the importance of data recording. Electronic data loggers should be used to minimize the probability of error due to data recording, handling and transmission.

It is very well known in the job of general experimentation the importance of having large amounts of proper data. At the same time the fortuning event of the evolution in the new technologies and computing statistics offers the great tool to the plant and animal researcher making him capable in handling the data in the most effective way for the most sophisticated specific scientific purposes.

In multi-year-locations experimentation, the very important job is referred to the data organization and manipulation, and mainly to the data recording as it is summarized in the following **Tzortzios.**[11] Among the main tasks are: (a) the general arrangement of the multi-year experimental data in a complete unique computer format; (b) the arrangement in a unique general data structure according to the nature of the variables; (c) the creation of new codes for the years, the various experiments, and probably for certain-specific parameters; (d) the creation of new variables of special interest as statistical products. All of these can be done only by the proper use of the many statistical packages which, fortunately, are available today.

Problems in the analysis and interpretation of results

Problems in this aspect are frequent and variable in nature. A much generalized problem is the absence of a preliminary exploratory data analysis to detect outliers or biological patterns that may suggest future research. Many times the purpose of the experiment is just to estimate the magnitude of the effect to assess its relative importance to the problem under investigation. In two volumes of Phytopathology,

66% of almost 200 tables and figures abused the application of the tests, and in two volumes of J. Animal Science, 53% of the tests were inadequate K. Lowry.[12] In experiments with repeated measurements in time or space the effect of time or space is generally included in the model as another factor disregarding the possible presence of autocorrelation.

The confusion between regression and correlation analysis is wide-spread. In regression analysis, it is infrequent to calculate the standard errors of the coefficients whereas, by-in-large, the coefficient of determination is the most frequently reported statistic. In many of the regression analyses one can see only the R2 coefficient without any indication of the precision of the estimates. Another frequent mistake is to use a single regression model in data structured by one or several classification criteria like sex, age, etc. Carbonell et al.[13] In this context, a word of caution about canned computer programs may be appropriate. The direct use of very friendly programs by the researchers without the advice of a biometrician, could lead to wrong conclusions if they are not aware of what the program is intended for and really does. Before using a computer program, the researcher should think carefully about the set of data he has available and the best way to approach the analysis instead of blindly rushing to use such programs.

Problems in reporting results

Publication is a major step in the scientific process and should deserve at least the same care as the previous phases of research. The problems in reporting can very often be traced back to problems in the design, or in the analysis and interpretation of results. Many times a detailed description of the experimental design, the factors and levels used and the structure of the data is omitted and is substituted by a reference of the computer program Finney.[14] As Nelson.[15] indicates, the refusal by some journals to include the ANOVA table is not compensated for by a detailed discussion of the statistical methods and models being used.

Biometrical education and training

Marvin Zelen[16] (1983) in his Invited speech in the IBS Conference (Biometrics © 1983 International Biometric Society) of the title "Biostatistical Science as a Discipline: A Look into the Future" noted:

"The field of biostatistics is enjoying unparalleled developments. Never before were members of our profession in such demand. Current applications are significantly influencing the direction of research in statistical methodology. It is not clear whether there is a discipline which can be termed 'biostatistics', but we are part of the emergence of a discipline which is termed 'biostatistical science'. It refers to the applications of statistics, probability, computing and mathematics to the life sciences, with the goal of advancing our knowledge of a subject-matter field in this area. A special role is envisioned for the Biometric Society to be more active in problems associated with the developing countries.

In the EMR2011 Conference, Ronald E. LaPorte[17] in an invited speech on the title *"Building Global Capacity in Statistics"* reported (for the "Supercourse" team): "World wide there are over 300 times more clinicians than there are statistics. In many developing countries there are no statistical training programs. This is at a time when there has been an explosion of data. There is a critical need for more individuals to be trained in statistics in developed and developing countries alike.

In most medical, and nursing schools worldwide in 4-6 year training students might have 15 minutes training in statistics. The general situation in developing countries is that on the average, biological researchers have had limited training in Experimental Design and advanced biometry. The main reason of it is that the universities are teaching more of descriptive statistics and methods and little in the area of experimental design and biometrical applications. Those researchers who have had the opportunity to travel and exchange ideas with international level researchers or who have obtained advanced degrees abroad in their chosen field are more apt to have a better background in experimental design.

What can be done to alleviate this situation?

It is rather easy to realize that we are not without help in this situation. Other countries and regions have gone through this same phase of development of statistical programs. The scientists in the developing countries can attempt to model growth and development after successful programs which were carried out in the developed countries. All together should start taking the advantage offered by the advances presented by the new information technologies and more particularly the computers science and the statistical packages. Tzortzios,[18] supported the idea of the new technologies use in creating Regions Networks which could assist in transferring the known information on teaching and research within the regions countries.

In a keynote talk of the title "*Biostatisticians, Biostatistical Science and the future"* in EMR2005 conference Marvin Zelen[19] noted:

"I prefer to use the term Statistical Science to describe the practice of Statistics. When the main field of application is in the biomedical sciences or agronomy we may often describe this activity as Biostatistical Science and its practitioners as Biostatistical Scientists. Nearly all of us have ready access to enormous communication and computational capabilities which were undreamed of a few decades ago. Many of us are on the Internet every day. This has changed the way we practice our science. Chief amongst these is the globalization of the way biostatistics is practiced. For example we have not fully taken advantage of the potential of our communication resources to educate our biostatistical scientists. I propose that our profession assemble courses on the internet which would be freely available. Many faculties have favourite courses which could be made widely available."

Ronald E. LaPorte[17] reported (for the "Supercourse" team): Ideally we would like to build more Master's and Ph.D. programs in developing countries. We want to double the training in statistics worldwide in the next 5 years. The reason that there is paucity is that few faculties can teach statistics. We are changing this. Our approach is simple; we have a network of over 50,000 faculties interested in global health and prevention from 174 countries. From this network we have collected 4800 top quality lectures, 75 from Nobel Prize winners. The last two years, responding to an invitation by Ronald LaPorte I-the author of this paper- (as an IBS member and EMR President) had a good collaboration with Professor Ronald LaPorte and his colleagues in an effort to develop an International Library (in the Library of Alexandria) on research methodologies –the so called RMLA- as a basic source of knowledge to the young scientists-researchers of the developing countries. Tzortzios S & Adam G[19] worked on creating an Integrated (interactive information) System, called AgroModel, aiming to improve the task of Biometry's courses for under- and post-graduate students and of training courses for researchers in the field of agriculture.[20]

The materials and methods required

The *AgroModel* was created to provide tools for database management, data manipulation and data analysis, in order to be used initially for educational purposes and later on for research as well. The system was built using object-oriented visual languages (an integration of Visual Basic, SQL and Web development languages HTML, Java) used also for advanced programming and work with the system. In addition, based on primary agricultural educational and research needs, an appropriate database structure was created on a relational model scheme, where various plant and animal descriptive and research data were stored into database structures. The database was under continuous improvement and updates since new data and findings could be continuously added. After the first familiarization with the *AgroModel* the user keeps it in mind in two forms, the general view of which is presented in Figures 5&6.

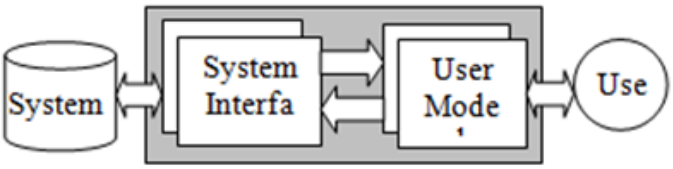

Figure 5 A general user interface.

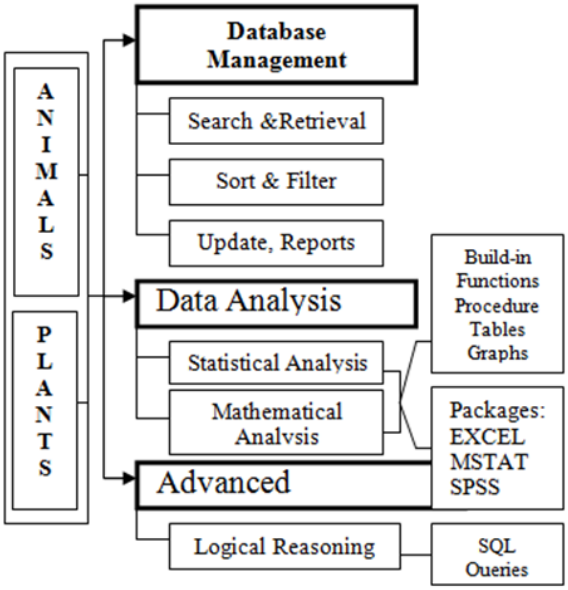

Figure 6 A detailed presentation of the environment.

A such environment provides build-in tools as well as interfaces to software packages (e.g. SPSS, SYSTAT, STATISTICA) for mathematical and statistical analysis applied mainly to agricultural data, but also to any type of data online on the Web. Being in such an integrated environment, where the compatibility between the databases and various statistical packages is available, the trainee could undertake any type of statistical analysis from the simplest descriptive statistics to the most sophisticated stability statistics approaches (regression models, cluster analysis, etc.). The system comprises a flexible structure that is under continuous improvement and evolvement in order to maintain the research information up to date. The overall integrated environment obtained is the platform, which is finally to be placed on the WWW in order to provide distance-learning education on the web, making the agricultural information available for the benefit of agricultural society and any scientific society, in general.

Being in a well-organized database the scientist - teacher or student – could attempt various data manipulations in order to derive interesting specific parameters; to create new variables for various applications; to aggregate groups of certain purposes; and so on.

A such process as an "inductive training" in the computer could become the most useful tool. First, effectively designed computer programs facilitate the manipulation of ideas and findings, making this process fast and tireless. Second, such programs running in high-speed computers produce an outbreak in statistical ability. Third, these programs have made it possible to test scientific theories based on huge number of variables, which was practically impossible to be handled some years ago.

A version of the application could be provided in the World Wide Web for any distance learning or other educational and research purposes, incorporating various links to important electronic resources (libraries, conferences, journals, etc.), offering interested information (scientific, technical, etc.) related to agriculture and other sciences as well.

Discussion and suggestions

The problems presented in the reviewed literature are too extensive and varied to have a simple and single origin and to have a magic solution. The poor statistical training and background of biological researchers are major factors responsible for the situation presented above. One of the most important causes is the teaching of statistics with too great a mathematical orientation and with emphasis on theory instead to the application to real world problems. Statistical training for biological researchers should be in the field (or laboratory) as well as in lecture rooms. More emphasis is needed on the comprehension of basic concepts than in their mathematical derivation. At many research centers, the quality of the biometric work has been variable, and often seriously defective. The fact that many papers containing examples of "a ritual approach to Biometry' are accepted for publication reduces the impact of criticism about the statistical methods being used and reduces the researchers incentive to solicit a specialized advice. Moreover, more importance should be placed by all the involved on the adequate and appropriate use of the statistical methods and the proper interpretation of results, rather than their theoretical background.

In fact, Biometrics, the journal of the International Biometric Society, is being criticized for becoming so highly specialized that much of its present content cannot be understood by most biologists and can be understood only with difficulty by many biometricians.

The following suggestions could be considered as an effort to indicate some possible solutions to the agony for a better practical efficiency of the biometrical applications in the life sciences research:

It has been proven that a better collaboration between the biometric centres or university labs with the biological (agricultural, environmental, medical) researchers within each country could give the required improvement in the whole research task-from the first apprehension of the research project-the experimental design up to its publication.

Similarly, of a great significance are the collaborations of the teaching and research teams in the developing countries with their colleagues in the developed ones. The IBS Regions and Groups could probably be the proper guides in such collaborations. It seems to be very important the specific effort that should be undertaken by the biometricians to address their teaching and research approach to the practical biological interests (according to the IBS aims and laws) and not to the theoretical statistical matters, as, unfortunately, it is still the case.

It is the time now for the biometricians to take advantage of the new technologies in creating integrated informatics systems in organizing the huge amounts of research data in the most effective ways for teaching and research purposes. The Biometrical journals could offer their help if they give the researchers know that they will not accept to publish papers if they don't refer to the applications to biological research. To the best result of the previous suggestions the positive contribution of the International Biometric Society-IBS could be very helpful by encouraging the IBS Regions and Groups to examine them seriously.

The Governments of all the countries (developed, developing and underdeveloped ones) should realize the task of the life sciences and its importance for the Life in Earth, and offer the proper financial and ethical support to the direct practical research urgently, if they want to keep their people satisfied to stay in their mother countries. The World Organizations, as the OECD, the United Nations, FAO and others, should realize the developing countries need for help and strongly support them, if they want to contribute to the whole world peoples' welfare, offering, at the same time, the solutions required to the serious problem of migration.

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None.

Conflict of interest

The author declares there is no conflict of interest.

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