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Report on the use of experimental statistics applied to research in an area of the Amazon Region

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ABSTRACT
We understand that the act of research is essential in the learning process and, mainly, in the construction of autonomous and critical individuals. Understanding the appropriate use of statistics leads to fewer errors in reporting results and interpreting conclusions. What we observe today are analyzes of poorly performed experiments and erroneously interpreted results. This justifies that the student himself, when constructing his article, is capable of carrying out the analyzes and interpreting the results. The project was developed with two students from the third period of the Higher Aquaculture Technology Course at the Federal Institute of Roraima. This work aimed to make students aware of the application of designs used in agricultural experimentation and their applications, through solving a list of exercises and to present the SISVAR computer system with diverse applications in the statistical analysis of experiments, due to its ease of access and use. The students were able to use data obtained from practical examples to: suggest the best design for each exercise, analyze the data and see if they followed the assumptions for carrying out the analysis of variance, formulate hypotheses for the validity of the F test, perform the analysis of variance and apply the F test. Using the F test, they were able to carry out the study of splits and find the best treatment in each exercise based on the Tukey test study or based on the regression study. We concluded that the students acquired the ability to interpret, analyze and resolve the information arising from the data collected during the research and made them aware of the different aspects of applying statistical methods proposed in the project.

Keywords: Experimentation, Aquaculture, Statistics, Amazônia, Fish, Teaching.

1 INTRODUCTION

The planning of strategic development programs in the most diverse areas, in order to be carried out efficiently, must create mechanisms in which data are collected, stored and studied in order to produce information that will guide the necessary guidelines in the appropriate management of such area. In relation to fishing, it could not be different. Unfortunately, Brazil lacks a set of regular monitoring statistics focused on fishing, according to what was mentioned on the Mar Sem Fim (2020) website.

We understand that the act of research is essential in the learning process and, mainly, in the construction of autonomous and critical individuals. Statistical analysis, present in scientific research and reported in original articles, allows the student to interpret the information from the data collected during the execution of the research and thus use it for the benefit of society. The comprehension of the proper use of statistics leads to fewer errors in the reporting of the results and in the interpretation of their conclusions (SILVA, 1995).

Agricultural research aims to improve the performance of agricultural systems in terms of their economic and social implications. The striking characteristic of agricultural systems is their complexity. The consequent complexity of agricultural research is more markedly high in a country with a large geographic scope and high social and economic heterogeneity, such as Brazil.

Environmental variation is a complex problem in achieving the expressiveness of agricultural research, greatly increasing the difficulties in inferences with the purpose of generating recommendations to farmers.

In the particular case of training in statistics, the program aims to enable researchers to use scientific methodology that contributes to the development of more effective research, which can have a relevant impact on the performance of agriculture.

In addition to the knowledge of his/her specific area, the researcher needs to have the appropriate mastery of the methods, techniques and procedures inherent to scientific research, indispensable to the effective development of research in his/her area. These include the statistical method, which is an integral part of the scientific method (SILVA, 1995).

For Stigler (1986), statistical methods were developed as a mixture of science, technology and logic in the solution and investigation of problems in various areas of human knowledge.

The understanding of the proper use of statistics leads to fewer errors in the reporting of the results and in the interpretation of their conclusions.

In recent decades, statistical calculations have been greatly facilitated by the use of computational applications. This allowed complex and time-consuming methods to be routinely applied. However, many researchers have replaced these applications by consulting a professional in the field of statistics. What is observed today are analyses of poorly performed experiments and erroneously interpreted results (SILVA, 2007). This justifies that the student himself, in the construction of his TCC or in an article, is able to perform the analyses and interpret the results.

Several statistical packages are available for the analysis of experiments, such as SAS – Statistical Analysis System – (Sas Institute Inc., 2000), which is, in general, one of the most used programs worldwide in the analysis of data in the agronomic, biological and social areas; STATGRAPHICS – Statistical Graphics System – (STATGRAPHICS, 1999); STATISTICA for Windows (STATISTICA, 2002), among others. National programs can be found in which the reader can have easier access, among them: SANEST – Statistical Analysis System for Microcomputers – of the Federal University of Pelotas (ZONTA & MACHADO, 1991); SISVAR – Analysis of Variance System – of the Federal University of Lavras (FERREIRA, 2000a); the SAEG – System of Statistical Analysis (RIBEIRO JÚNIOR, 2001) and the GENES – Computational Application in Genetics and Statistics (CRUZ, 2001), both from the Federal University of Viçosa.

This work aimed to make the students of the Aquaculture Technology course of IFRR/CAM, aware of the application of three types of design widely used in agricultural experimentation, namely: completely randomized design - DIC, randomized block design - DBC and Latin square design - DQL and its applications, through resolution of list of exercises and to present the SISVAR computer system with diverse applications in the statistical analysis of experiments, due to its ease of access and use.

2 METHODOLOGY

2.1 Project Proposal

The project was developed with two students from the third period of the Higher Course in Aquaculture Technology at the Federal Institute of Roraima.

It was proposed to the students, as a form of training, that they solve lists of exercises by Banzatto and Kronka (1992). The examples taken from the books served only as a means of training in calculations. It was up to the students to indicate how the planning was thought by the author, indicating the reason for the adopted design; It was also up to them to elaborate the hypotheses to be accepted or rejected in the Sir Ronald Fisher test (F-test) of the analysis of variance, perform the analysis of variance, test the hypotheses and depending on the results of the F-test, followed by a resolution of the unfolding of the test: Tukey's test for qualitative data or regression study in the case of quantitative data. They first solved it using only a scientific calculator and then plotted the data in Microsoft Office Excel and solved it in the SISVAR software.

In the resolution of the exercises, the designs have mathematical models and, to perform the analysis of variance, we must consider whether the mathematical model accepts some hypotheses necessary for its validity of the analysis.

2.1.1 Completely randomized design - DIC

The resolution of a list with 5 exercises involving the design entirely at random was proposed, whosemathematical model is:

$$\text{A - DIC - } y_{ij} = m + t_i + e_{ij}$$

where:

y_{ijk} is the observed value of the trait studied, *in treatment i (*i = 1, 2, ..., *I*) and in repetition *j* (j = *1, 2, ..., J*);

m is the overall mean of the experiment;

t_i is the effect of treatment *I*;

e_i is the error associated with the observation

y_{ij} or effect of uncontrolled factors on *yij observation*.

2.1.2 Randomized Block Design - DBC

At this stage, it was proposed to solve a list with 4 exercises involving the design in randomized blocks. The mathematical model of the randomized block design

$$\text{B - DBC - } yji = m + ti + Bj + e_{ij}$$

where:

y_{ij} is the observed value of the trait studied, in treatment i (i = 1, 2, ..., *I*) and is found in block *j* (j = *1, 2, ..., J*);

m is the overall mean of the experiment;

t_i is the effect due to treatment i, which has been applied to the plot;

Bj is the effect due to the block j in which the plot is located

e_{ij} *is* the effect of uncontrolled factors on the plot that received treatment I in block J.

2.1.3 Latin Square Design - DQL

At this stage, the resolution of a list with 5 exercises involving the Latin square design was proposed. The mathematical model of the Latin square design.

$$\text{C - DQL - } yjik = m + li + cj + tk(ij) + e_{ijk}$$

where:

$y_{ij\ k}$ *is* the value observed in the parcel that received treatment k and which is found in row i and column j;

m is the overall mean of the experiment;

l_i is the effect of line i in which the plot is located;

cj is the J column effect, which has been applied to the plot;

tk(ij) is the treatment effect k and which is found in row i and column j;

e_{ijk} *The effect of uncontrolled factors on the plot that received treatment I in block .*

It is not uncommon to find that one or more of the basic hypotheses is not verified, and then, before proceeding to the analysis of variance, the experimental data must be transformed in such a way that the basic assumptions are met (BANZATTO and KRONKA, 1992).

The basic hypotheses to be valid in analysis of variance are:

A- Additivity: the effects of factors occurring in the mathematical model must be additive.

B- Independence: errors or deviations due to the effect of uncontrolled factors must be independent.

C- Homogeneity of variances: errors or deviations because of uncontrolled factors must have a common variance σ^2 tag.

D- Normality: errors or deviations due to the effect of uncontrolled factors should have a normal distribution of probabilities.

This implies that the experimental data fit the normal probability distribution.

One of the most frequent cases of non-satisfaction of the basic hypotheses is the one in which there is no homogeneity, that is, the variance is not the same in the different treatments (BANZATTO and KRONKA, 1992).

2.1.4 Simple linear regression and correlation study

When it is desired to study the simultaneous behavior of two or more variables, Regression and Correlation analysis are used to evaluate the desired information. In regression, we estimated the relationship of one variable with another, expressing the dependent variable as a function of the independent variable. Regression studies sets of variables that are supposed to be in a cause-and-effect relationship (AZEVEDO, 2016). It is the study of the behavior of a dependent variable (Yi) as a function of the variation of one or more independent variables (Xi, Zi, Wi, ...) assuming that these variables are in a cause-and-effect relationship (Azevedo, 2016). Correlation, which is sometimes confused with regression, studies the degree to which two or more variables vary simultaneously. That is, the degree of interrelationship between the variables: dependent variable and the independent variable. Regression and correlation methods cannot be applied to qualitative variables (attributes). The variables need to be continuous. According to the regression function, we can have: Rectilinear, Exponential, Parabolic, Potential Correlation (AZEVEDO, 2016).

2.2 USE OF THE SISVAR PROGRAM

The Sisvar program is a statistical analysis system that can also be used in teaching. SISVAR is one of the most widely used Brazilian statistical analysis programs in the country, either directly in the statistical analysis of scientific works from the most different areas of scientific knowledge or in the teaching of basic and experimental statistics. Sisvar has a number of competitive advantages, the main one being its great interactivity with the user, providing a simple, efficient, powerful, very robust and accurate environment. These are the main reasons for its enormous use by a large part of the scientific community (FERREIRA, 2000).

3 RESULTS AND DISCUSSION

In the IHD design, the students performed the resolution of Banzatto and Kronka (1992).

In an experiment aimed at controlling the aphid *(Apis gossypii* Glover) in cucumber culture, Macedo (1970) used 6 replicates of the following treatments:

A - Witness; B - Ethyl azines; C - Supracid 40CE dose 1; D - Supracid 40CE dose 2 and E - Diazinon 60CE.

The data obtained regarding the number of aphids collected 36 hours after spraying are shown in Chart 1.

Table 1. Number of aphids collected 36 hours after spraying.

	Repetitions						
Kicked.	1	2	3	4	5	6	S2
A	2.370	1.687	2.592	2.283	2.910	3.020	233.749,60
B	1.282	1.527	871	1.25	824	920	75.558,80
C	562	321	636	317	485	842	40.126,17
D	173	127	132	150	129	227	1.502,27
E	193	71	82	62	96	44	2.791,87

Source: Banzatto and Kronka, 1992.

As the data were counts, it was suggested that the Hartley test be performed to verify the assumption of homogeneity of the variances.

$$Hc = S^2 \max/S^2 \min = 233.749,60/1.502,27 = 155,60^{**}$$

According to the Hartley test table, for 5 groups and 5 degrees of freedom, H $5_{\% =}$ 16.3 and H1% = 33.0 were obtained. Since Hc (155.60) > H (5.5) 1% (33.0) were rejected, the hypothesis of homogeneity of variances was rejected, i.e., the data did not follow the normal distribution; Then the data transformation was done. The data in Table 3.2.1 were transformed using the transformation (ln x). After the transformation of the data, the Hartley test was performed again with the transformed data, and it was found that the data then had a normal distribution after its transformation Hc (5.62^{ns}) < H (16.3) 5% and H (33.0) 1%, so the analysis of variance can be performed (table below).

Table 2. Analysis of variance with transformed data (ln x), aiming at the control of aphids in cucumber culture.

Sources of variation	G.L	Q.M.	Fc
Treatments	4	11,4785	103,92**
Error	25	0,1105	

Source: Banzatto and Kronka, 1992. **significant at 1% probability by the F-test.

As the Fc value exceeds the critical value at the level of 1% probability, it is significant (P<0.01) Chart 2, it is concluded that the insecticides tested have different effects on the number of aphids collected 36 hours after spraying in the cucumber crop. The mean of the treatments was calculated and the Tukey test was performed on the mean of treatments to verify which of the treatments controlled the number of aphids in the cucumber culture the most, chart 3.

Table 3. Average of treatments and Tukey's test

Treatments	Transmolded media	Unmolded Medium
Witness	7,7973 a	2.434
Ethyl azinfos	6.9549 B	1.048
Supracid 40CE dose 1	6.2062 C	496
Supracid 40CE dose 2	5,0293 d	153
Diazinon 60CE	4.4013 and	82
DMS	0,1357	
D	0,5645	

Means followed by the same letter did not differ from each other according to Tukey's test (P>0.05); DMS minimal significant difference, Δ Tukey (5%). Source: author's elaboration

Figure 1. Aphid numbers after 36 hours of application of the treatment on cucumber plants.

Source: author's elaboration

Chart 3 and Figure 1 show that the insecticide that best controlled the number of aphids in the cucumber crop was diazinon 60CE (Trat. E), which had the lowest number of aphids. The coefficient of variation statistic was also calculated, resulting in c.v.=5.47%. This coefficient of variation of 5.47%, very low in agriculture, indicates small variation of the data or great precision when we affirm that the insecticide was Diazinon 60CE was the one that best controlled the aphid population in cucumber plants under the conditions studied.

In the same way, it was suggested to the students to solve four more exercises in a completely random design and to perform the analyses using a scientific calculator, Microsoft Office Excel and SISVAR software.

Next, the students were asked to perform the analysis of the experiment in a randomized block design. The experiment by Cunha (2019) was used as a practice, chart 4. Effect of supplement use in cow feed on milk production in kg.

Table 4. Milk production values (kg)

	Treatments			
Blocks	No add-on	Cassava	Araruta	Sweet Potato
Gear	6,4	10,9	12,0	11,2
Dutch	6,2	11,6	10,9	11,6
Jersey	6,2	11,4	11,5	10,9
Nellore	7,1	10,4	11,1	12,1
Guzerá	6,6	12,4	11,8	10,1

Source: Cunha, 2019.

The students used the raw data (CUNHA, 2019) to formulate the hypotheses of the model (DBC), performed the analysis of variance, tested the hypotheses through the F test and made the unfolding through the Tukey test, once they accepted the hypothesis that there are different responses in milk production with the use of supplements, which was observed in the F test of the analysis of variance, Table 5.

Table 5. Analysis of variance for milk yield (kg).

Sources of variation	G.L	Q.M.	Fc
Treatments	3	29,187	60,06**
Blocks	4	0,0305	
Error	12	0,486	

Source: Cunha, 2019. **significant at 1% probability by the F-test.

After the F statistics, the critical values of F were searched in the tables at the level of 1% probability, obtaining: for 3.12 g.l. (1% = 5.95). Comparing the F stats with the critical values, it is concluded that the F test was significant at the level of 1% probability; hypothesis $H_{1\ \text{was accepted}}$ and it was concluded that at least two of the treatments differed from each other in relation to milk production (kg). As the treatments are qualitative and the F test was significant, the Tukey test was performed to find out where this difference was between treatments in Frame 6.

Table 6. Average of treatments and Tukey's test

Treatments	Transmolded media
Twelve-Beat	11,46 a
Araruta	11,34 a
Cassava	11,18 a
No add-on	6,50 b
DMS	1,31
D	4,20

Means followed by the same letter did not differ from each other according to Tukey's test (P>0.05); DMS significant minimal difference, Δ Tukey. Source: author's elaboration

By Tukey's test at 5% probability, it was observed that milk production increased with the supplementation of roots and tubers in the animals' diet. The three treatments with supplementation were equal to each other in increasing milk production and superior to the treatment without supplementation. The coefficient of variation statistic was also calculated, c.v. = (standard deviation/overall mean)*100. The coefficient of variation statistic was also calculated, resulting in c.v.=6.89%. This coefficient of variation of 6.89%, which is very low in agriculture, indicates a small variation in the data or great precision, when we affirm that the supplementation in the diet of the animals increased milk production.

As previously reported, the students performed the calculations using a scientific calculator, then plotted the data in Microsoft Office Excel and performed the analyses again in the SISVAR software. And also, as a form of training, they solved four more exercises.

Another very common type of design used in animal areas is the Latin square design - DQL, when there are two experimental conditions (physical or biological) heterogeneous enough to interfere with the inferences of the treatments to be tested. In this case, the blocks are arranged in two different ways, one constituting rows and the other columns.

It was proposed to the students to perform the analyses based on experiments Toledo Del Pino (2017).

In a forage cane competition experiment, Toledo Del Pino (2017), 5 varieties of forage cane arranged in a 5x5 Latin square were used. Forage cane varieties: A - CO290, B - CO294, C - CO297, D - CO299 and E - CO295.

The control was carried out by means of horizontal and vertical blocks and aimed to eliminate influences due to differences in fertility in two directions. The yields, in kg/plot, were as follows: Table 7:

Table 7. Production of 5 varieties of forage cane in kg/plot

	Columns				
Lines	1	2	3	4	5
1	432(D)	518(A)	458(B)	583(C)	331(E)
2	724(C)	478(E)	524(A)	550(B)	400(D)
3	489(E)	384(B)	556(C)	297(D)	420(A)
4	494(B)	500(D)	313(E)	486(A)	501(C)
5	515(A)	660(C)	438(D)	394(E)	318(B)

Source: Toledo del Pino, 2017.

The students formulated the hypotheses of the model, performed the analysis of variance, first in the calculator and then in the SISVAR application, and drew the conclusions.

Table 8. Analysis of variance for milk production (kg/plot).

Sources of variation	G.L	Q.M.	Fc
Treatments	4	34372,06	12,09**
Lines	4	7620,16	
Blocks	4	13910,16	
Error	12	2842,8933	

Source: Toledo del Pino, 2017. **significant at 1% probability by the F-test.

They concluded that there were differences in yield between the five varieties of forage cane test F at 1% probability Chart 8. They performed Tukey's test at 5% probability frame 9, and calculated the coefficient of variation, c.v. = 11.33%.

Table 9. Average of treatments and Tukey's test.

Forage cane varieties	Transmolded media
CO297	604,8 a
CO290	492,6 b
CO294	440,8 b
CO299	413,4 b
CO295	401,0 b
DMS	107,5
D	4,51

Means followed by the same letter did not differ from each other according to Tukey's test (P>0.05); DMS significant minimal difference. Source: author's elaboration

Conclusion: the forage sugarcane variety CO297 was the one with the highest production and the others had statistically lower production than CO297 and similar among themselves.

Next, an analysis of variance was proposed, studying linear regression with data from Ragazzi (1979).

Effect of gypsum doses on common bean (*Phaseolus vulgaris* L.) Ragazzi (1979) used a completely randomized experiment with 4 replications to study the effects of 7 gypsum doses: 0, 50, 100, 150, 200, 250 and 300 kg/ha on several characteristics of the common bean plant 10.

Table 10. Weight of 1,000 seeds, in grams.

Gypsum doses kg/ha	Repetitions			
	1	2	3	4
0	134,8	139,7	147,6	132,3
50	161,7	157,7	150,3	144,7
100	160,7	172,7	163,4	161,3
150	161,3	168,2	160,7	161,0
200	165,7	160,0	158,2	151,0
250	171,8	157,3	150,4	160,4
300	154,5	160,4	148,8	154,0

Source: Ragazzi (1979).

Analysis of variance was performed, Chart 11. Since Fc was significant, and since the treatments were quantitative, a regression study was performed using the SISVAR program.

Table 11. Analysis of variance for milk production (kg/plot).

Sources of variation	G.L.	Q.M.	Fc
Treatments	6	302,055	7,39**
Error	21	40,84	
C.V.%	4,09	Overall Average	156,09

Source: Ragazzi (1979). **significant at 1% probability by the F-test.

Chart 12 shows that the first and second degree equations were significant, at 1% probability by the F test.

Table 12. Sequential Sums of Squares - Type I.

Sources of variation	G.L.	S.Q.	Q.M.	Fc	Pr>F
b1	1	423,154375	423,154375	10,361**	0,004
b2	1	1156,25601	1156,25601	28,312**	0,000
Regression deviation	4	232,915595	58,228899	1,426	0,260
Error	21	857,650000	40,840476		

Source: author's elaboration

Observing the results, chart 13, it can be seen that there is a tendency for an increasing response to a certain extent, and then decreasing.

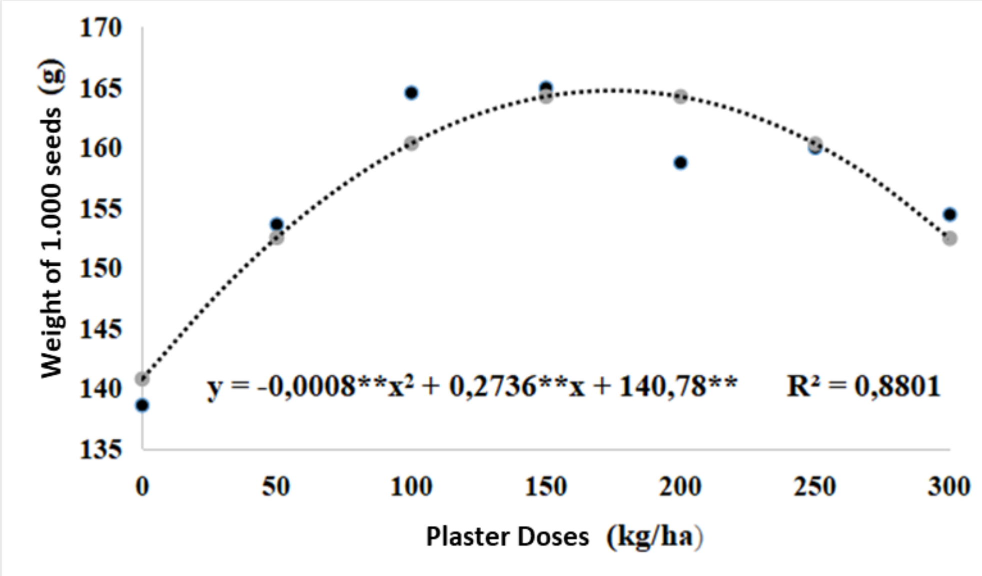
Table 13. Independent variable, observed mean and estimated means.

Values of the independent variable	Observed averages	Estimated averages
0,000	138,6000	140,9863
50,000	153,6000	152,2053
100,000	164,5250	159,7143
0,000	162,8000	163,5131
200,000	158,7250	163,6018
250,000	159,9750	159,9803
300,000	154,4250	152,6488

Source: author's elaboration

As the treatments are quantitative, the study was carried out using regression analysis as shown in figure 2.

Figure 2. Weight of 1,000 bean seeds, depending on the doses of gypsum applied to the soil.



Source: author's elaboration

Since the first derivative of equation y = -0.0008x 2+$^{0.2736x+140.78}$ is negative, the equation passes as maximum. The gypsum dose in the soil, of 171 kg/ha, was the one that produced the highest weight of 1,000 bean seeds of 164.1728 grams

4 CONCLUSIONS

The students were able to understand the difference between each of the designs: DIC, DBC and DQL, since in the resolution of each proposed exercise it was necessary to understand the type of design involved, since the form of resolution changes according to the most appropriate design. Once the exercise was solved, the students arrived at the analysis table called the analysis of variance table, in which they had to confront the hypotheses mentioned above. And depending on the accepted hypothesis, the exercise continued with the development of other calculations called Tukey's test or regression study, calculation of the standard error and calculation of the coefficient of variation; with resolution and interpretation of what each of the statistics means. We conclude that the students acquired the ability to interpret, analyze and solve the information from the data collected during the execution of the research and made them aware of the various aspects of the application of statistical methods proposed in the project.

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