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WEB SISDAM APPLICATION AND STATISTICAL MULTIVARIATE TECHNIQUES IN SELECTION OF RICE LINES (*Oryza sativa* L.) IN LOS PALACIOS

Aplicación web SISDAM y Técnicas Estadísticas Multivariadas en la selección de líneasde arroz (*Oryza sativa* L.) en Los Palacios

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ABSTRACT. With the objective of using the web SISDAM application, in combination with statistical multivariate techniques, to select rice lines with productive high potential in Los Palacios, a study was carried out where the genotypes distributed according to a Modified Augmented Design. Twelve morphoagronomic characters were evaluated during rice crop cycle. SISDAM provided a graphic guide, with a strict control of evaluated variables and its localization in the field, it also reduced the time of capture and processing of the information. The combination of tools used, facilitated the work achieving a results integral analysis and greater efficiency in the selection of 27 promissory lines, which can be included in superior studies of the Plant Breeding Program to complete its characterization.

Keys words: computer application, plant breeding, statistical methods, yield

RESUMEN. Con el objetivo de utilizar la aplicación web SISDAM, en combinación con técnicas estadísticas multivariadas, para seleccionar líneas de arroz con alto potencial productivo en Los Palacios, se llevó a cabo un estudio donde los genotipos se distribuyeron según un Diseño Aumentado Modificado. Se evaluaron 12 caracteres morfo agronómicos durante el ciclo de desarrollo del cultivo. SISDAM proporcionó una guía gráfica, con un estricto control de las variables evaluadas y su localización en el campo, además redujo el tiempo de captura y procesamiento de la información. La combinación de las herramientas empleadas, facilitó el trabajo logrando un análisis integral de los resultados y mayor eficiencia en la selección de 27 líneas promisorias, las cuales pueden ser incluidas en estudios superiores del Programa de Mejoramiento Genético para completar su caracterización.

Palabras clave: aplicaciones del ordenador, mejoramiento genético de plantas, métodos estadísticos, rendimiento

INTRODUCTION

The adoption of high-yielding cultivars helps to improve the livelihoods of rural farmers in a sustainable way (1), hence the importance of genetic improvement programs, which in rice are of great relevance as it constitutes a basic food grain for About half the population of the planet and that its global demand is increased by population growth and consumption patterns of different regions (2, 3).

The current development of research in the field of genetic improvement and the premise of economizing land and resources raises the need to value experimental designs that enable adequate efficiency with maximum economy. Modified Increased Design (DAM, according to its acronyms in English)), as an experimental field design appropriate for this stage provides a convenient way to measure environmental heterogeneity and allows adjustment of test lines through control lines. The combination of this design with Multivariate Techniques adequately analyzes the multiple relationships that are established to arrive at a more complete and realistic understanding of decision making in the selection of genotypes from the Rice Improvement Program (4).

On the other hand, today the Information and Communication Technologies act on our society, which motivates and accelerates the processes of change that radically modify the work forms and the production processes, constituting an irreplaceable element for the social advance wealth generation, the fight against poverty, hunger and the prevention of climate change.

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The SISDAM (Automated System for Data Processing according to a Modified Increased Design)[A] web application has been in operation since June 2014 in the "Los Palacios" Scientific Unit of the National Institute of Agricultural Sciences. Data obtained from experiments designed according to a DAM in research related to the genetic improvement of rice cultivation.

Considering the foregoing background, this research aimed to use the SISDAM web application, in combination with the multivariate statistical techniques of Conglomerate Analysis and Multiple Linear Regression, for the selection of rice lines with high productive potential under Los Palacios conditions.

MATERIALS AND METHODS

The work was carried out in areas of the "Los Palacios" Basic Scientific Science Unit belonging to the National Institute of Agricultural Sciences during the rainy season. The rice genotypes were planted under flooding conditions on a Hydromorphic Gley Nodular Petroferric soil.

The distribution of the materials was performed according to a DAM, which was structured by a Latin Square (3x3), with three control lines (A: INCALP-5, B: INCALP-7 and C: Selection 1) Control plots for each control line and 66 test lines, including INCA LP-5, INCA LP-7, selection 1 and 63 promising materials resulting from the rice breeding program, randomly distributed in the corresponding subplots.

The sowing was carried out directly to trickle in plots of 2 m^2 and the cultural attention of fertilization, irrigation and phytosanitary treatments were carried out according to the indications established in the Technical Instructions for the Cultivation of Rice[B].

The following quantitative traits were evaluated during the crop development cycle:

- Cycle at 50 % flowering, C (days).
- Final height of the plants, A (cm).
- Flag Leaf Length, LHB (cm).
- Flag Leaf Width, AHB (cm).
- Grain width, AG (mm).
- Panicle length, LP (cm).
- Panicle per m2, Pm^2.
- Grains filled by panicle, Gll.
- Panicle grains, Gv.
- Mass of 1000 grains, Mg (g).
- Agricultural yield, Y (t ha^{-1}).
- Number of tillers, NH.

The methodologies of the Standard Evaluation System and the Varietal Description Form for rice cultivation were used in the evaluations carried out.

The panicles per square meter were sampled once per plot in an area of 0,25 m^2 and panicles filled and vain by the 1000 grains mass were determined in 20 central panicles taken at random, and the agricultural yield was calculated in 1 m^2. The other observations were made in 10 plants selected at random in each plot.

The data obtained for each evaluated variable were adjusted by the row-column method, according to the DAM used.

The adjusted data matrix (66 genotypes x 12 variables) was processed using the multivariate cluster analysis technique (using squared Euclidean distance), Pearson correlations and a multiple regression, to evaluate the magnitude and direction of the relationship Performance (dependent variable) with the remaining variables, using the Minitab version 15.0 statistical package in all cases.

RESULTS AND DISCUSSION

The numbers representing the 20 lines with the best behavior for each variable are shown in Table I, where a ranking is shown according to the adjustment by variables of the values observed for each of the test lines, performed by the row method -column according to a modified augmented design.

Cycle characters, plant height and vain grains are sorted from lowest to highest and the remainder from highest to lowest. This upward ordering of these three characters is based on the fact that, in the case of the cycle, the development of early germplasm has among its advantages a better use of the sowing schedule, the use of less fertilizers and the lower consumption of water[C]; likewise, a lower height can undoubtedly improve the resistance to bedding and considerably reduce the yield losses associated with this character (5). In the same way, the number of vain grains per panicle has a negative effect on rice yield and it is a consequence of multiple causes. In the case of semi-dwarf Indian cultivars, up to 15 % of emptiness[D].

[A] Cámara, F. A. *Sistema automatizado para el procesamiento y control de información en la aplicación del Diseño Aumentado Modificado en la Unidad Científica Tecnológica de Base «Los Palacios»*. Tesis de Diploma, Universidad de Pinar del Río, 2014, Pinar del Río, Cuba, 81 p.

[B] MINAG. *Instructivo Técnico del Arroz*. Inst. Instituto de Investigaciones del Arroz, 2008, La Habana, Cuba, p. 113.

[C] Pérez, N. *Obtención de cultivares de arroz (Oryza sativa L.) resistentes a Pyricularia grisea Sacc. con buen comportamiento agronómico*. Tesis de Doctorado, Instituto Nacional de Ciencias Agrícolas, 2012, Mayabeque, Cuba, 118 p.

[D] Castro, R. *Determinación y solución de las causas que provocan el vaneamiento de los granos de arroz*. Informe final de proyecto territorial de investigación-desarrollo 2000-2003, Inst. Instituto Nacional de Ciencias Agrícolas, 2003, La Habana, Cuba.

Table I. Ranking of the 20 best test lines for the characters evaluated according to the DAM using the row-column adjustment method

Ranking	C	A	LHB	AHB	AG	LP	Pm^2	Gll	Gv	Mg	R	NH
1	34	65	63	36	65	44	26	2	33	35	52	48
2	65	60	7	65	1	56	52	3	21	48	23	41
3	62	12	41	55	7	4	3	62	19	63	4	4
4	35	5	53	27	63	63	23	52	65	23	21	7
5	61	10	62	13	59	43	35	23	15	44	62	8
6	5	14	1	12	24	41	48	35	57	20	17	17
7	39	51	52	1	50	20	32	63	54	62	35	28
8	40	66	22	35	61	36	50	50	56	36	3	29
9	44	58	61	16	57	30	21	51	51	1	5	49
10	45	11	58	52	3	45	4	46	43	3	8	43
11	47	44	51	50	53	57	51	8	2	8	24	45
12	48	40	64	6	30	32	57	5	3	17	51	21
13	19	34	24	57	2	5	5	21	38	24	1	5
14	42	15	3	23	66	64	11	36	30	11	46	34
15	43	38	4	53	62	50	8	17	44	45	26	33
16	59	27	30	4	41	42	46	26	20	52	50	47
17	7	33	8	20	46	61	24	1	18	4	63	22
18	11	57	20	56	22	35	1	4	8	21	57	23
19	13	18	54	62	29	24	17	44	63	5	20	27
20	18	36	44	54	27	26	62	24	39	51	11	31

The web application used (SISDAM), provided a graphical guide (Figure 1), which did not exist until this moment. In it, the investigator can carry out the location of the genotypes as appropriate (controls, subcontrollers and test lines) for their localization in the field and execute the experiment sowing from an DAM, with a strict control of the variables already evaluated that users can establish a valid range of values for each of them, making data capture more efficient, a process that was done manually.

In addition, the outputs are displayed to users in two different formats, as the application is on a Web platform, reports are displayed in HTML within the application itself and in addition they are allowed to export to Microsoft Excel and in each case are presented, for each of the test lines, their original values and those adjusted by the model. In this way the resulting information can be processed in any other statistical package.

Once the basic problems are known, the specific objectives of the genetic improvement can be established and in this sense this ranking constitutes a useful tool for the plant breeder, that is, according to the needs and requirements of the research, to select those that could be of greater interest. This methodology allows comparing a considerable number of test lines, overcoming the limitations of an unreplicated experiment, which presupposes an economic benefit due to the reduction of area, saving of experimental material and control of environmental heterogeneity (4).

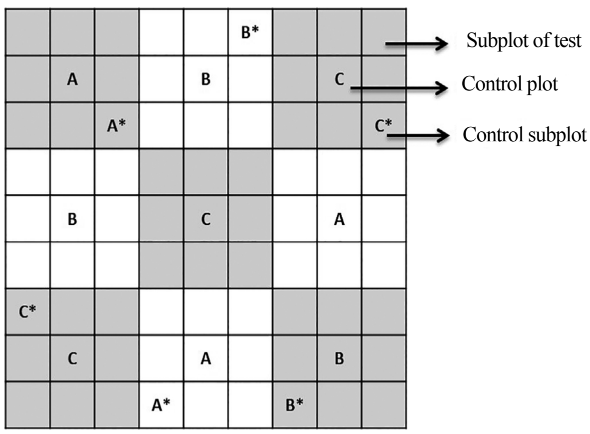

Figure 1. Layout of the Modified Augmented Design for the 3x3 Latino Square

To carry out an integral study we used the multivariate analysis of Conglomerates with the matrix of data adjusted previously by the DAM. Table II shows the phenotypic correlations (Pearson's correlations) among the analyzed variables.

The components were strongly and positively correlated (panicle per square meter, full grains per panicle and mass of 1000 grains). Similar results have been obtained by other authors (6, 7). In addition, the performance had the same behavior with panicle length, height and cycle.

Strong and positive, it is also the correlation between the length of the panicle with the full grains, the mass of 1000 grains, the length of the flag leaf and the height of the plant. The same relationship between panicle length and grain mass has been reported in other studies (8). There was also a coincidence of strong and positive correlations between panicle length and plant height, when correlation and cluster analysis were performed to evaluate the performance and traits related to it in rice genotypes (9).

A significant and direct relationship showed the cycle with full grains per panicle and panicles per square meter.

The number of tillers, width of the flag leaf and the grain were not correlated with any other character. In a research on the characterization of isogenic lines resistant to Pyriculariosis, neither was the width of the flag leaf correlated with any other character[C], although other authors have reported correlations of this variable with performance (10).

It is considered that the two important characters related to the panicle are the number of full grains per panicle and their weight, because there are genotypes with long panicles, but with few grains (11). Several authors affirm that the mass of 1000 grains belongs to the variety, although they emphasize some intracultivar variability and indicate that an increase in the yield can be achieved selecting materials of greater weight in the grain[E].

The Cluster Analysis allowed the classification of the genotypes, grouping in a same class those with similar characteristics, taking advantage of the working possibility with the best groups by variables, achieving a more efficient selection.

[E] Quintero, C. E. *Factores limitantes para el crecimiento y productividad del arroz en Entre Ríos, Argentina*. Tesis de Doctorado, Universidad de la Coruña, 2009, 167 p.

Table II. Matrix of phenotypic correlations

	C	A	LHB	AHB	AG	LP	Pm²	Gll	Gv	Mg	R
A	0,242 0,050										
LHB	0,113 0,366	0,301 0,014									
AHB	0,176 0,158	-0,059 0,637	0,026 0,833								
AG	0,087 0,487	0,075 0,551	0,429 0,000	0,139 0,266							
LP	-0,053 0,671	0,339 0,005	0,371 0,002	-0,004 0,976	0,066 0,599						
Pm²	0,359 0,003	0,303 0,013	-0,069 0,582	-0,165 0,186	-0,008 0,948	-0,065 0,607					
Gll	0,481 0,000	0,253 0,040	0,273 0,026	0,131 0,294	0,171 0,170	0,338 0,006	-0,122 0,331				
Gv	0,067 0,592	0,129 0,301	0,028 0,824	-0,056 0,655	-0,017 0,893	0,036 0,774	0,348 0,004	-0,269 0,029			
Mg	0,136 0,277	0,244 0,048	0,146 0,241	-0,059 0,636	-0,070 0,575	0,470 0,000	0,028 0,825	0,174 0,162	0,113 0,365		
R	0,701 0,000	0,384 0,001	0,212 0,088	0,081 0,516	0,135 0,281	0,380 0,002	0,324 0,008	0,765 0,000	-0,020 0,874	0,492 0,000	
NH	0,126 0,314	0,319 0,009	-0,012 0,923	-0,132 0,292	-0,018 0,885	0,299 0,041	0,043 0,734	0,146 0,243	0,091 0,468	0,122 0,150	0,232 0,070

Cell content: Pearson correlation, P-value

The corresponding dendrogram is observed in Figure 2, in which 10 classes were formed. The means by variables and the lines corresponding to each class are shown in Table III.

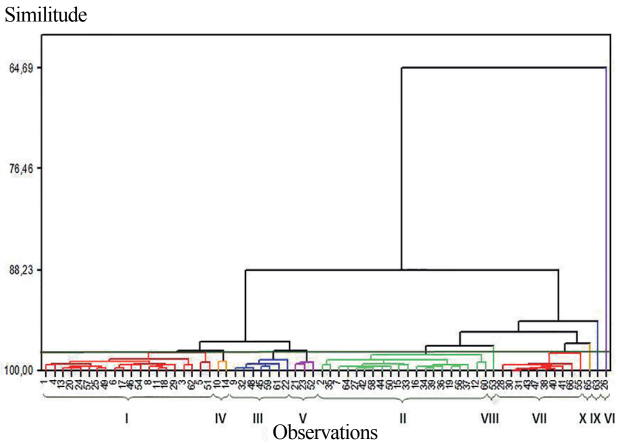

Figure 2. Dendrogram obtained according to the Conglomerate Analysis

Class V, composed of lines 23 and 52 and the INCA LP-7, proved to have the highest yields, probably influenced by the high values of its components (mass of 1000 grains, full grains per panicle and panicles per square meter), in addition to presenting the highest number of fertile children, the longest cycle and the highest height.

Also, the types VI, IX and I that grouped 22 test lines, which included the control cultivars INCA LP-5 and Selection 1, were followed with good behavior for the performance and its components.

The Breeding Program in Cuba has allowed the obtaining of an important group of cultivars with high yield potential that have benefited the country's germplasm; Notwithstanding the progress made, we must continue to work in this direction to further enrich it with superior cultivars that have different genetic sources and capable of adapting to the heterogeneous cultivation conditions. The performance values in these lines are similar to those obtained in more recent cycles in Venezuela, which are considered high in relation to the average records of other Latin American countries such as Panama and Bolivia (12).

Table III. Distribution of genotypes in herds and means by classes, according to the Conglomerate Analysis

Classes	C	A	LH	AH	AG	LP	Pm^2	Gll	Gv	Mg	R	NH	Effectives
I	121,7	96,0	33,0	1,02	1,88	22,3	327,9	83,6	18,5	28,2	5,91	10,1	20
II	117,6	92,5	31,4	1,04	1,76	23,0	275,2	86,3	15,4	28,0	5,41	9,8	20
III	114,4	102,1	33,7	0,94	2,02	22,4	368,0	68,4	24,9	27,3	4,92	10,0	7
IV	119,5	78,1	24,5	0,88	1,34	19,6	314,0	56,0	30,0	26,5	3,95	9,0	2
V	130,3	109,0	32,6	1,05	1,88	22,4	376,7	99,0	15,0	30,0	7,45	10,4	3
VI	123,0	105,8	27,2	0,92	1,66	23,5	344,0	85,0	21,0	27,0	6,50	8,1	1
VII	114,4	94,3	33,0	0,98	1,83	23,6	221,8	86,8	15,0	28,6	5,21	10,3	10
VIII	121,0	101,6	41,4	1,06	2,28	23,4	250,0	60,0	32,0	26,0	4,00	10,2	1
IX	120,0	102,1	87,7	1,00	2,74	25,5	250,0	100,0	13,0	31,0	6,18	8,7	1
X	111,0	64,1	23,3	1,46	3,00	13,1	220,0	64,0	27,0	16,0	2,21	6,0	1

Classes	Lines
I	1, 3, 4, 5 (INCA LP-5), 6, 8, 11, 13, 17, 18, 20, 24, 25, 29, 46 (Selection 1), 49, 51, 54, 57, 62
II	2, 7, 12, 15, 16, 19, 27, 33, 34, 35, 36, 37, 39, 42, 44, 50, 56, 58, 60, 64
III	9, 22, 32, 45, 48, 59, 61
IV	10, 14
V	21 (INCA LP-7), 23, 52
VI	26
VII	28, 30, 31, 38, 40, 41, 43, 47, 55, 66
VIII	53
IX	63
X	65

In addition, in this case it is important to note that the test was performed in the rainy season where lower yields are obtained compared to the low rainy season. Therefore, some authors emphasize the relevance of studies related to the evaluation of cultivars and sowing times (13).

The worst yields were characteristic of the ten lines that integrated classes X, IV and VIII, which also presented the lowest values for the full grain characters per panicle, 1000 grain mass and panicle length, and were the most of vain grains per panicle.

Table IV shows the 20 lines that were selected by the DAM and the 25 included in the three classes of analysis of clusters with higher average values of yield. Lines 35 and 50 in the DAM do not appear among those selected by the cluster analysis and lines 6, 13, 18, 25, 29, 49 and 54 are among the classes of the cluster that were not selected by the row adjustment Column in the DAM. In this way, the 27 best-performing lines (1, 3, 4, 6, 8, 11, 13, 17, 18, 20) were selected from a comprehensive analysis, combining DAM results and cluster analysis, (23, 24, 25, 26, 29, 35, 49, 50, 51, 52, 54, 57, 62, 63) including INCA LP-5, INCA LP-7 and Selection 1 commercial cultivars that were used as control.

Table IV. Test lines selected by the DAM and the Conglomerate Analysis for yield character

Modified Augmented Design	1, 3, 4, INCA LP-5, 8, 11, 17, 20, INCA LP-7, 23, 24, 26, 35, Selection 1, 50, 51, 52, 57, 62, 63
Cluster Analysis	1, 3, 4,INCA LP-5, 6, 8, 11,13, 17, 18, 20, INCA LP-7, 23,24, 25, 26, 29, Selection 1, 49, 51, 52, 54, 57, 62, 63

Table V shows the results of multiple linear regression analysis, where yield is the dependent variable and cycle, plant height, panicle-filled grains, panicle length, 1000-grain mass, and the number of panicles per square meter were the independent variables, because they were the ones that showed the highest correlation with the dependent character.

The prediction equation of the model is:

$$R = -9{,}94 + 0{,}0478\,C - 0{,}00272\,A + 0{,}0317\,LP + 0{,}00603\,Pm^2 + 0{,}0491\,Gll + 0{,}122\,Mg.$$

Table V. Results of the Multiple Linear Regression Analysis where the performance is the dependent variable

Parameter	Estimation	Standard error	Statistic T		P-Value
Constant	-9,9354	0,9539	-10,42		0,000
C	0,047817	0, 008965	5,33		0,000
A	-0,002721	0,004320	-0,63		0,531
LP	0,03170	0,02079	1,52		0,133
Pm^2	0,0060317	0,0008949	6,74		0,000
Gll	0,049130	0,004164	11,80		0,000
Mg	0,12199	0,01666	7,32		0,000
		Analysis of variance			
Source	Sum of squares	GL	Mean square	F	P-Value
Model	66,574	6	11,096	111,96	0,0000
Residue	5,847	59	0,099		
Total	72,421	65			
R^2	91,9 %				

The model proposed by the multiple linear regression analysis allows, through the estimated coefficients, to express the expected change in the dependent variable yield for each unit of change of the independent variables studied. Since the p-value in the analysis of variance is less than 0,01; there is a statistically significant relationship between the variables for a confidence level of 99 %. The variable height of the plant presents a p-value of 0,531, the highest in the independent variables, being thus the one that less information contributes to the model.

The R_2 statistic indicates that the model accounts for 91,9 % of the variability in yield, determining that the linear combination of independent variables for studies under similar conditions is an optimal predictor of yield. In different investigations other authors have used this analysis with good results (14, 15).

CONCLUSIONS

- In general, the web application facilitates the efficient use of the Modified Increased Design contributing to the development of the Genetic Improvement Programs of cultivars in the country, which until now had a tool for data processing of this design. SISDAM enhances the advantages offered by DAM in comparing a considerable number of test lines, overcoming the limitations of an unreplicated experiment, providing an economic benefit due to area reduction, saving of experimental material and control of Environmental heterogeneity.

- Although the selection, according to a DAM, is performed for each variable independently, the combination of the SISDAM application and the statistical techniques employed facilitates the work of plant breeders, since a comprehensive analysis of the results and greater efficiency is achieved Selection of promising lines, which can be included in higher studies of the Genetic Improvement Program to complete their characterization.

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