ISSN impreso: 0258-5936
ISSN digital: 1819-4087

Ministerio de Educación Superior. Cuba
Instituto Nacional de Ciencias Agrícolas
http://ediciones.inca.edu.cu

EVALUATION OF DIFFERENT INDICES TOLERANCE TO DROUGHT BASED ON MULTIVARIATE ANALYSIS

Evaluación de diferentes índices de tolerancia a la sequía basado en análisis multivariados

Tony Boicet Fabre✉, Michel Baldaquín Hernández, Ana D. Boudet Antomarchi, Yanitza Merino Hernández, Alejandro Alarcón Zayas and Wilmer Almarales Frías

ABSTRACT. Under two different irrigation conditions, yield of ten Cubans cultivars of bean (*Phaseolus vulgaris* L.), were evaluated with the objective of evaluating different drought tolerance indices based on multivariate analysis in such a way that contribute to the interpretation of its effectiveness to discriminate tolerance variety to drought. The experimental design was completely randomized and four replications, grain yield under drought and irrigated conditions was evaluated and used to calculate stress *indices:* tolerance indice (TOL), stress susceptibility indice (SSI), geometric mean production (MPG), mean production (MP), stress tolerance indice (STI), drought resistance indice (DI), relative drought indice (RDI), sensitivity drought indice (SDI) and abiotic tolerance indice (ATI), principal component, cluster, correlation and descriptive analysis between grain yield in both conditions were calculated. In this study softly demonstrated that each indice contribute to identify variety with drought tolerance, and multivariate analysis contribute to interpreter of indices effectiveness, and it is advisable to combine the multivariate analysis and use several indices, due to difference in occasion of the results obtained in the discrimination of variety to drought.

Key words: cultivars, bean, *Phaseolus vulgaris* L., grain yield, drought response

RESUMEN. Con el objetivo de evaluar diferentes índices de tolerancia a la sequía mediante análisis multivariado para contribuir a la interpretación de la efectividad de estos índices en discriminar variedades tolerantes a la sequía, se evaluó el rendimiento de diez cultivares cubanos de frijol (*Phaseolus vulgaris* L.), bajo dos regímenes de riego. El experimento se condujo bajo un diseño de bloques completos al azar con cuatro repeticiones, y en la cosecha, los rendimientos de ambos tratamientos de riego se utilizaron para el cálculo de los índices de estrés: índice de tolerancia (TOL), índice de susceptibilidad a la sequía (SSI), productividad geométrica media (MPG), productividad media (MP), índice de tolerancia a la sequía (STI), índice de resistencia a la sequía (DI), índice relativo de sequía (RDI), índice de sensibilidad a la sequía (SDI), e índice de tolerancia abiótica (ATI), a los que se le realizaron análisis de componentes principales, de clúster, correlación y descriptivos. Se demostró que cada índice contribuye a identificar variedades tolerantes a la sequía, y el análisis multivariado aplicado a los mismos, contribuye a la interpretación de su efectividad, pero es recomendable, por las diferencias observadas en ocasiones en los resultados obtenidos en la discriminación de las variedades con los índices utilizados, combinar los análisis estadísticos multivariados, además de utilizar en el estudio, varios de estos índices de tolerancia.

Palabras clave: cultivares, frijol, *Phaseolus vulgaris,* rendimiento, respuestas a sequía

INTRODUCTION

Knowing the responses of plants to drought, besides being important, it is fundamental to understanding their tolerance to this phenomenon (1); hence, the selection of drought-tolerant crops is one of the main tasks for plant breeders (2). Occasionally,

Universidad de Granma. Carretera a Manzanillo Km 17 $^{1}/_{2}$ Bayamo, Granma. Código postal 85 100
✉ tboicetf@udg.co.cu

since there are no auxiliary criteria for the evaluation and selection of drought tolerant cultivars in field conditions, the use of selection indexes is used (3).

Several of these indices have been proposed, based on mathematical relationships based on differences in performance under stressful and non-stressful conditions (4), and they are used in many studies to select genotypes according to their results in contrasting humidity environments (1, 5).

To evaluate these indices and obtain greater effectiveness in the selection of drought-tolerant genotypes, different statistical procedures are used (6), mainly multivariate, such as principal component analysis (4,7-10), correlation analysis of the indices used with the performance obtained in stressful and non-stressful conditions (11,12), cluster analysis (13,14), and also descriptive statistics (11), by means of the ranking method (13,15).

This work was carried out with the objective of evaluating different indices of tolerance to drought by means of multivariate analysis, to contribute to the interpretation of these indices effectiveness in discriminating varieties tolerant to drought.

MATERIALS AND METHODS

In order to reach the proposed objective, the results of a field experiment conducted to evaluate the response of ten bean cultivars (*Phaseolus vulgaris* L.) (Table 1) to two soil moisture conditions during the 2012/2013 campaign were analyzed in Rio Cauto town, in Granma province on a Fluvisol soil that is not very differentiated, according to the Soil Classification of Cuba (16).

Table 1. Cultivars used

No	Cultivars	Origin country	Grain color
1	Velasco Largo	Cuba	Rojo
2	CC 25-9R	Cuba	Rojo
3	Delicias 364	Cuba	Rojo
4	P-219	Cuba	Rojo
5	CC 25-9N	Cuba	Negro
6	Holguín-519	Cuba	Negro
7	Pilón	Cuba	Blanco
8	Bonita 11	Cuba	Blanco
9	P 127	Cuba	Crema
10	P3047	Cuba	Crema

The experimental design was randomized complete blocks with four repetitions, and two irrigation treatments. In one of the treatments the irrigations were applied considering the water requirements of the bean crop (*Phaseolus vulgaris* L.) (Treatment without water deficit) (17), and in the other the irrigations were applied only until the pre-flowering (terminal drought treatment). The delivery of water to the plants was carried out using the sprinkler irrigation technique.

Each experimental plot was composed of four rows of four meters long each, with a distance between plants of 0,70 x 0,15 m. In each plot, the yields of both treatments were obtained from the two central furrows in one meter in length.

To evaluate drought tolerance, the following indices were used (according to its acronym in English):

Tolerance index $TOL = Rr - Rs$ (18)

Susceptibility index to drought $SSI = 1 - (Rs/Rr)/1 - (\overline{Rs} - \overline{Rr})$ (19)

Geometric average productivity $MPG = \sqrt{Rs * Rr}$ (3)

Average productivity $MP = (Rs + Rr)/2$ (19)

Drought tolerance index $STI = Rs * Rr/\overline{Rr}^2$ (3)

Drought resistance index $DI = Rs * [(Rs/Rr)/\overline{Rs}]$ (3)

Relative Drought Index $RDI = (Rs/Rr)/(\overline{Rs}/\overline{Rr})$ (19)

Drought sensitivity index $SDI = Rr - Rs/Rr$ (1)

Abiotic tolerance index $ATI = [(Rr - Rs)/(\overline{Rr}/\overline{Rs}))] * \left(\sqrt{\overline{Rr} * \overline{Rs}}\right)$ (5)

In the above formulas Rr, Rs, $\overline{(Rr)}$ and $\overline{(Rs)}$ represent the yield under irrigation and drought conditions for each cultivar and the average yield in irrigation and drought for all cultivars respectively.

Statistical analysis

With the results obtained, the following statistical analyzes were carried out: for the evaluated indices and the yield in both moisture conditions of all the cultivars, a correlation analysis using Pearson's simple correlation coefficient, using the statistical package SPSS version 22.0, as well as an analysis of the main components using the statistical package STATGRAHICS centurion XV, also a cluster analysis using the square of Euclidean distances and Ward's minimum variance method, with the statistical package STATISTICA version 10.0.

The ranking method was also used, calculated by the following relationship:

$$RS = (R) + (SDR) \quad (20)$$

where:
RS is the sum of the rank or order of all the indices in each cultivar.

R is the rank or average order of all the indices of a cultivar, obtained from the order of each index through equal indices of all cultivars.

SDR is the standard deviation of ranges or order of the indices and calculated according to the formula:

$$SDR = \sqrt{Si^2} = \frac{\sum_{i=1}^{m}(Rij - \overline{Ri})^2}{n-1}$$

Where Rij is the rank or order of the indices and it is the average of the ranges or order of all the indices for the cultivar.

The ranges or order were assigned to each cultivar for each tolerance index. A cultivar with higher values of each of the criteria Rr, Rs, STI, MPG, MP, YSI, RDI and DI, received a rank or order of 1, while the cultivars with lower values of each of the SSI, TOL, SDI and ATI indices, received a rank or order of 1.

RESULTS AND DISCUSSION

In the analysis of the results of all the calculated indices, it was observed that each of these indices characterized the cultivars studied in a different way. According to these results, MPG, MP and STI identified the cultivars Velasco largo, CC 25-N and Holguín 519 as the most tolerant, and the cultivars Pilón, Bonita 11 and P1127, the least tolerant (Table 2).

Based on the SSI, TOL, SDI and ATI indices, the most tolerant cultivars were Holguín 519, Pilón and P-219, and the least tolerant CC 25-9R, Bonita 11 and P1127.

For the RDI index, the most tolerant ones were, Holguín 519, Pilón and CC 25-9N; and CC 25 -9R with Bonita 11 and P1127 the most susceptible. The DI index characterized as more tolerant the cultivars Holguin 519, Velasco long and CC 25-9N, and the most susceptible to CC 25 -9R, Bonita 11 and P1127. The results of this analysis indicate that the indices differ in the discrimination of the cultivars in their tolerance to drought, therefore identifying drought tolerant cultivars based on a single index as a criterion is not advisable (7,10), and it could not be effective

Correlation analysis

To determine the most effective indices in the selection of the cultivars in different conditions of humidity, the analysis of correlation between the yields under the two conditions of humidity with all the indices, is useful and can be calculated (4).

In this experiment it was observed that there were positive and significant correlations between the performance under irrigation with the MGP, MP, STI, DI, and ATI indices, and the drought yield with MPG, MP, STI, RDI and DI, revealing that these, according to the analysis, they were the most appropriate indices to select cultivars in the humidity conditions of the study (Table 3).

The correlation analysis is very useful to find the total degree of association between all the characteristics studied, so, together with the different results obtained, sometimes, between the indexes used in discriminating crops with respect to their tolerance to drought (Table 2), it is convenient to carry out an analysis of this type between the yield and the different indices, in both humidity conditions (11, 21).

Table 2. Average yield (t ha^{-1}) in both soil moisture conditions and the different tolerance rates used

Cultivars	Rr	Rs	MPG	MP	STI	SSI	TOL	SDI	RDI	DI	ATI
Velasco Largo	2,22	1,75	1,97	1,99	1,31	0,93	0,47	0,21	1,02	1,04	0,72
CC 25-9R	1,86	1,39	1,61	1,63	0,87	1,11	0,47	0,25	0,97	0,78	0,58
Delicias 364	1,67	1,27	1,46	1,47	0,71	1,05	0,40	0,24	0,99	0,73	0,45
P-219	1,55	1,27	1,40	1,41	0,66	0,79	0,28	0,18	1,06	0,78	0,30
CC 25-9N	1,81	1,44	1,61	1,63	0,88	0,90	0,37	0,20	1,03	0,86	0,46
Holguín-519	1,83	1,66	1,74	1,75	1,02	0,41	0,17	0,09	1,17	1,13	0,23
Pilón	1,57	1,34	1,45	1,46	0,71	0,64	0,23	0,15	1,10	0,86	0,26
Bonita 11	1,53	1,01	1,24	1,27	0,52	1,49	0,52	0,34	0,86	0,50	0,50
P 1127	1,56	0,95	1,22	1,26	0,50	1,72	0,61	0,39	0,79	0,43	0,57
P3047	1,65	1,24	1,43	1,45	0,69	1,09	0,41	0,25	0,97	0,70	0,45
Average	1,73	1,33									

Rr= Yield with irrigation (t ha^{-1}); Rs= Yield in drought (t ha^{-1}); MPG= geometric average productivity; PM= Average productivity; ITS= Drought tolerance index; ISS= Index of susceptibility to drought; Tol= Tolerance; SDI= Index of sensitivity to drought; RDI= relative index of drought; DI= drought resistance index; ATI= Abiotic tolerance index

Table 3. Correlation coefficients between yield and drought tolerance indices

	Rr	Rs	MPG	MP	STI	SSI	TOL	SDI	RDI	DI	ATI
Rr	1										
Rs	0,863**	1									
MGP	0,950**	0,978**	1								
MP	0,962**	0,968**	0,999**	1							
STI	0,959**	0,966**	0,997**	0,998**	1						
SSI	-0,271	-0,720*	-0,559	-0,524	-0,524	1					
TOL	0,121	-0,398	-0,196	-0,155	-0,157	0,920**	1				
SDI	-0,237	-0,694*	-0,529	-0,493	-0,494	0,999**	0,932**	1			
RDI	0,266	0,716*	0,554	0,519	0,519	-1,000**	-0,922**	-0,999**	1		
DI	0,708*	0,967**	0,892**	0,873**	0,873**	0-,865**	-0,614	-0,846**	0,863**	1	
ATI	0,602	0,124	0,329	0,367	0,366	0,576	0,848**	0,601	-0,581	-,131	1

Rr= Yield with irrigation (t ha^{-1}); Rs= Yield in drought (t ha^{-1}); MPG= geometric average productivity; PM= Average productivity; ITS=Drought tolerance index; ISS= Index of susceptibility to drought; Tol= Tolerance; SDI= Index of sensitivity to drought; RDI= relative index of drought; DI= drought resistance index; ATI= Abiotic tolerance index.
** The correlation is significant at the 0,01 level. * The correlation is significant at the 0,05 level

In summary, the analysis of correlation between yield and tolerance indices can be a good criterion to discriminate the best cultivars, as well as the most appropriate indices for a given environment (6,13).

To determine the most effective indices in the selection of the cultivars in the different conditions of humidity, the analysis of correlation between the yields under the two conditions of humidity with all the indices, is useful and can be calculated (4).

Analysis of principal components

This analysis turns out to be a statistical technique of information synthesis or reduction of the dimension. Its purpose in this study is to obtain a smaller number of linear combinations of the 11 variables studied, which better explain the variability of the data.

The analysis of the main components of the tolerance indices used (Table 4) showed that most of the variability was associated with the first two components. These contributed together 99,64 % of the total variance of the trial, that is, 11 indices were reduced to two components. Through its combination, the ideal cultivar can be selected for environments with and without drought (22).

The variables that contributed the greatest positive variation to the main component 1 were Rr, Rs, MPG, MP, STI, RDI and DI. This component was related to potential yield and tolerance to drought. In component 2 the most effective indices were Rr, TOL and ATI, so it was associated with yield under stress and tolerance to drought.

A bidimensional representation (biplot) of the tolerance indices and the spatial distribution of the lines in the first two components is shown in Figure 1. This allows a better interpretation of the results explained above, since all the attributes are simultaneously compared.

Table 4. Main components of tolerance indices used

Tolerance index	Components	
	1	2
Rr	0,25	0,39
Rs	0,35	0,12
MPG	0,32	0,24
MP	0,31	0,25
STI	0,31	0,26
SSI	-0,32	0,25
TOL	-0,25	0,39
SDI	-0,32	0,24
RDI	0,32	-0,24
DI	0,35	-0,01
ATI	-0,08	0,53
Proper values	7,73	3,23
Contribution of total variation	70,27	29,38
% accumulated	70,27	99,66

In Figure 1, it is observed that the DI, Rs, MPG, MP, STI and Rs indices were positively associated, also positive association existed between the SSI SDI and TOL indices, evidenced by the angle between them. In relation to the cultivars, according to this analysis, they turned out to be the cultivars Holguín 519, CC 25-9N the most tolerant. According to research carried out (23), those genotypes with high PC1 and low PC2 are the most recommended to be used under stress conditions.

Cluster analysis

This analysis is a multivariate technique that seeks to group elements (or variables) trying to achieve maximum homogeneity in each group formed, and the greatest differences between these groups. This

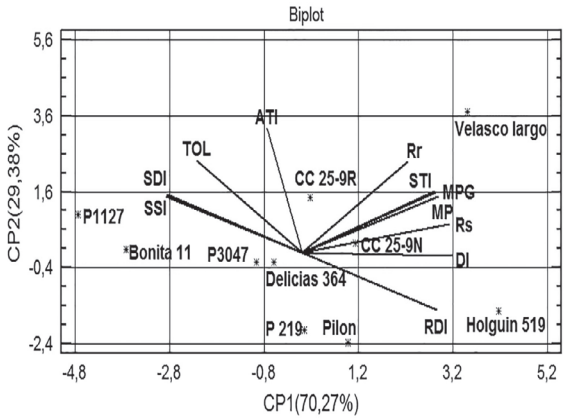

Figure 1. Biplot of the first and second component for drought tolerance indices

makes it suitable to classify the cultivars under study, according to their tolerance to drought, according to Fernandez's classification (4).

In Figure 2, based on the indices of tolerance to drought, in both moisture conditions (with and without stress) and yield, three groups were formed with 2, 6 and 2 cultivars respectively. The first group united the cultivars with the highest yields under both conditions, and tolerances such as MPG, MP, STI and DI. These cultivars were the most tolerant.

The cultivars of the second group had relatively lower yields in the stress condition and they were considered tolerant. The third group included those cultivars with the lowest values in yield in both humidity conditions, as well as low values in MPG, MP, STI and DI, for this reason they were the least tolerant. Cluster analysis is widely used in most studies to classify genotypes of different crops in relation to their response to drought.

Ranking method

This method is used by many researchers to have a broader criterion and determine the most drought tolerant cultivars, according to the average range, sum of the range and the standard deviation of all the indices

In this analysis are more tolerant cultivars with low values of standard deviation and lower average range, that is, lower value of the sum of ranges (Table 5).

According to this method of analysis of crop responses to drought, Holguin-519 and CC 25-9N were the most tolerant cultivars; Different responses according to this analysis, gave the cultivars Bonita 11 and P1127, which were identified as the most susceptible to drought. This method has been used by other researchers for similar analysis (10,13,14), although with other crops.

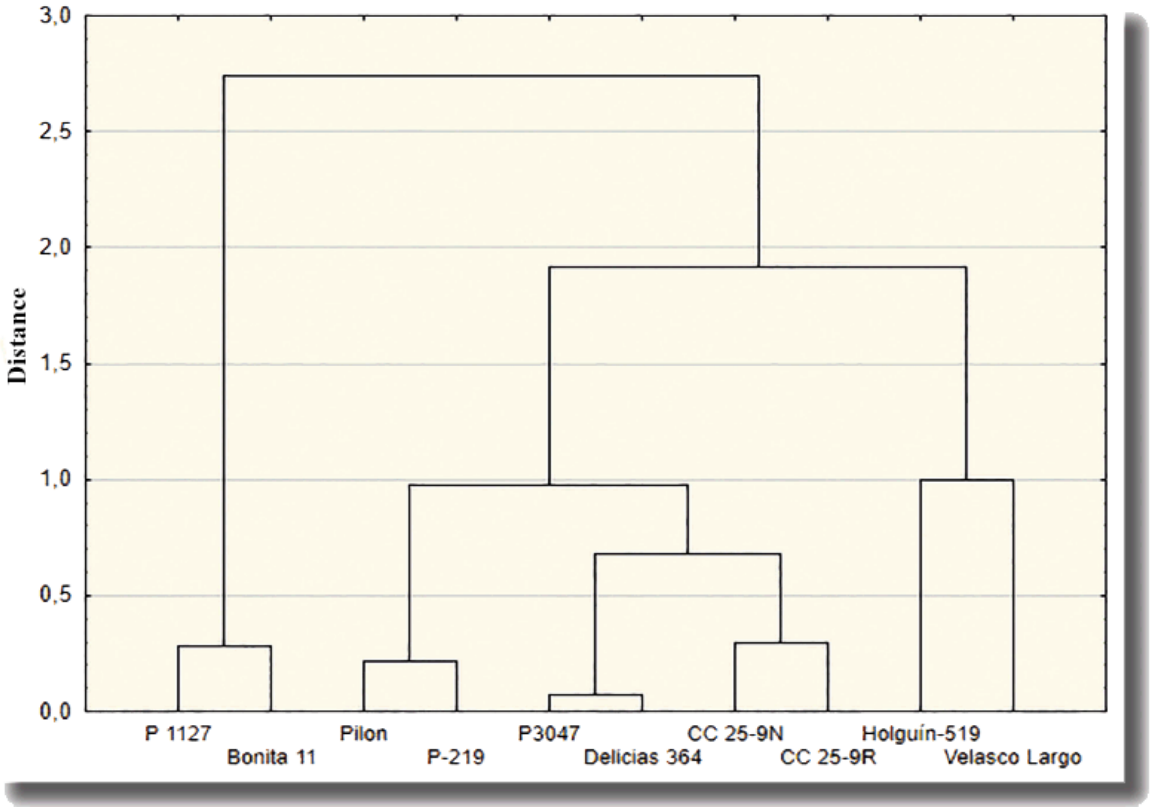

Figure 2. Dendogram applying Ward's method in the classification of cultivars based on tolerance indices

Table 5. Average range, standard deviation and sum of ranges of tolerance indices

Cultivars	Rr	Rs	MPG	MP	STI	SSI	TOL	SDI	RDI	DI	ATI	SDR	R	RS
Velasco Largo	1	1	1	1	1	5	8	5	5	2	10	3,6	3,2	6,8
CC 25-9R	2	4	4	3,5	4	8	7	8	8	5,5	9	5,7	2,3	8,0
Delicias 364	5	6,5	5	4	5	6	5	6	6	6	4	5,3	0,8	6,2
P-219	9	6,5	7	6	8	3	3	3	3	5,5	3	5,2	2,3	7,5
CC 25-9N	4	3	3	3,5	3	4	4	4	4	3	6	3,8	0,9	4,6
Holguín-519	3	2	2	2	2	1	1	1	1	1	1	1,5	0,7	2,2
Pilón	7	5	9	9	6	2	2	2	2	4	2	4,5	2,8	7,4
Bonita 11	10	8	8	7	9	9	9	9	8	8	7	8,4	0,9	9,3
P 1127	8	9	10	8	10	10	10	10	9	9	8	9,2	0,9	10,1
P3047	6	7	6	5	7	7	6	7	8	7	5	6,4	0,9	7,3

Rr= Yield with irrigation (t ha^{-1}); Rs= Yield in drought (t ha^{-1}); MPG= geometric average productivity; PM= Average productivity; ITS= Drought tolerance index; ISS= Index of susceptibility to drought; Tol= Tolerance; SDI= Index of sensitivity to drought; RDI= relative index of drought; DI= drought resistance index; ATI= Abiotic tolerance index; SDR= Standard deviation; R= Average range; RS= sum of ranges

CONCLUSIONS

The results obtained in this work show that each index allows the identification of drought tolerant varieties and the multivariate analysis applied to them, contributes to the interpretation of the effectiveness of these indices in the discrimination of drought-tolerant cultivars, although it is recommended that for the differences observed in the results obtained in the discrimination of the varieties, combine the multivariate statistical analyzes and use in the study several of these tolerance indexes.

BIBLIOGRAPHY

1. Farshadfar E, Mohammadi R, Farshadfar M, Dabiri S. Relationships and repeatability of drought tolerance indices in wheat-rye disomic addition lines. Australian Journal of Crop Science. 2013;7(1):130.
2. Dehbalaei S, Farshadfar E, Farshadfar M. Assessment of drought tolerance in bread wheat genotypes based on resistance/tolerance indices. International Journal of Agriculture and Crop Sciences. 2013;5(20):2352-8.
3. Fernandez George CJ. Effective selection criteria for assessing stress tolerance. En: ed. Kuo C.G. Proceedings of the International Symposium onadaptation of vegetables and other food crops in temperature and water stress. Asian vegetable research and Development Center; 1992. 257-270 p.
4. Khan FU, Mohammad F. Application of stress selection indices for assessment of nitrogen tolerance in wheat (*Triticum aestivum* L.). JAPS, Journal of Animal and Plant Sciences. 2016;26(1):201-10.
5. Mousavi S.s, Yazdi Samadi B, Naghavi M.r, Zali A.a, Dashti H, Pourshahbazi A. Introduction of new indices to identify relative drought tolerance and resistance in wheat genotypes. Desert. 2008;12(2):165-78.
6. Ashraf A, El-Mohsen A, Abd El-Shafi MA, Gheith EMS, Suleiman HS. Using different statistical procedures for evaluating drought tolerance índices of bread wheat genotypes. Advance in Agriculture and Biology. 2015;4(1): 19-30. doi:10.15192/PSCP.AAB.201 5.4.1.1930
7. Cyril A, Elick G, Birte K. Screening sweetpotato (*Ipomoea batatas*) genotypes under soil moisture. Archives of Applied Science Research. 2015;7(11):23-9.
8. Subhani GM, Abdullah, Ahmad J, Anwar J, Hussain M, Mahmood A. Identification of drought tolerant genotypes of barley (*Hordeum vulgare* L.) through stress tolerance indices. JAPS, Journal of Animal and Plant Sciences. 2015;25(3):686-92.
9. Mohammad MMS, Ali RH, Mohseni M, Nabavi T. Assessment of wheat yield response to water shortage using various tolerance índices. Philipp agric scientist. 2015;98(3):262–269.
10. Farshadfar E, Jamshidi B, Aghaee M. Biplot analysis of drought tolerance indicators in bread wheat landraces of Iran. International Journal of Agriculture and Crop Sciences. 2012;4(5):226-33.
11. Sahar B, Ahmed B, Naserelhaq N, Mohammed J, Hassan O. Efficiency of selection índices in screening bread wheat lines combining drought tolerance and high yield potential. Journal of Plant Breeding and Crop Science. 2016;8(5):72-86. doi:10.5897/JPBCS2016.0561
12. Esmaeilpour A, Van Labeke M-C, Samson R, Ghaffaripour S, Van Damme P. Comparison of biomass production-based drought tolerance indices of pistachio (*Pistacia vera* L.) seedlings in drought stress conditions. International Journal of Agronomy and Agricultural Research. 2015;7(2):36-44
13. Khalili M, Naghavi MR, Aboughadareh AP, Talebzadeh SJ. Evaluating of drought stress tolerance based on selection índices in spring canola cultivars (*Brassica napus* L.). Journal of Agricultural Science. 2012;4(11):78-85. doi:10.5539/jas.v4n11p78
14. Noorifarjam S, Farshadfar E, Saeidi M. Evaluation of drought tolerant genotypes in bread wheat using yield based screening techniques. European Journal of Experimental Biology. 2013;3(1):138-43.

15. Moradi Z, Farshadfar E, Shirvani H. Screening of Drought Tolerant genotypes in Bread Wheat (*Triticum aestivum*) using Morpho-physiological Traits and Integrated Selection Index.Biological Forum. An International Journal. 2015;7(1):163-72.
16. Hernández A, Pérez J, Castro N, Bosch D. Clasificación de los suelos de Cuba 2015. Ediciones INCA; 2015. 91 p.
17. Faure Á, Benítez R, León N, Chaveco O, Rodríguez O. Guía técnica para el cultivo del frijol común (*Phaseolus vulgaris* L.). La Habana, Cuba: Asociación Cubana de Técnicos Agrícolas y Forestales; 2013.
18. Rosielle AA, Hamblin J. Theoretical Aspects of Selection for Yield in Stress and Non-Stress Environment 1. Crop Science. 1981;21(6):943-6. doi:10.2135/cropsci1981.0011183X002100060033x
19. Fischer RA, Maurer R. Drought resistance in spring wheat cultivars. I. Grain yield responses. Australian Journal of Agricultural Research. 1978;29(5):897-912. doi:10.1071/ar9780897
20. Farshadfar E, Elyasi P. Screening quantitative indicators of drought tolerance in bread wheat (*Triticum aestivum* L.) landraces. European Journal of Experimental Biology. 2012;2(3):577-84.
21. Dorostkar S, Paknyiat H, Ahmadi KM, Ghorbani R, Aliakbari M, Sobhanian N, *et al*. Evaluation of several drought tolerance criteria in cultivated varieties of barley (*Hordeum vulgare* L.) and Their Relationships with Yield Reduction. Science Research. 2016;4(2):226-32. doi:10.11648/j.sr.20160402.11
22. Aliakbari Massumeh, Razi Hooman, Kazemeini Seyed Abdolreza. Evaluation of drought tolerance in rapeseed (*Brassica napus* L.) cultivars using drought tolerance indices. International journal of Advanced Biological and Biomedical Research. 2014;2(3):696-705.
23. Majidi MM, Rashidi F0, Sharafi Y. Physiological traits related to drought tolerance in Brassica. International Journal of Plant Production. 2015;9(4).

Received: 17 de noviembre de 2016
Accepted: 6 de noviembre de 2017

Revista Cultivos Tropicales
Instituto Nacional de Ciencias Agrícolas