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ORIGINAL ARTICLE

Restricted selection indexes used in sour passion fruit intrapopulational recurrent selection

Índices de seleção restritos empregados na seleção recorrente intrapopulacional do maracujazeiro azedo

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ABSTRACT: Sour passion fruit has great relevance for Brazil by its socioeconomic importance. Although it is one of the most important fruit trees in the Brazilian fruit production, its productivity is still very low due to the lack of genotypes that are homogenous, productive, and adapted to the different regions of the country. This denotes the need for advances in genetic improvement of this fruit species. In this context, the objective of this work was to estimate genetic gains in sour passion fruit progenies under intrapopulation recurrent selection, using different restricted selection indexes: Kempthorne & Nordskog, Tallis, and James; and non-restricted selection indexes: Smith, Hazel, and Mulamba & Mock. Thus, 13 agronomic characteristics were evaluated in 118 full-sib families and three controls. The selection indexes used to obtain the genetic gains were Mulamba & Mock, Smith, Hazel, and Kempthorne & Nordskog, with the assignment of random weights. The Tallis index was applied to the restriction for fruit mass, and the restriction of James for productivity gains. The Genes program was used to analyze the selection indexes. The restricted selection indexes of Kempthorne & Nordskog, Tallis, and James are more suitable for the selection of full-sib families of sour passion fruit than the Smith, Hazel, and Mulamba & Mock non-restricted selection indexes, and can be applied in recurrent selection programs. The results indicate that the addition of the restrictions proposed by Tallis and James are not efficient for increasing gains when compared to the Kempthorne & Nordskog, since they obtained similar gains.

RESUMO: *O maracujazeiro azedo possui grande relevância para o Brasil pela importância socioeconômica. Embora seja uma das fruteiras de maior destaque na produção nacional, a produtividade ainda é muito baixa, pela falta de genótipos homogêneos, produtivos e adaptados as diferentes regiões do país, refletindo a necessidade do avanço com melhoramento genético. Neste contexto, o objetivo deste trabalho foi estimar os ganhos genéticos com índices de seleção restrito diferentes: Kempthorne & Nordskog, Tallis e James e os índices não restritos: Smith, Hazel e Mulamba & Mock em progênies de maracujazeiro azedo sob seleção recorrente intrapopulacional. Desta forma, foram avaliadas 13 características agronômicas em 118 famílias de irmãos completos e três testemunhas. Os índices de seleção empregados para obtenção dos ganhos genéticos foram Mulamba & Mock, Smith, Hazel e Kempthorne & Nordskog com a atribuição de pesos aleatórios. O índice de Tallis foi aplicado a restrição para massa de fruto e o restrito de James para ganhos de produtividade. Para a análise dos índices de seleção foi utilizado o programa Genes. Os índices de seleção restritos de Kempthorne & Nordskog, Tallis e James são mais adequados à seleção de famílias de irmãos completos de maracujazeiro azedo do que os índices de seleção não restritos de Smith, Hazel e Mulamba & Mock, podendo ser aplicados em programas de seleção recorrente. Os resultados indicam que a adição das restrições propostas por Tallis e James não foram eficientes para o aumento de ganho, em comparação com Kempthorne & Nordskog, uma vez que obtiveram ganhos semelhantes.*

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1 Introduction

Brazil stands out as the world's largest producer and consumer of sour passion fruit (Passiflora edulis Sims.). In 2014, Brazil produced 838,284 tons in 57,183 hectares of cultivated area (IBGE, 2016). However, the national average productivity of 14,488 kg ha-1 is still low mainly due to the lack of available cultivars adapted to different regions of the country. Thus, breeding programs should be developed to meet this demand.

The fastest and most convenient way to obtain genetic gains for a trait is by carrying out selection directly on it. Thus, the use of selection indexes is a viable solution (Cruz et al., 2012) to obtain a superior genotype, which brings together all the favorable traits simultaneously, with comparatively higher performance and the conditions to meet market demands.

When a selection index is used, a numerical value that serves as an additional trait is obtained, resulting from the combination of certain traits selected for simultaneous selection. Therefore, the gain for one trait is reduced, but this decrease is offset by better distribution of gains in the set of traits (Cruz et al., 2014). Genetic gains are obtained by maximizing the correlation between the genotypic value and the index, aiming to obtain maximum efficiency in selection and, particularly, to gradually improve the frequency of favorable alleles for the set of important traits (Cruz, 2006).

Selection indexes have been applied in sour passion fruit breeding, with positive and balanced genetic gains (Dalbosco et al., 2018; Krause et al., 2012; Neves et al., 2011; Silva & Viana, 2012). Among those, the indexes of Smith (1936), Hazel (1943), Williams (1962), Pesek & Baker (1969) and Mulamba & Mock (1978) have stood out. However, there is limited information available in the literature on the use of methodologies of restricted selection indexes to obtain predicted genetic gains in sour passion fruit breeding.

Initially, restriction was proposed by Kempthorne & Nordskog (1959), so that the assignments of linear functions aim to simultaneously maximize gain, i.e., one or more traits are restricted to optimize gain for another set of traits of interest. The restriction proposal of Kempthorne & Nordskog (1959), allowed other restricted indexes to appear, including those of Tallis (1962) and James (1968).

Thus, this study aimed to estimate the genetic gains obtained by the restricted selection indexes of Kempthorne & Nordskog (1959), Tallis (1962) and James (1968) and the non-restricted indexes of Smith (1936) & Hazel (1943) and Mulamba & Mock (1978) in sour passion fruit progenies under intrapopulation recurrent selection and compare their efficiency rates.

2 Material and methods

The experiment was planted in September 2014 in the experimental area of the Universidade do Estado do Mato Grosso, in the city of Tangará da Serra, MT (latitude 14º39' and longitude 57º25'; and an altitude of 321 m). The region has a tropical climate, with well-defined dry and rainy seasons, average annual rainfall ranging from 1300 m to 2000 mm year-^{1}, and annual temperature ranging from 16 to 36 °C (Martins et al., 2010).

The soil is classified as Dystroferric Red Latosol, clayey, with plain to slightly wavy relief (Embrapa, 2006). Liming and fertilization of plantation and cover were carried out according to soil analysis, following the recommendations of Borges et al. (2006).

The experiment was arranged in a randomized block design, with three replicates and three plants per plot, 3.0 m spacing between plants and 3.0 m between planting rows, to enable the machinery to move within the experiment. The plants were conducted by vertical support structure, with 2.5 m fence posts, spacing of 6.0 m and flat wire number 12, used from the height of 2,0 m above the soil. Cultural practices such as irrigation, fertilization, pruning, pest and disease control were recommended for sour passion fruit culture (Bruckner & Picanço, 2001). Manual pollination was performed twice a week throughout the experiment.

In the experiment, one hundred eighteen full-sib families (FS) and three additional controls were assessed. One genotype was achieved from the UNEMAT sour passion fruit breeding program called UNEMAT S30 population, and the commercial cultivars FB200 and BRS Rubi do Cerrado.

The traits productivity and number of fruits were carried out only in the first year of cultivation, and are assessed on September 2015. The chemical and physical traits of the fruits were evaluated from May to September 2015, using nine fruits per plot.

The following traits were assessed: days for flowering (DFL), productivity (Prod) in kg ha-1 year-1, fruit mass (MF) in g, number of fruits (NF), average fruit length in mm (CF), average fruit diameter in mm (DF), fruit shape (FF), average shell thickness in mm (EC), pulp yield (RP), pulp color (CP), total soluble solids (SS), and total titratable acidity (ATT). The ratio was determined by dividing the SS value found by the ATT value found.

The analysis of variance was used for each trait using the Genes software system (Cruz, 2013); and the average matrices and phenotypic and genotypic covariances were generated. The values of mean squares obtained by analysis of variance were used to estimate the genetic parameters related to the genetic and environmental effects of the static model (Cruz, 2013).

The following procedure was used for the simultaneous selection of traits. The traits NF, Prod, MF, CF, DF, FF, RP, CP, SS and ratio were assessed aiming at increase and the traits DFL, EC and ATT aiming at decrease.

The agronomic characteristics present different levels of economic importance. Thus, in this study, economic weights were randomly assigned and tested until the values that provided the greatest genetic gains were identified. The economic weight established for the main traits NF, Prod and MF were 20, 100, 10, respectively, and the value 1 was adopted for the other traits considered secondary. The restricted selection index of Tallis (1962) was applied for the restriction on the trait MF; and selection index of James (1968), for the restriction of gains on the trait productivity. The analyses of the selection indexes were performed using the Genes software system (Cruz, 2013).

The non-restricted selection index of Mulamba & Mock (1978), consisted in classifying the genotypes for each trait in an order favorable to breeding. Thus, we have:

$$Ii = \sum p_j r_{ij}$$

Where:

I_i = Index of the i-th FS;

p_j = the economic weight assigned to the j-th trait;

r_{ij} = rank of the i-th FS in the j-th trait.

The non-restricted selection index of Smith (1936) & Hazel (1943), was carried out through the linear combination of various traits of economic interest; the weighting coefficients were estimated so as to maximize the correlation between the index and the genotypic aggregate. The aggregate consisted of another linear combination, including the genetic values which were weighted by the respective weighting coefficients, estimated by the expression:

$$H = a_1 g_1 + a_2 g_2 + \ldots a_n g_n = \sum_{i=0}^{n} a_i g_i = g'a$$

and

$$I = b_1 y_1 + b_2 y_2 + \ldots + b_n y_n = \sum_{i=0}^{n} b_i y_i = y'b$$

Where: H = genotypic aggregate or linear combination of the unknown genotypic values;

I = selection index to be estimated;

n = number of traits in the index;

g' = vector (1 x n) of the unknown genetic values of the n traits considered;

y' = vector (1 x n) of the averages;

a = vector (n x 1) of the economic weights (or values) previously established by the breeder; b = vector (n x 1) of the weighting coefficients of the index.

So that:

P = matrix (n x n) of phenotypic variances and covariances; and

G = matrix (n x n) of genetic covariances, obtained for average family level.

Thus, vector b was estimated by means of:

$$b = p^{-1} Ga$$

When the selection was conducted on the index, the expected gain in the trait i was expressed by:

$$\Delta g_{j(I)d} = DS_{j(I)} h_j^2$$

The restricted selection index of Kempthorne & Nordskog (1959) was applied considering two different situations: first, two restrictions were performed (Cov(I,gj)=0) simultaneously for the traits MF and ATT, and in the second situation, restriction was applied only for the trait MF.

The coefficients of the index were given by the following formula:

$$b = [I - P^{-1} GC (C'GP^{-1} GC)^{-1} C'G] P^{-1} Ga$$

Where:

b = vector of the coefficients of the estimated index;

I = value of the selection index;

P = matrix of the phenotypic variances and covariances;

G = matrix of the genotypic variances and covariances;

a = vector of economic weight of the traits studied;

C = n x r matrix of restrictions (r was the number of restrictions performed in the index), so that b´GC = 0.

So that Cij (i 1,2, ..., n and j = 1, 2, ..., r) element of the C matrix, then it is verified: Cij = 1 if; i = j and Cij = 0, in the opposite cases.

After the analysis of gains obtained in the Kempthorne & Nordskog (1959) index, the performance of the restricted selection index of Tallis (1962) was carried out using the economic weight of 20, 100 and 10 for the traits NF, Prod and MF, respectively, and the others were equal to 1. Restriction was applied only for the trait MF, and the values of 1000 and 5000 were randomly applied per trial to Cov(I,gj). The formula proposed by Tallis (1962) is provided:

$$b = [I - P^{-1} GC (C'GP^{-1} GC)^{-1} C'G] P^{-1} Ga + P^{-1} GC (C'GP^{-1} GC)^{-1} GC)^{-1} K$$

Where:

b = vector of the coefficients of the estimated index;

I = value of the selection index;

P = matrix of the phenotypic variances and covariances;

G = matrix of genotypic variances and covariances;

a = vector of economic weight of the traits studied;

C = (n x r) matrix of restrictions, in which the coefficients of the genotypic values of the variables under restriction have unitary value, and the other coefficients, value equal to zero; and

K = (r x 1) vector of the arbitrary values established for the covariances between the scores of the index and the genetic values of the traits under restriction.

In addition to the restriction established in the Tallis index (1962) (Cov (I,gj) ≠ 0), James (1968) proposed the restriction of gains (value of bj). In this work, the restriction of gains (RG) was established for the trait productivity, with three different weights, namely, 50, 100 and 200, so as to obtain:

$$b' GC = k'$$

b' = vector of size 1 x n, of weighting coefficients of the traits in the index;

G = matrix of size n x n, of genetic variances and covariances between the traits;

C = matrix of size n x r, with elements 0 and 1, which determine the r restrictions of gains on the n traits;

K' = vector of dimension 1 x r, which contains the values established for each covariance between the index and the trait under restriction; and

r = number of restrictions performed related to the gains (or covariances).

Estimates of prediction of gain per selection, using selection indexes, were obtained according to the selection of 25%, and the best 30 full-sib families were selected.

The relative efficiency was calculated for the main traits number of fruits and productivity, by comparing the restricted and non-restricted selection indexes. The following expression of Faria et al. (2012), was adapted to estimate the relative efficiency:

$$ER(\%) = \frac{< GS}{> GS} X\ 100$$

Where:

ER = Relative efficiency;

<GS = Selection index with greater genetic gain;

>GS = Selection index with lower genetic gain; and

100% reference value.

It was carried out the index of coincidence of the 30 FSs selected by selection indexes. The method of Hamblin & Zimmermann (1986), was used to estimate the coincidence index, given by the expression:

$$IC(\%) = \frac{A - C}{C - B} X\ 100$$

Where:

A = is the number of FSs that coincide in two selection indexes;

B = is th number of FSs selected, in this case, 30; and

C = the number of coincidences randomly assigned; in this case, with the adoption of 10% of B.

3 Results and Discussion

There was a significant difference between the full-sib families (FS) assessed for the traits DFL, Prod, CF, DF, FF, EC, RP, ATT and ratio at 1% probability ($p \leq 0.01$) and for the traits NF and MF, with significant difference at 5% probability ($p \leq 0.05$), which indicates genetic variability in the population, which is fundamental for the selection of superior genotypes and achievement of genetic gains.

In the assessment of genetic gains of the non-restricted selection index of Mulamba & Mock (MM) sum ranks provided balanced gains of 16.27 and 13.99% for number of fruits (NF) and productivity (Prod), respectively (Table 1). The non-restricted selection index of Smith & Hazel (SH) obtained lower gains; 12.28% for the trait NF and 8.66% for Prod, besides reducing fruit mass (MF) in 1.16%. The trait NF has an inverse correlation with MF.

Neves et al. (2011), compared different selection indexes to optimize gains from the simultaneous selection of traits of sour passion fruit and concluded that the MM index provided satisfactory total gains, based on the genotypic and phenotypic analysis. Krause et al. (2012), selected superior progenies from the sour passion fruit intrapopulation breeding program and observed positive genetic gains in the agronomic traits of interest with the use of the MM selection index.

Table 1. Means and estimates of percentage gains for the traits days for flowering (DFL), number of fruits (NF), productivity (Prod), fruit mass (MF), fruit length (CF), fruit diameter (DF), fruit shape (FF), shell thickness (EC), pulp yield (RP), pulp color (CP), soluble solids (SS), total titratable acidity (ATT) and the ratio between them, in 118 FS of sour passion fruit, Tangará da Serra - MT, 2015

Tabela 1. Médias e estimativas dos ganhos percentuais das características dias para o florescimento (DFL), número de fruto (NF), produtividade (Prod), massa de fruto (MF), comprimento do fruto (CF), diâmetro de fruto (DF), formato de fruto (FF), espessura de casca (EC), rendimento de polpa (RP), coloração de polpa (CP), teor de sólidos solúvel (SS), acidez total titulável (ATT) e a razão entre elas, em 118 FIC de maracujazeiro azedo, Tangará da Serra - MT, 2015

Selection Index1/	Restriction	COV²/	Value of bj³/	Selection Gain (%)					
				DFL	NF	Prod	MF	CF	DF
				Days	un ha⁻¹	kg ha⁻¹	g	------mm------	
MM	-	-	-	-4,67	16,27	13,99	0,23	-1,20	-0,29
SH	-	-	-	-4,50	12,28	8,66	-1,16	-3,05	-1,05
KN 1	MF	-	-	-7,57	19,27	17,87	0	-2,29	-1,02
KN 2	MF e ATT	-	-	-7,79	18,32	16,90	0	-2,79	-1,24
Tallis 1	MF	1000	-	-7,57	19,27	17,87	0,0025	-2,29	-1,02
Tallis 2	MF	5000	-	-7,57	19,26	17,86	0,0124	-2,29	-1,02
James 1	MF	1000	50	-7,56	19,27	17,82	0	-2,28	-1,04
James 2	MF	1000	100	-7,57	19,24	17,88	0	-2,30	-1,00
James 3	MF	1000	200	-7,44	18,78	17,61	0	-2,27	-0,90
James 4	MF	5000	50	-7,56	19,27	17,82	0	-2,28	-1,04
James 5	MF	5000	100	-7,57	19,24	17,88	0	-2,30	-1,00
James 6	MF	5000	200	-7,44	18,78	17,61	0	-2,27	-0,90
				Averages					
General (FS + Controls)				146,6	47602,3	8997,9	191,1	92,7	79,3

Selection Index1/	Restriction	COV²/	Value of bj³/	Selection Gain (%)						
				FF	EC	RP	CP	SS	ATT	Ratio
				CF/DF	Mm	%		ºBrix	g 100 mL⁻¹	
MM	-	-	-	-0,61	0,59	1,11	0,16	0,19	0,70	0,03
SH	-	-	-	-1,05	-0,35	2,69	-0,14	0,13	1,21	-0,61

Table 1. Continuation...

Tabela 1. Continuação...

Selection Index1/	Restriction	COV²/	Value of bj³/	Selection Gain (%)						
				FF	EC	RP	CP	SS	ATT	Ratio
				CF/DF	Mm	%		ºBrix	g 100 mL^{-1}	
KN 1	MF	-	-	-1,31	-0,66	3,11	-0,91	0,95	2,13	-1,37
KN 2	MF e ATT	-	-	-1,58	-0,68	3,14	-0,80	1,10	0	1,06
Tallis 1	MF	1000	-	-1,31	-0,66	3,11	-0,91	0,95	2,13	-1,37
Tallis 2	MF	5000	-	-1,31	-0,65	3,11	-0,91	0,95	2,13	-1,38
James 1	MF	1000	50	-1,28	-0,58	2,93	-0,91	0,95	2,22	-1,47
James 2	MF	1000	100	-1,33	-0,72	3,24	-0,90	0,96	2,07	-1,30
James 3	MF	1000	200	-1,41	-0,96	3,76	-0,87	0,95	1,75	-0,97
James 4	MF	5000	50	-1,28	-0,58	2,93	-0,91	0,95	2,26	-1,47
James 5	MF	5000	100	-1,33	-0,72	3,24	-0,90	0,95	2,07	-1,30
James 6	MF	5000	200	-1,41	-0,95	3,76	-0,87	0,95	1,75	-0,97
				Averages						
General (FS + Controls)				1,17	6,4	41,7	4,9	11,7	3,4	3,6

[1]/MM Mulamba & Mock, SH Smith & Hazel, KN Kempthorne & Nordskog. 2/COV Covariance between the scores of the index and the genetic value of the character equal to 1000 and 5000 for the trait MF. 3/Restriction of gain equal to 50, 100 and 200 for the trait Prod.

A restriction for the trait MF was adopted for the restricted selection index of Kempthorne & Nordskog (KN 1), since it presented negative gain for this trait for the SH index. Thus, the gains for the trait NF and Prod were 19.27% and 17.87% (Table 1), respectively. In addition, no decrease was observed for MF, which is a very important trait for the fresh market. The traits diameter (DF) and fruit length (CF) decreased by 1.02 and 2.29%, respectively. However, according to the Brazilian program for the improvement of trade patterns and horticultural packaging (Brasil, 2011), the classes are determined by a numerical scale (1-5), according to the measure of the fruit diameter. Thus, it was observed that the improved averages fell under class 4 (≥ 75 to < 85 mm), which is considered an excellent rating standard. The selection gain for shell thickness (EC) decreased by 0.66%, while pulp yield (RP) and soluble solids (SS) increased by 3.11% and 0.95%, respectively, thus providing fruits with thinner shell and thicker inner cavity pulp, which are traits of interest for the industry. According to Hafle et al. (2009), fruits with thinner shell are more marketable due to their increased pulp yield. Besides, processing industries demand fruits with high sugar content. The higher the fruit SS, the lower the quantity of raw material for the achievement of the final product. Thus, fruits with higher content of soluble solids will be more accepted fruit market (Nascimento et al., 1999). According to Nascimento et al. (2003), the industry needs 11 kg of fruits with SS ranging between 11º and 12º brix to obtain 1 kg of concentrate juice at 50° brix. Thus, the higher the SS value, the lower the amount of fruits used to obtain a certain amount of concentrate juice. This increases efficiency and reduces industrial production costs. Therefore, the genetic gains were satisfactory and balanced.

Compared to the MM and SH selection indexes, the genetic gains were higher for the main traits. It was observed that the relative efficiency of the selection gain, using the KN 1 index, for the trait NF, was 56.92% and 18.44% higher than that of SH and MM, respectively. Prod was 106.35% and 27.33% superior than SH and MM indexes (Table 2). While using the restricted selection index of Kempthorne & Nordskog to restrict a trait, Bhering et al. (2012), concluded that a balanced gain was obtained for the traits of agro-industrial interest.

Table 2. Relative efficiency between the restricted selection indexes of Kempthorne & Nordskog (KN 1), Tallis (Tallis 1) and James (James 2) and non-restricted indexes of Mulamba & Mock (MM) and Smith & Hazel (SH), for the traits productivity and number of fruits. Tangará da Serra - MT, 2015

Tabela 2. Eficiência relativa entre os índices de seleção restritos de Kempthorne & Nordskog (KN 1), Tallis (Tallis 1) e James (James 2) e não restritos de Mulamba & Mock (MM) e Smith & Hazel (SH), para as características produtividade e número de fruto. Tangará da Serra - MT, 2015

Selection Index	Restriction	COV¹/	Value of bj¹/	Number of Fruits		Productivity	
				SH	MM	SH	MM
KN 1	MF	-	-	156,92	118,44	206,35	127,73
Tallis 1	MF	1000	-	156,92	118,44	206,35	127,73
James 2	MF	1000	100	156,68	118,25	206,47	127,81

[1]/COV Covariance between the scores of the index and the genetic value of the character equal to 1000 for the trait MF. 2/Restriction of gain equal to 100 for the trait Prod.

Also using the KN 2 selection index, two restrictions were established in the traits fruit mass and total titratable acidity, simultaneously. However, the genetic gains for the traits NF (18.32%) and Prod (16.9%) were lower than that of KN 1 for only one restriction. Highly positive phenotypic correlation between two traits were obtained in studies on other crops (Sousa Leite et al., 2016).

In the restricted selection index of Tallis, the covariance value was different from zero (Cov (I, g_j) ≠ 0), and the values of 1000 (Tallis 1) and 5000 (Tallis 2) were assigned. The genetic gains for the main traits NF and Prod were similar, but for the trait under restriction (MF), it was obtained gain of 0.0025%, when the Tallis 1 index was used. However, the use of Tallis 2 allowed gain of 0.0124% (Table 1). Therefore, as the covariance value increases, the gains in the trait under restriction increases proportionately. However, these gains are very little, and no significant effect resulted from the assignment of non-zero values for the covariance. By comparing the gains in the main traits obtained by Tallis 1 index and the MM and SH indexes, it is observed that the Tallis index was also more efficient (Table 2). The comparisons between KN and Tallis provide similar values. The result of Bizari et al. (2017) corroborates that the summation index of Mulamba & Mock provides better gains in their index study.

In the restricted selection index of James, besides the restriction of covariance between the scores of the index and the genetic value of the character, the restriction of gains for the trait Prod was conducted by assigning the values of 50, 100 and 200. It was observed that the predicted genetic gains achieved similar values for the restrictions of gains assessed (Table 1). James index also showed gains similar to those obtained by the KN 1 and Tallis indexes, which demonstrates that the restriction of gain for the trait Prod did not cause significant changes. In the comparison between the James 2 and SH indexes, the relative efficiency of the selection gain was higher than 56.68% for NF and 106.47% for Prod. Compared with the MM index, superiority reached 18.25% for NF and 27.81% for Prod (Table 2).

According to Teodoro et al. (2015), the use of this approach in plant breeding has been increasing and includes, for example, adaptability and stability evaluations in genotypes of different crops. These authors concluded that selection indexes are an effective alternative for adaptability and phenotypic stability studies in plant breeding programs.

The coincidence rates among the best restricted indexes assessed (KN 1, Tallis 1 and James 2) were high, exceeding 96.3%. The coincidences between the restricted and non-restricted indexes were lower than 74.1% (Table 3). According to Pedrozo et al. (2009), the higher the coincidence index between two indexes, the higher the agreement of the results of selection between them.

Regardless the traits that are focused for selection, whose weighting coefficients are estimated to maximize the correlation between the index itself and the aggregate genotypic value, this index is considered as non-restricted, since undesirable responses may occur in some characters within the aggregate genotypic values. Therefore, simultaneous selection of characters is a practice that maximizes chances of success in the breeding process (Cruz et al., 2014). This is shown in the results found by Dalbosco et al. (2018), in which the highest genetic gains were obtained when the coefficient of genetic variation, genetic standard deviation, and random weight were assigned as economic weight for indexes in non-parametric selection.

Table 3. Index of coincidence of the 30 FS selected from sour passion fruit by the selection indexes of Mulamba & Mock (MM), Smith & Hazel (SH), Kempthorne & Nordskog (KN 1), Tallis (Tallis 1) and James (James 2). Tangará da Serra-MT, 2015

Tabela 3. Índice de coincidência das 30 FIC selecionadas de maracujazeiro azedo pelos índices de seleção de Mulamba & Mock (MM), Smith & Hazel (SH), Kempthorne & Nordskog (KN 1), Tallis (Tallis 1) e James (James 2). Tangará da Serra-MT, 2015

Selection index	Restriction	COV[1]/	Value of bj[2]/	Index of coincidence			
				SH	KN 1	Tallis 1	James 2
MM	-	-	-	29,6	51,9	51,9	51,9
SH	-	-	-	-	74,1	70,4	70,4
KN 1	MF	-	-	-	-	100	96,3
Tallis 1	MF	1000	-	-	-	-	96,3
James 2	MF	1000	100	-	-	-	-

[1]/COV Covariance between the scores of the index and the genetic value of the trait equal to 1000 for the trait MF. 2/Restriction of gain equal to 100 for the trait Prod.

4 Conclusions

The restricted selection index of Kempthorne & Nordskog (1959), Tallis (1962) and James (1968) are more suited for the selection of full-sib families for the non-restricted selection indexes of Smith (1936) & Hazel (1943) and Mulamba & Mock (1978) and can be applied in sour passion fruit recurrent selection programs. The results indicate that the addition of restrictions proposed by Tallis (1962) and James (1968) was not efficient in increasing gain in relation to the Kempthorne & Nordskog index (1959), since their gains were similar.

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