academicJournals

Vol. 16(40), pp. 1984-1989, 4 October, 2017
DOI: 10.5897/AJB2017.16176
Article Number: 50DDD4966233
ISSN 1684-5315

http://www.academicjournals.org/AJB

African Journal of Biotechnology

Full Length Research Paper

Selection of loose-leaf lettuce breeding lines based on non-parametric indexes

Willame dos Santos Candido[1*], Dora Enith Tobar-Tosse[2], Renato Silva Soares[2], Lucas da Silva Santos[3], Carolina Andrade Franco[2] and Leila Trevisan Braz[2]

[1]Universidade Federal de Goiás (UFG), Regional Jataí, Rua Riachuelo, Jataí, Goiás, Brasil.
[2]Faculdade de Ciências Agrárias e Veterinárias (FCAV), Universidade Estadual Paulista (UNESP), Jaboticabal, São Paulo, Brasil.
[3]Departamento de Agronomia, Universidade Federal Rural da Amazônia (UFRA), Capanema, Pará, Brasil.

Received 30 July, 2017; Accepted 21 September, 2017

Non-parametric selection indexes (that is, require no estimation of parameters) can be used to help the selection process in the final stage of genetic enhancement. In this context, the objective of this study was to evaluate the efficiency of non-parametric selection indexes to choose promising lineages of loose-leaf lettuce, so that genetic gain of each lineage can be estimated and then registered in the Ministry of Agriculture. The indexes of Mulamba and Mock, Elston and Schwarzbach were used in the analysis. Ten genotypes of loose-leaf lettuce were evaluated, with eight of them being lineages (L_1, L_2, L_3, L_4, L_5, L_6, L_7, L_8) and two commercial cultivars (Vanda and Vera). The experiments occurred in six different locations of cultivation during the autumn and winter seasons of 2014. Experimental delineation was composed of random blocks, with four repetitions and the evaluated characteristics were: total production, commercial production, number of leaves, plant volume and stem length. The effects of genotype (G), location (L), and G x L interaction were significant for all characteristics. Indexes were correlated to classify the genotype. The Mulamba and Mock index stood out because it enabled good direct gains for the evaluated characteristics and because of its easy construction. Therefore, this index is recommended for selection of loose-leaf lettuce genotypes in the stage of cultivar recommendation in different locations. As the best lineages of loose-leaf lettuce were L_2, L_3, L_7 and L_8, these lineages have been considered promising and are recommended for registration.

Key words: Agronomic performance, *Lactuca sativa,* nonlinear indexes, spearman correlation.

INTRODUCTION

Lettuce is one of the most consumed vegetables in the world and its consumption has grown yearly. This is mainly due to new dietary habits that the population has adopted, which includes lettuce as an indispensable ingredient of its meals. In this context, market demand for high quality lettuce is already a reality, since consumers

*Corresponding author. E-mail: candidows.melhorista@gmail.com.

have become more selective and critical when choosing their foods. The Lettuce Breeding Program of the University of the State of São Paulo (UNESP-FCAV) has been active since 2003 and has worked on two different matters. The first regards *Bremia lactucae* L. breed identification in lettuce production regions of the State of São Paulo involves annual monitoring (Braz et al., 2007; Castoldi et al., 2012; Galatti et al., 2012; Nunes et al., 2016; Souza et al., 2011). The second is related to crossing of loose-leaf lettuce genitors and differentiating lettuces of *Dm* genes resistant to *B. lactucae*, with the intention of obtaining new lineages with positive agronomic and *B. lactucae* resistant traits (Castoldi et al., 2014). Currently, the program works on promising lineages that can be evaluated in different cultivation locations.

Agronomic yield assays performed in different locations which use different cultivation systems is an important stage of genetic enhancement, because necessary agronomic and productive characteristics are tested so that new lineages can be recommended in the future. The use of non-parametric selection indexes (indexes that do not require parameter estimations) can help in the lineage selection process when getting to the final stage of genetic enhancement. Non-parametric indexes have the intention of classifying genotypes in a simple way (Garcia and Souza Junior, 1999).

A few studies have reported the efficiency of non-parametric selection indexes in the beginning of progenies enhancement programs (Neves et al., 2011; Oliveira et al., 2008), as well as in advanced lineage selection stages (Marinho et al., 2014; Vittorazzi et al., 2013). However, studies using selection indexes on lettuce are still scarce. In this context, the objective of this study was to verify the efficiency of non-parametric selection indexes in choosing promising lineages of loose-leaf lettuce in order to register them in the Brazilian Ministry of Agriculture and to estimate genetic gains based on the same indexes.

MATERIALS AND METHODS

The experiments were installed during autumn and winter of 2014, in the cities of Monte Alto, São Simão, Aramina, Mogi das Cruzes, Biritiba Mirim, and Salesópolis - São Paulo State (Brazil). Experimental design was based on random blocks with six experimental groups and four repetitions. Treatments composed of 10 genotypes (8 lineages and the 2 commercial cultivars Vanda and Vera) and six (6) locations (Monte Alto, São Simão, Aramina, Mogi-das-Cruzes, Biritiba-Mirim, and Salesópolis). Each plot composed of 28 plants distributed in 4 rows with each row 1.75 m long and plants were spaced at 0.25 m intervals, but only the 6 central plants of each group were evaluated. The evaluated lineages came from the initial crossings of JAB 4-13-7 (male genitor, possessor of the *DM*18 gene of *B lactucae* resistance) with commercial cultivars: Argelis (A) – possessor of the *B. lactucae* resistance factor R-38, Vanda (V), Venerada (Vn) and Solaris (S) (all female genitors). This lineage resisted the *B. lactucae* breeds that occurred in the State of São Paulo (Castoldi et al., 2014).

The agronomic evaluated characteristics were: total production in g plant $^{-1}$ (TP), commercial production in g plant $^{-1}$ (CP), number of leaves per plant (NL), volume of the plants (cm^3 planta^{-1}) (V) and stem length in cm (SL). These measurements were done at harvest point (45 days after transplantation). Total production (TP) was obtained by calculating the average of the fresh mass in 6 plants (without extracting the old leaves). Commercial production (CP) was obtained by measuring the average weight of the fresh mass in 6 plants after removal of old leaves and of spare stem. NL represents the total number of leaves that reached the length of at least 3 cm in each plant. Volume (VOL) was calculated by multiplying the diameters of extremities, D_1 and D_2, and the height (h) of 6 plants from each of the portions (groups). In order to calculate V, the volume formula of 2 diameter used ellipsoid was: $V = 4/3\ \pi\ (D_1/2)\ (D_2/2)\ h$. Stem length (SL) was measured using a graduated ruler. The obtained data were initially submitted to the normality test and homogeneity of residual variances, and normality of the data was detected. Subsequently, data were submitted to statistical analysis of variance by location (environment), in which the variation sources were considered random. To do so, the statistical genes computer program (Cruz, 2013) was used. The formula adopted for joint analysis was:

$$Y_{ijk} = m + g_i + a_j + b/a_{jk} + ga_{ij} + e_{ijk}$$

Where, Y_{ijk} is the mean phenotypic value of the group; m is the average; g_i is the fixed effect of the i^{-th} genotype; b/a_{jk} is the effect of k repetition in location j; ga_{ij} is the interaction effect of genotype i in location j and e_{ijk} is the experimental error. The selection indexes were constructed following Mulamba and Mock (1978), Elston (1963) and Schwarzbach (1972) and Wricke and Weber (1986). The expected gain by direct selection in the i^{-th} character was estimated based on selection indexes studied through the following expression:

$$GS_i = (X_{si} - X_{oi})h_i^2 = DS_i h_i^2 \text{ and } GS_i(\%) = \frac{GS_i}{X_{oi}}\ x\ 100$$

Where, X_{si} is the average of selected samples for characteristic i; X_{oi} is the original average of the population; DS_i is the selection differential carried out in the population; and h_i^2 is the heritability of characteristic i. In order to compare lineage classification using the indexes of Mulamba and Mock (1978), Elston (1963) and Schwarzbach (1972), the Spearman correlation between them was obtained.

RESULTS AND DISCUSSION

Significant effects were verified for genotypes, locations and genotype x location (GXA) for all evaluated characteristics (Table 1). For the Monte Alto location (Table 2), the Mulamba and Mock (1978) indexes selected lineages L_2, L_3 and L_7, whereas the Elston index (1963) indicated lineages L_2, L_3 and L_4 and the Schwarzbach index (1972) chose lineages L_4, L_7 and L_8. Lineages L_2 and L_3 were indicated by both the I_{MM} and I_E indexes. Index I_{MM} presented the lowest rank; D_i represented shortest distance from the genotype to the ideotype and I_E the highest value. Lineage L_4 indicated by indexes I_E and D_i, also presented higher results for TP, CP and V. These characteristics are relevant for lettuce cultures since the consumer market demands bulky plants and good-looking leaves. Thus, lineages L_2, L_3 and

Table 1. Variation analysis chart of 6 random block experiments with ten loose-leaf lettuce genotypes, conducted in 6 different locations in autumn-winter, 2014.

FV	GL	Average square				
		TP	CP	NL	V	SL
Block/location	18	8102.57	5994.67	5.50	79301734.96	0.75
Genotype (G)	9	25850.03**	2009.27**	114.21**	341670068.37**	11.74**
Location (L)	5	486894.78**	423561.97**	360.46**	1778274902.9**	26.73**
G X L	45	4605.83**	3705.96**	6.17*	29966030.15**	0.89**
Error	162	2589.83	2055.57	4.10	14569571.94	0.28
Average		381.55	347.52	25.98	25546.68	4.53
CV		13.34	13.05	7.79	14.94	11.76

FV, Sources of variation; GL, degrees of freedom; TP, total production (g/plant); CP, commercial production (g/plant); NL, number of leaves; V, plant volume (cm³/plant); SL, stem length (cm). **, * relative to 1 and 5% probability, respectively, by the F test. CV = coefficient of variation.

Table 2. Indexes: Mulamba and Mock (I_{MM}), Elston (I_E) and Schwarzback (D_i), applied to the characteristics total production (g/plant); commercial production (g/plant); number of leaves; plant volume (cm³/plant) and stem length (cm) for 10 genotypes of loose-leaf lettuce in 6 different locations in the autumn and winter seasons of 2014.

Genotypes	Monte Alto-SP			São Simão-SP		
	I_{MM}	I_E	D_i	I_{MM}	I_E	D_i
L_1	36	7.95	5.00	32	8.09	4.19
L_2	**19**	**9.90**	3.55	**19**	**9.20**	4.22
L_3	**20**	**9.83**	3.50	**21**	8.87	3.79
L_4	21	**9.48**	**3.39**	**21**	8.53	**3.27**
L_5	39	0.00	5.96	32	0.00	4.43
L_6	24	9.22	3.64	27	8.78	3.45
L_7	**20**	9,26	**3.29**	**18**	**9.07**	**2.53**
L_8	31	9.04	**3.36**	**21**	**8.95**	**3.14**
'Vanda'	31	9.35	4.32	45	0.00	6.32
'Vera'	39	0.00	5.85	39	0.00	5.57

Genotypes	Salesópolis-SP			Biritiba Mirim-SP		
	I_{MM}	I_E	D_i	I_{MM}	I_E	D_i
L_1	30	5.67	4.09	27	**8.96**	3.65
L_2	39	4.82	4.44	35	8.69	4.40
L_3	24	7.25	2.93	35	8.54	4.15
L_4	32	6.50	3.82	34	8.46	3.82
L_5	26	0.00	5.71	23	0.00	3.20
L_6	**12**	**7.94**	**1.63**	**12**	**9.46**	**2.54**
L_7	**14**	**7.50**	**2.50**	**11**	**9.09**	**1.85**
L_8	**16**	**7.67**	**2.06**	**17**	8.79	**2.08**
'Vanda'	41	0.00	4.60	39	7.34	5.26
'Vera'	41	0.00	5.87	42	0.00	6.85

Genotypes	Mogi das Cruzes-SP			Aramina-SP		
	I_{MM}	I_E	D_i	I_{MM}	I_E	D_i
L_1	24	**8.78**	4.39	23	**9.09**	3.18
L_2	37	7.78	4.80	**21**	**9.13**	**2.86**
L_3	27	8.42	4.18	**21**	**9.35**	3.84
L_4	**23**	8.52	**3.46**	29	7.70	3.65
L_5	34	0.00	5.06	37	0.00	4.68

Table 2. Contd.

L_6	27	8.18	3.56	36	5.38	4.50
L_7	**9**	**9.22**	**2.10**	**21**	8.08	**2.48**
L_8	**13**	**8.80**	**1.86**	**12**	8.89	**1.76**
'Vanda'	37	8.17	4.65	32	7.43	4.25
'Vera'	44	0.00	6.69	43	0.00	5.69

Results in bold indicate the selected genotypes using the index in the location.

Table 3. Estimates of genetic gains in percentage, by the indexes of selection of Mulamba and Mock (IMM), Elston (IE) and Schwarzback (Di) applied to the characters total production (TP) (g / plant); commercial production (CP) (g / plant); number of leaves (NL); plant volume (V) (cm³ / plant); stem length (SL) (cm) for ten genotypes of crisphead lettuce, in six environments, in the fall-winter of 2014, based on the selection at each site..

Indexes	Monte Alto-SP						São Simão-SP					
	TP	CP	NL	V	SL	Total	PT	PC	NF	VOL	CC	Total
I_{MM}	10.13	9.09	3.16	14.98	9.49	46.85	5.28	4.88	4.23	7.75	3.16	25.30
I_E	8.34	6.85	-0.61	16.17	11.71	42.46	5.93	5.17	8.84	4.52	3.97	28.43
Di	2.98	3.32	3.95	-1.03	-1.82	7.40	3.78	3.05	9.17	0.58	-1.29	15.29

Indexes	Salesópolis-SP						Biritiba Mirim-SP					
	TP	CP	NL	V	SL	Total	TP	CP	NL	V	SL	Total
I_{MM}	9.07	10.96	7.33	1.66	-4.46	24.56	12.93	13.51	7.75	13.12	-2.13	45.18
I_E	9.07	10.96	7.33	1.66	-4.46	24.56	11.14	11.34	6.48	15.96	3.74	48.66
Di	9.07	10.96	7.33	1.66	-4.46	24.56	12.93	13.51	7.75	13.12	-2.13	45.18

Indexes	Mogi das Cruzes-SP						Aramina-SP					
	TP	CP	NL	V	SL	Total	TP	CP	NL	V	SL	Total
I_{MM}	6.05	6.06	10.50	6.51	-3.42	25.70	2.34	2.55	5.53	11.41	7.18	29.01
I_E	6.77	6.31	9.29	8.66	2.40	33.43	2.66	2.58	1.46	24.08	25.00	54.32
Di	6.05	6.06	10.50	6.51	-3.42	25.70	2.13	2.38	7.82	2.41	-1.60	13.14

L_4 are the most indicated for cultivation in Monte Alto, taking into consideration the group of characters evaluated.

The other lineages and commercial cultivars Vanda and Vera did not present satisfactory agronomic development. Their selection index results were low when compared to the lineages selected, which does not justify their cultivation in the Monte Alto region. Direct gains in Monte Alto, based on the adopted 30% selection intensity, were higher for V, with a 14.98 to 16.17% increase by the I_{MM} and I_E indexes. Additionally, higher total gains were obtained in all characteristics by the same indexes. The D_i index showed no satisfactory gains when compared to indexes I_{MM} and I_E, especially for TP and V (Table 3).

Rosado et al. (2012) found different results than the ones presented in the current study where they worked with simultaneous selection using selection indexes in progenies of sour passion fruit trees and verified the use of the Elston index which was not capable of distributing gains fitting for the purposes of that research. Thus, based on the results, it is possible to deduce that gains from index are subject to variation according to the greatness of the evaluated measurements. However, the same authors found that the index based on the additions of the Mulamba and Mock rankings was the most adequate, because it promoted balanced gain distribution. This result did support the results obtained in the current study.

In the region of São Simão (Table 2), indexes did not indicate the same lineages as the ones selected in Monte Alto. The Mulamba and Mock (I_{MM}) index identified 5 lineages: L_2, L_3, L_4, L_7 and L_8. On the other hand, the Elston index (I_E) indicated lineages L_4, L_7 and L_8, which was in agreement with the other 2 indexes that selected lineages L_2, L_7 and L_8. The Schwarz back index (D_i) also indicated lineages L_4, L_7 and L_8 for plantation in São Simão, which is also in agreement with the I_{MM} index.

The highest direct gain was in NL (9.17%), measured by D_i, however the highest gain values were for the I_E

(28.43%) and I_{MM} (25.30%) indexes. The I_E index showed the highest gain percentage for NL (8.84%) and the I_{MM} index presented the highest gain for V (7.75%) (Table 3). Terres et al. (2015), working to estimate genetic gains using different indexes in hybrid potato populations, verified that the use of indexes resulted in better selection gain estimations. One of the best indexes to use for genetic potato enhancement was the Mulamba and Mock (1978) index, which is in agreement with the obtained results. Similarly, Teixeira et al. (2012), using selection indexes in simultaneous component enhancement in the production of açaí fruits, also confirmed that the Mulamba and Mock (1978) index was the most efficient to estimate gains in production components.

In Salesópolis (Table 2), all indexes selected lineages L_6, L_7 and L_8 as the best genotypes. The selected lineages had the superior results for the set of evaluated characteristics, but especially stood out in TP, CP and NL when compared with the commercial tested cultivars. This revealed that the selected lineages had good aptitude in agronomic performance assays. Selection gains were highest for CP (10.96%) and SL reduction was -4.46%, which indicates that planting conditions in this region tend to stand out due to its commercial production. Total gains for all 3 indexes were lower than those obtained in other locations, such as in Biritiba Mirim (Table 3). In Biritiba Mirim (Table 2), indexes I_{MM} and D_i recommended the same lineages: L_6, L_7 and L_8. The I_E index indicated lineages L_6 and L_7 as well, differing therefore from the I_{MM} and D_i indices in the recommendation of L_1 lineage only instead of L_8. The highest obtained gains were for CP (13.51%) and V (13.12%), using the I_{MM} and D_i indexes. The highest total direct gains were observed by the I_E index (48.66%), which showed 15.96% of gain in V; its highest gain. However, using I_{MM} and D_i indexes, superior gains were obtained for TP, CP and NL and -2.13% reductions for SL (Table 3).

In Mogi das Cruzes (Table 2), both I_{MM} and D_i indexes indicated that lineages L_4, L_7 and L_8 were the best choices. I_E indicated lineages L_1, L_7 and L_8. Total direct gains for all characteristics were higher in the I_E index (33.43%) and NL and V especially stood out. However, the characteristic that had the highest gain was NL (10.5%), shown by I_{MM} and D_i indexes (Table 3).

Cities located in the “green belt” (Cinturão Verde) of São Paulo State (Salesópolis, Biritiba Mirim and Mogi das Cruzes) obtained similar results for the best lineages to plant. L_7 and L_8 were indicated as the best lineages to plant in the winter (Table 2). This relationship is due to similar climate and soil conditions found in this region of the State, which stimulate lineages to behave similarly. For cultivation conditions of Aramina (Table 2), the I_{MM} index indicated L_2, L_3, L_7 and L_8 as the best lineage genotypes to plant. On the other hand, I_E recommended lineages L_1, L_2 and L_3 and D_i selected L_2, L_7 and L_8. Total direct gains were highest when using the I_E index (54.32%), while the I_{MM} index enabled total gain of 29.01% and D_i had the worst total gains (Table 3).

In order to verify the relationship among the used indexes in the analysis of each location, Spearman correlation estimation was done, and significant correlations were observed. In Monte Alto, the observed correlations were: I_{MM} and I_E (0.902**), I_{MM} and D_i (0.734*) and between I_E and D_i ($0.549^{n.s}$); in São Simão, they were I_{MM} and I_E (0.898**), I_{MM} and D_i (0.802**) and between I_E and D_i ($0.631^{n.s}$); in Salesópolis, they were I_{MM} and I_E (0.874**), I_{MM} and D_i (0.842**) and between I_E and D_i (0.982**); in Biritiba Mirim, they were I_{MM} and I_E (0.730*), I_{MM} and D_i (0.980**) and between I_E and D_i (0.676*); in Mogi das Cruzes, they were I_{MM} and I_E (0.938**), I_{MM} and D_i (0.910**) and between I_E and D_i (0.893**); and in Aramina, they were I_{MM} and I_E (0.884**), I_{MM} and D_i (0.931**) and between I_E and D_i (0.702*). Significant correlations between I_{MM} and I_E and between I_{MM} and D_i occurred, while correlations between I_E and D_i for Monte Alto and São Simão were the lowest within all results. Therefore, one can deduce that the I_{MM} selection index may be best to use in advanced selections of lettuce lineages, due to its correlations with the other indexes and because of its easy application. Lessa et al. (2010), working with diploid hybrid selection of banana trees, based on non-parametric indexes, also verified strong correlations between Elston and Mulamba and Mock indexes, and between Mulamba and Mock and Schwarz back indexes, which were 0.76 and 0.63, respectively. Their results are in agreement with the results obtained in the research described here.

Conclusion

The Mulamba and Mock index enabled positive gains for the evaluated characteristics due to its strong correlations with the other studied indexes and because it can be easily obtained. Its use is recommended for loose-leaf lettuce genotype selection in the cultivar recommendation phase. Lineages L_2, L_3, L_7 and L_8 presented good productive potential, which improves the possibility of introducing new cultivars of loose-leaf lettuce, which positively respond to the climatic conditions of the autumn and winter seasons, in São Paulo State.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENTS

The authors would like to thank the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – CAPES for the scholarship granted to the first author and Universidade Estadual Paulista - UNESP/FCAV for the opportunity to pursue the doctor degree.

REFERENCES

Braz LT, Dalpian T, Camargo M, Pissardi MA (2007). Identification of races of *Bremia lactucae* in São Paulo, Brazil. Acta Hortic. 1:317-321.

Castoldi R, Charlo HCO, Dalpian T, Melo DM, Botelho AP, Braz LT (2012). Identification of new *Bremia lactucae* races in lettuce in São Paulo State. Hortic. Bras. 30(2):209-213.

Castoldi R, Charlo HCO, Melo DM, Candido WS, Vargas PF, Dalpian T, Braz LT (2014). Obtaining resistant lettuce progenies to downy mildew. Hortic. Bras. 32:69-73.

Cruz CD (2013). GENES - a software package for analysis in experimental statistics and quantitative genetics. Acta Sci. 35(3):271-276.

Elston RC (1963). A weight-free index for the purpose of ranking or selection with respect to several traits at a time. Biometrics 19(1):85-97.

Galatti FS, Castoldi R, Braz LT, Panizzi RC (2012). Monitoring of *Bremia lactucae* races in 2010 and 2011 in the state of São Paulo. Summa Phytopathol. 38(4):271-279.

Garcia AAF, Souza Júnior CL (1999). Comparison of non-parametric selection indices for the selection of cultivars. Bragantia 58(2):253-267.

Lessa LS, Ledo CAS, Santos VS, Silva SO, Peixoto CP (2010). Selection of (AA) diploid banana hybrids using three non-parametric indices. Bragantia 69(3):525-534.

Marinho CD, Gravina GA, Sebastião LCA, Almeida NC, Daher RF, Brasileiro BP, Paula TOM, Amaral Júnior A T (2014). Indexes in the comparison of pré-commercial genotypes of common bean. Ciênc. Rural 44(7):1159-1165.

Mulamba NN, Mock JJ (1978). Improvement of yield potential of the Eto Blanco maize (*Zea mays* L.) population by breeding for plant traits. Egypt. J. Genet. Cytol. 7(1):40-51.

Neves LG, Bruckner CH, Cruz CD, Viana AP, Barelli MAA (2011). Gain prediction with different selection index for yellow passion fruit characterization. Rev. Bras. Frutic. 33(4):1322-1330.

Nunes RC, Castoldi R, Gomes RF, Tobar-Tosse DE, Braz LT (2016). Survey of races of the causal agent of downy mildew of lettuce in the state of São Paulo in 2012 and 2013. Summa Phytopathol. 42(1):53-58.

Oliveira EJ, Santos VS, Lima DS, Machado MD, Lucena RS, Motta TBN, Castellen MS (2008). Selection on yellow passion fruit progenies by multivariate indices. Pesqui. Agropecu. Bras. 43(11):1543-1549.

Rosado LDS, Santos CEM, Bruckner CH, Nunes ES, Cruz CD (2012). Simultaneous simulations selection in progenies of yellow passion fruit using selection indices. Rev. Ceres 59(1):95-101.

Schwarzbach E (1972). Einige Anwendungsmöglichkeiten elektronischer Datenverarbeitung (EDV) für die Beurteilung von Zunchtmaterial. Arb. Tag. Öesterr. Pfl anzenz Gumpenstein, pp. 277-287.

Souza JO, Dalpian T, Braz LT, Camargo M (2011). New races of *Bremia lactucae*, causal agent of lettuce downy mildew, identified in São Paulo State, Brazil. Hortic. Bras. 29(3):282-286.

Teixeira DHL, Oliveira MSP, Gonçalves FMA, Nunes JAR (2012). Selection index for simultaneously improving fruit production components of assai palm. Pesqui. Agropecu. Bras. 47(2):237-243.

Terres LR, Lenz E, Castro CM, Pereira AS (2015). Genetic gain estimates using different selection index methods in three potato hybrid populations. Hortic. Bras. 33(3):305-310.

Vittorazzi C, Amaral Júnior AT, Gonçalves LSA, Candido LS, Silva TRC (2013). Selecting pre-cultivars of popcorn maize based on non-parametric indices. Ciênc. Agron. 44(2):356-362.

Wricke G, Weber EW (1986). Quantitative genetics and selection in plant breeding. Berlin: Walter de Gruyter. 406p.