IJANR International Journal of Agriculture and Natural Resources

Int. J. Agric. Nat. Resour. 49(1):62-72. 2022
www.ijanr.cl

PLANT BREEDING, GENETICS AND GENETIC RESOURCES

DOI 10.7764/ijanr.v49i1.2301

RESEARCH PAPER

Dynamics and prediction of genetic gains through selection indices in (*Allium cepa* L.) genotypes

Vanessa C.V. Segundo[1], Renato Innecco[1], Joelson A. de Freitas[2], Gabriel M. Maciel[3], José M.Q. Luz[4], Ana P.O. Nogueira[4], Ana C.S. Siquieroli[3], and Joicy V.M. Peixoto[3]

[1]Federal University of Ceará (UFC), Campus Pici, Av. Mister Hull, CEP: 60356-001, Fortaleza, Ceará, Brazil.

[2]Murray River Seeds Co. Albury, Australia.

[3]Federal University of Uberlândia (UFU), Campus Monte Carmelo, Rodovia LMG 746, km 01, s/n, CEP 38.500-000, Monte Carmelo-MG, Brazil.

[4]Federal University of Uberlândia (UFU), Campus Glória. BR 050, Km 78, s/n, CEP: 38410-337, Uberlândia – MG, Brazil.

Abstract

V.C.V. Segundo, R. Innecco, J.A. de Freitas, G.M. Maciel, J.M.Q. Luz, A.P.O. Nogueira, A.C.S. Siquieroli, and J.V.M. Peixoto. 2022. Dynamics and prediction of genetic gains through selection indices in (*Allium cepa* L.) genotypes. Int. J. Agric. Nat. Resour. 62-72. The greatest challenge in onion breeding programs is achieving gains from plant selection in an efficient manner. Selection indices are already in use for many species but are rare in onion. The aim of this study was to characterize the gain from selection in onion germplasm through nonparametric indices. To bring about this dynamic, four experiments were conducted with different sets of genotypes. Several agronomic characteristics were evaluated. Estimates of gains and selection of genotypes were obtained from the selection index based on rank sum, from the genotype-ideotype distance index, and from the multiplicative index. To test the efficiency of the indices used, the coefficient of coincidence was calculated. The total gains from selection were greater through use of the multiplicative index, with values of 31.84% for the advanced lines and 37.4% for the segregating genotypes. It was possible to select superior onion lines in each experiment. The coefficients of coincidence, all with values greater than 0.5, confirmed that the indices provided a margin of safety in the selection of superior genotypes.

Keywords: *Allium cepa* L., combined selection, onion breeding, selection criteria.

Introduction

Onions are the third most cultivated vegetable in the world (Epagri, 2013). In Brazil, approximately 60 thousand hectares are used for onion production (IBGE, 2017).

Diverse studies have sought to achieve increases in yield and make the crop more profitable for the grower (Kurtz et al., 2016; Maciel et al., 2019;

Received Nov 13, 2020. Accepted Mar 14, 2022
Corresponding author: joicyvmpeixoto@ufu.br; joicyvmpeixoto@gmail.com

Santos & Oliveira, 2011; Santos et al., 2018; Vidigal et al., 2010). However, in most cases, studies have focused on cultivars previously selected through traditional selection methods (Santos & Oliveira 2011), creating *a priori* the requirement for evaluation of new selection techniques already consolidated in other species. There are reports on the efficiency of the use of the selection index in simultaneously obtaining genetic gains in various traits in maize (DoVale et al., 2011), soybean (Bizari et al., 2017; Leite et al., 2018), carrot (Carvalho et al., 2017), passion fruit (Dalbosco et al., 2018) and lettuce (Peixoto et al., 2020) crops. However, there is no consensus for the efficiency of the different nonparametric indices on onion germplasm. To achieve this objective, through selection, the genetic material must combine a set of promising traits that provide high yields and meet consumer preferences (Cruz et al., 2012), making selections for onions even more complex (Havey, 2018; Machado et al., 2019).

Selection of individuals or progenies can involve a certain complexity because most traits of importance are of a genetic – quantitative nature. These traits may exhibit gene epistasis and unfavorable correlations with each other and may also be strongly affected by the environment and the genotype-environment interaction (Cruz et al., 2014), which cause the selection process to be more difficult. Restrictive selection of superior individuals based on one or a few traits can lead to low performance of individuals when the objective is complementarity among the traits from the agronomic perspective (Cruz et al., 2012). In this context, the aim of this study was to characterize the gain from selection in onion germplasm through nonparametric indices.

Material and Methods

Four experiments were conducted in Uberlândia, MG, Brazil (18°54'41'' S, 48°15'21'' W), in 2016 and 2017 with genotype groups from the onion breeding program: 1) experiment conducted in 2016, 109 genotypes, advanced lines (lines obtained after successive self-fertilizations); 2) experiment conducted in 2016, 227 genotypes, segregating lines (segregating populations); 3) experiment conducted in 2017, 53 genotypes, advanced lines; 4) experiment conducted in 2017, 110 genotypes, segregating lines.

Treatments were represented by the number of genotypes, and a randomized block design (RBD) was used, with two replications. Plots consisted of a plant bed of 1 meter length by 0.9 meter width, with five rows spaced at 0.20 meters, and plants spaced at 0.05 m in the row, resulting in 100 plants per plot.

For the nonnumeric traits, scores were attributed ranging from 1 to 9, with 1 as the worst value and 9 as the best value of the trait. The following agronomic traits were evaluated: plant vigor – scores (1-9), at 90 days after sowing (DAS), simultaneously observing leaf diameter, plant height, and number of leaves; diameter of the lower region of the pseudostem "neck" –scores (1-9) with 1 representing pseudostems with excessive thickening and 9 representing lesser thickness; plant architecture – scores (1-9), with 1 for prostrate plants and 9 for upright plants; leaf waxiness – scores (1-9), with 1 as absence of wax and 9 as having a great deal of wax; plant cycle, number of days from sowing date to harvest date; bulb color – scores (1-9), with the highest score attributed to bulbs with dark brown color; bulb shape – scores (1-9), with 1 as flattened bulbs and 9 as globular bulbs; uniformity of bulb shape – scores (1-9), with the highest score for the greater the predominance of one or few shapes in the plot; mean bulb weight, ten bulbs were used from the plot, registered in grams; dry out of leaf tips - scores (1-9), with the higher score for plants that did not exhibit dry out of the leaf plant tissues; bulb firmness, five bulbs per plot were collected, with the data expressed in kgf . cm -2 ; and postharvest durability of the bulbs, 15 bulbs were collected per plot and they were stored under ambient temperature and moisture conditions. After 60 days, the remaining bulbs were counted.

Estimates of gains and selection of genotypes were obtained from selection indices based on the rank sum of Mulamba and Mock (1978) and from the genotype-ideotype distance index and multiplicative index (Subandi et al., 1973).

The gains expected from selection were calculated using the following equations:

$$GS_i = S_iD.h_i^2$$

where GS_i is the gain expected from selection for trait i; S_iD is the selection differential based on selection by the index, i.e., the mean of the lines selected for trait i minus the overall mean of the lines; and is the heritability for trait i.

$$GS_i\% = \frac{GS_i}{\overline{X}_0} \text{ x } 100$$

where $GS_i\%$ is the percentage of expected gain from selection for trait i; GS_i is the expected gain from selection for trait i; and is the overall mean of the lines.

In the rank sum index of Mulamba and Mock (1978), the orders from each genotype were added, giving rise to the selection index, represented as follows:

$$I = r_1 + r_2 + \cdots + r_n$$

where I is the value of the index for a determined individual or family; r_j is the classification (or rank) of an individual in relation to the j-th variable; and n is the number of variables considered for the index.

The weights attributed to the variables were given by:

$$I = p_1r_1 + p_2r_2 + \cdots + p_nr_n$$

where p_j is the economic weight attributed by the user to the j-th trait.

In the genotype-ideotype distance index (Cruz 2006), X_{ij} was considered the mean phenotypic value of the i-th genotype in relation to the j-th trait. In addition, Y_{ij} is considered to refer to the mean transformed phenotypic value, and C_j is a constant relative to the mean depreciation of the genotype for not being within the standards desired by the breeder.

The following was established: LI_j is the lower limit to be exhibited by the genotype in relation to trait j; LS_j is the upper limit to be exhibited by the genotype; and VO_j is the optimal value to be exhibited by the genotype under selection.

If $LIj \leq Xij \leq LSj$, then $Yij = Xij$

If $Xij < LIj$, $Yij = Xij + VOj - Cj$

If $Xij > LSj$, $Yij = Xij + VOj + Cj$

It was considered that $C_j = LS_j - LI_j$, and the value of C_j ensured that any value of X_{ij} within the interval of variation around the optimum would result in a value of Y_{ij} with magnitude near the optimal value, in contrast with the values of X_{ij} outside this interval. Thus, the transformation of X_{ij} is made with the purpose of ensuring depreciation of the phenotypic values that are not within the interval considered optimal of the standard to be exhibited by the genotype to be selected.

The values of Y_{ij} were standardized and weighted by the weights attributed to each trait, as specified below: $y_{ij} = \sqrt{a_j}\,\frac{y_{ij}}{S(Y_j)}$

where $S(Y_j)$ is the standard deviation of the mean phenotypic values obtained by the transformation presented, and a_j is the weight or economic value of the trait.

The VO_j was also standardized and weighted as follows:

$$vo_j = \sqrt{a_j}\,\frac{VO_j}{S(Y_j)}$$

Then, the values of the index were calculated and expressed by the distance between the genotype and the ideotype from the following equation:

$$I_{DGI} = \sqrt{\frac{1}{n}\sum_{j=1}^{n}(y_{ij} - vo_j)^2}$$

The ideotype was determined as the genotype with the minimum mean value for the plant cycle and maximum values for the other variables.

The multiplicative index (Subandi et al., 1973) was estimated by the following equation:

$$I = y_1^{k1} y_2^{k2} \ldots y_n^{kn}$$

where y_j is the mean value of trait j; k_j is 1 if the direct relation of the index with the variable is considered; and k_j is -1 if the inverse relation of the index with the variable is considered.

For the rank sum index on and the multiplicative index, the inferior selection direction and inverse selection direction were adopted, respectively, for the plant cycle trait in order to select earlier genotypes. The other traits were selected with the superior selection direction so that the genotypes with the highest values for the respective traits would be selected.

In each experiment, the selection proportion was 20% of the superior genotypes. In the rank sum index and multiplicative index methodologies, the economic weights were determined according to the priority of importance attributed to each trait. Thus, the traits were weighted in the following manner: uniformity of bulb shape > bulb shape > bulb color = mean bulb weight = bulb firmness = postharvest durability of the bulbs > plant cycle > plant vigor > pseudostem diameter = dry out of the leaf tips > leaf waxiness.

The coefficient of coincidence between each index was calculated based on the selected genotypes for the purpose of testing the efficiency of the indices used. To generate the indices, the GENES computational application (Cruz, 2013) was used.

Results and Discussion

Upon analyzing the rank sum index, it was observed that for the advanced and segregating lines, the bulb color trait obtained the highest individual gain from selection, 9.09% and 13.66%, respectively. The highest gain from selection obtained by the genotype-ideotype distance index in the advanced lines was by the mean bulb weight trait (12.33%). In the segregating lines, bulb color had the highest gain from selection (14%) (Table 1).

Similar to the genotype-ideotype index, the trait with the highest gain from selection by the multiplicative index in the advanced lines was mean bulb weight (11.84%), and in the segregating lines, the highest gain observed was for the bulb color trait (11.31%). The multiplicative index also showed a negative gain only for the plant cycle variable, which is desirable because the preference is for plants that have an early cycle (Table 1). According to Bhering et al. (2012), a greater quantity of positive gains is important since the objective is to obtain high gains for all the variables evaluated. Onion cultivars have different physiological requirements regarding bulb formation and flowering. Early cycle plants are less demanding in photoperiod, and their harvest is earlier compared to those of medium and late cycles. An earlier cycle avoids problems from excess rain, heat, and hail in this last phase of the crop (Epagri, 2013).

Table 1. Estimate of gains from selection obtained for nine traits through selection based on rank index, genotype-ideotype distance index, and multiplicative index for 109 advanced lines and 227 segregating lines of onion in the municipality of Uberlândia, MG, Brazil, 2016.

Characters[a]	Selection gains %					
	Rank sum		Genotype-ideotype		Multiplicative	
	Advanced lines	Segregating lines	Advanced lines	Segregating lines	Advanced lines	Segregating lines
PV	4.48	4.19	2.05	4.83	2.65	4.99
PA	4.16	4.79	7.68	6.16	4.16	7.92
DP	-1.99	-0.53	-3.97	-1.57	3.64	8.56
LW	-1.81	-1.91	-2.72	-1.04	1.21	2.76
Cycle	-4.25	-3.11	-0.67	-1.85	-3.59	-5.08
BC	9.04	13.66	4.50	14.0	6.77	11.31
BS	5.02	5.52	5.65	4.99	4.4	1.68
UBS	1.59	3.54	3.25	2.86	0.76	1.06
BW	7.99	5.79	12.33	8.45	11.84	4.2
Total	24.23	31.94	28.10	36.83	31.84	37.4

[a]PV: plant vigor; PA: plant architecture; DP: diameter of the lower region of the pseudostem "neck"; LW: leaf waxiness; BC: bulb color; BS: bulb shape; UBS: uniformity of bulb shape; BW: mean bulb weight.

The two traits (color and mean bulb weight) were those that in general exhibited greater genetic gains, regardless of the methodology of the selection index (Table 1). This shows that obtaining lines with dark brown color and greater mean bulb weight can be successfully achieved. Both of these traits are important for economic value in onion.

The intensity of yellow bulb color is a trait with easy genetic fixation observed in practical terms of selection. The fact that the values of genetic gains for dark yellow bulb color are higher in the segregating lines (Table 1) compared to the advanced lines can be explained by a possible dominance effect of the alleles favorable to the trait. Such evidence has likewise been found in practice, which involves selection and crosses of lines with intense bulb coloring, when observing the descendants of these crosses.

In contrast, for mean bulb weight, the opposite occurred. That is, regardless of the index adopted to estimate genetic gain, it was greater for the advanced lines (Table 1) than for the segregating lines. This result suggests a predominant additive effect for the trait.

The pseudostem diameter, leaf waxiness, and plant cycle traits exhibited predominantly negative genetic gains when the three selection index methods were used (Table 1). Thus, these traits were reduced, which is desirable for the pseudostem diameter and plant cycle traits, since the leaf waxiness trait should be considered with greater reservations in breeding programs. The uniformity of the bulb shape trait also exhibited a low genetic gain of approximately 2.2% (Table 1).

Evaluation of the totals for the gains resulting from trait selection shows that the multiplicative method for estimation of the selection index provided the highest gains from selecting for the advanced lines (31.84%) and segregating lines (37.4%). Bhering et al. (2012) also obtained a greater total gain upon using the multiplicative index, corroborating the results of the present study.

Analysis of the estimates of total genetic gain, regardless of the selection index adopted, showed that the segregating lines exhibited greater estimates of gains than the advanced lines (Table 1). This result was expected because, as the genotypes are genetically advanced, gains from selection tend to be lower. However, through appropriate strategies, the breeder seeks to maximize gains within the genetic and financial resources available.

In the experiments conducted in 2017 (Table 2), the trait for postharvest durability had the highest gains from selection both in advanced lines and in segregating lines for all the indices.

Furthermore, the gains from selection for postharvest durability were greater in the advanced lines than in the segregating lines for the three types of indices adopted in the estimates of gains from selection (Table 2). This result suggests that a possible additive effect of the alleles that control postharvest conservation may be involved. Additive variance is the main source of genetic variation studied, and it is the parameter that allows success in selection in initial generations (Cruz et al., 2014).

The bulb firmness trait, in general, was the second greatest in terms of gains from selection, considering the three types of indices adopted in the estimation of gains from selection. The values of these gains ranged from 8.74% to 10.4% (advanced lines) and from 6.57% to 9.59% (segregating lines) (Table 2).

Gains from selection for mean bulb weight were similar to those observed in the experiments conducted in 2016. However, large discrepancies were not observed between the gains estimated for advanced lines and segregating lines as found in 2016. In that year, the highest gains were obtained in the advanced lines (Table 1). In contrast, in the experiment conducted in 2017, a similar result was observed only for the multiplicative index. The other indices exhibited an opposite result, i.e., greater gains in segregating lines (Table 2). This result shows that the segregating lines of

Table 2. Estimate of gains from selection obtained for nine traits by selection through the rank sum index, genotype-ideotype distance index, and multiplicative index for 53 advanced lines and 110 segregating lines of onion in the municipality of Uberlândia, MG, Brazil, 2017.

Characters[a]	Selection gains %					
	Rank sum		Genotype-ideotype		Multiplicative	
	Advanced lines	Segregating lines	Advanced lines	Segregating lines	Advanced lines	Segregating lines
PV	2.48	7.11	0.29	7.92	2.04	9.82
PA	3.79	0.76	4.6	1.9	3.39	2.28
DP	-0.30	-1.95	0.26	-1.81	0.54	-1.66
LW	2.10	-	1.09	-	3.12	-
DLT	6.81	-5.25	3.11	-6.46	12.97	2.28
Cycle	-7.11	-2.84	-4.63	-2.59	-6.63	-4.26
BC	4.67	7.37	6.45	7.69	2.29	3.91
BS	3.67	2.72	2.75	3.29	3.21	2.33
UBS	0.29	0.72	2.99	1.08	0.74	0.00
BW	8.58	9.25	7.5	8.32	11.15	7.59
BF	10.38	8.74	10.4	9.59	8.74	6.57
BPH	30.38	21.18	23.88	17.18	31.20	25.94
Total	65.75	47.81	58.69	46.11	72.76	54.8

-: nonsignificant trait (F test) not considered in forming the indices. [a]PV: plant vigor; PA: plant architecture; DP: diameter of the lower region of the pseudostem “neck”; LW: leaf waxiness; DLT: dry out of leaf tips; BC: bulb color; BS: bulb shape; UBS: uniformity of bulb shape; BW: mean bulb weight; BF: bulb firmness; BPH: bulb postharvest.

onion have promising traits that can be exploited in breeding.

The results of gains from selection for bulb color were slightly lower (Table 2) than those exhibited in 2016 (Table 1). Likewise, they were greater when estimated for segregating lines compared to those estimated for advanced lines. Once more, it can be inferred that a possible dominance effect of the alleles that control the intense brown color of the bulb is present.

In all the experiments conducted in 2016 and 2017, the vast majority of the plant cycle and pseudostem diameter traits proved to be negative, generating a decrease in their value. This result shows the efficiency of selection for genotypes with shorter cycles and smaller pseudostem diameters.

The other traits exhibited mean gains from selection of approximately 4.9% (plant vigor), 2.8% (plant architecture), 3.0% (bulb shape), 1.0% (uniformity of bulb shape), and 2.1% (leaf waxiness) (Table 2). In regard to the dry out of the leaf tip trait, positive gains for advanced lines were observed in the three indices used. However, for segregating lines, positive gains were observed only upon using the multiplicative index (Table 2).

In general, the multiplicative index led to the highest total gain from selection (just as in the experiments conducted in 2016), followed by the rank sum index (Tables 1 and 2). The index with the lowest total gain in this case was that of the genotype-ideotype distance index for both experiments conducted in 2017, advanced lines and segregating lines (Table 2). Terres et al. (2015) estimated genetic gains through selection indices in hybrid potato populations and concluded that the best indices to be used in potato breeding programs are the multiplicative index and the rank sum index. This result corroborates those obtained in the present study.

The big disadvantage of the multiplicative selection index is the lack of weighting of traits, as it only allows them to be maximized or minimized. Thus, traits considered more important had the same weight as the others in classification, unlike the rank sum and ideotype-genotype distance indices. The latter even allows selection of genotypes within a range of variation determined by the breeder and not only extreme values.

In the present study, the multiplicative index exhibited the highest estimates of gains. It can be feasibly adopted in a breeding program aiming to maximize gains from selection. However, since this index does not attribute weights to the importance of the different traits that compose it, it can be disadvantageous when one wishes to consider multiple traits with different weights. According to Pedrozo et al. (2009), the efficiency of selection upon using an index should be considered a characteristic inherent to the population characterized.

In obtaining commercially competitive hybrids, the different market demands should be observed and weighed. Therefore, the flexibility of the genotype-ideotype index in considering different weights of the traits also makes it appealing for use.

The rank sum and ideotype-genotype distance indices showed 77.78% similarity in the selection of the segregating lines analyzed in 2016. The three indices used in this study were similar at a level of approximately 55.56% (4, 15, 22, 49, 50, 51, 57, 58, 59, 64, 65, 67, 68, 69, 82, 87, 91, 104, 116, 169, 170, 171, 186, 192, and 216) in the selection of segregating lines characterized in the same year (Table 3).

For the experiments conducted in 2017, the same response noted in the experiments conducted in 2016 was observed. This result consisted of the greater similarity of selection of lines between the rank sum index and genotype-ideotype distance index, both for advanced lines of onion (11, 12,16, 17, 19, 24, 27, 46 and 48) and for segregating lines (4, 6, 7, 8, 13, 17, 19, 21, 24, 26, 28, 29, 44, 45, 54, 94, 95, and 109) (Table 3).

Table 3. Superior genotypes selected by the rank sum index, genotype-ideotype distance index, and multiplicative index in 109 advanced lines and 227 segregating lines of onion in 2016 and in 53 advanced lines and 110 segregating lines of onion in 2017, Uberlândia, MG, Brazil.

Lines	Index[a]	Genotypes selected
Advanced (2016)	RS	64 108 54 97 100 107 28 104 106 53 70 61 59 26 48 60 16 49 35 34 24 27 25
	GI	107 108 100 64 54 53 104 70 1 48 25 97 65 34 4 28 96 50 84 21 106 90
	M	108 64 100 107 97 53 104 54 85 60 28 61 41 19 106 48 65 50 34 84 94 49
Segregating (2016)	RS	104 58 202 106 49 67 116 59 50 111 170 68 51 12 46 4 91 171 22 15 65 82 134 179 160 57 169 216 203 178 69 42 87 163 13 64 192 186 125 34 55 196 188 164 61
	GI	58 104 202 59 57 67 49 46 2 51 12 178 171 170 50 106 64 32 22 4 169 65 68 82 83 134 116 92 15 216 77 179 13 225 69 91 111 186 56 43 192 23 87 163 223
	M	104 50 58 68 49 51 57 15 67 107 69 59 169 82 170 91 64 216 61 8 22 192 83 171 116 3 186 93 54 4 166 87 77 130 63 125 223 75 65 62 112 16 124 152 88
Advanced (2017)	RS	12 46 48 16 24 13 19 27 18 17 11
	GI	12 46 48 17 9 11 53 27 19 24 16
	M	47 13 12 17 11 18 23 24 46 19 48
Segregating (2017)	RS	6 21 7 54 8 13 109 45 17 4 26 24 94 98 19 28 29 20 44 95 65 46
	GI	29 54 21 7 13 6 45 8 26 28 4 109 17 19 24 44 57 95 25 94 11 34
	M	13 39 6 8 54 19 28 29 51 7 109 21 50 78 45 34 20 63 24 17 47 4

[a]RS: rank sum index; GI: genotype-ideotype distance index; and M: multiplicative index

Various studies suggest greater gain in using the rank sum index in soybean (Bizari et al., 2017), lettuce (Candido et al., 2017), and sour passion fruit (Dalbosco et al., 2018) and the multiplicative index in physical nuts (Bhering et al., 2012), potato (Terres et al., 2015), and common bean (Ribeiro et al., 2018).

The genotypes selected by the different selection index methods in advanced and segregating lines in 2016 and 2017 and the coefficients of coincidence obtained for the genotypes selected are shown in Tables 3 and 4.

A good margin of safety was observed in the selection of superior genotypes since most of the coefficients were greater than 0.5. For the advanced lines studied in 2016, the highest coefficients of coincidence were between the rank sum and multiplicative indices (0.7) and between the genotype-ideotype and multiplicative indices (0.7). In relation to the segregating lines studied in that same year, the most prominent coefficient of coincidence was between the rank sum and genotype-ideotype indices (0.8) (Table 4).

For the advanced lines studied in 2017, the highest coefficients were between the rank sum and genotype-ideotype indices (0.8) and between the rank sum and multiplicative indices (0.8). The segregating lines evaluated in that same year obtained the highest coefficient of coincidence between the rank sum and genotype-ideotype indices (0.8) (Table 4).

In a commercial onion breeding program, weighting by the degree of importance of each agronomic trait during the selection process of genotypes, whether they are lines or hybrids, is a highly relevant aspect. The greatest difficulty for the breeder is in making choices (usually with a large number of accessions evaluated) that are simultaneously practical and effective in obtaining genetic gains.

Consistency was found among some of the genotypes evaluated among the selection methods (Table 4). In addition, satisfactory coincidence

Table 4. Coefficients of coincidence of the selection indices applied to 109 advanced lines and 227 segregating lines of onion in 2016 and to 53 advanced lines and 110 segregating lines of onion in 2017, Uberlândia, MG, Brazil.

Lines	Index	Genotype-ideotype	Multiplicative
Advanced (2016)	Rank sum	0.6	0.7
	Genotype-ideotype	-	0.7
Segregating (2016)	Rank sum	0.8	0.5
	Genotype-ideotype	-	0.6
Advanced (2017)	Rank sum	0.8	0.8
	Genotype-ideotype	-	0.6
Segregating (2017)	Rank sum	0.8	0.7
	Genotype-ideotype	-	0.7

was found between the selection indices (all above 0.5), which implies that the choice of the index should provide the best balance in the distribution of selection gains.

Conclusions

Satisfactory gains for selection in onion were predicted for color, mean weight, firmness, and postharvest durability of bulbs. In all the experiments evaluated, the highest total gains per selection were obtained using the multiplicative index. However, given the versatility of the genotype-ideotype distance index and satisfactory estimated gains, its adoption for selection in onion is also recommended. From the indices, it was possible to select superior onion lines from each experiment. Through calculation of the coefficients of coincidence, all the indices were considered efficient.

Resumen

V.C.V. Segundo, R. Innecco, J.A. de Freitas, G.M. Maciel, J.M.Q. Luz, A.P.O. Nogueira, A.C.S. Siquieroli, y J.V.M. Peixoto. 2022. Dinámica y predicción de ganancias genéticas a través de índices de selección en genotipos (*Allium cepa* L.). Int. J. Agric. Nat. Resour. 62-72. El mayor desafío en los programas de mejoramiento de cebollas es obtener beneficios de la selección de manera satisfactoria. Los índices de selección ya se utilizan en diversas especies, pero son raros en cebolla. El objetivo de este estudio fue caracterizar la ganancia de la selección en germoplasma de cebolla a través de índices no paramétricos. Para lograr esta dinámica, se llevaron a cabo cuatro experimentos con diferentes conjuntos de genotipos. Se evaluaron varias características agronómicas. Las estimaciones de ganancias y selección de genotipos se obtuvieron a partir del índice de selección basado en la suma de rangos, del índice de distancia genotipo-ideotipo y del índice multiplicativo. Para probar la eficiencia de los índices utilizados, se calculó el coeficiente de coincidencia. Las ganancias totales de la selección fueron mayores mediante el uso del índice multiplicativo, siendo los valores de 31,84% para las líneas avanzadas y 37,4% para los genotipos segregantes. Fue posible seleccionar líneas de cebolla superiores en cada experimento. Los coeficientes de coincidencia, todos con valores superiores a 0,5, confirmaron que los índices proporcionaron un margen de seguridad en la selección de genotipos superiores.

Palabras clave: *Allium cepa* L., criterios de selección, mejoramiento de cebolla, selección combinada.

References

Bhering, L.L., Laviola, B.G., Salgado, C.C., Sanchez, C.F.B., Rosado, T.B., & Alves, A.A. (2012). Genetic gains in physic nut using selection indexes. *Pesquisa Agropecuária Brasileira*, 47(3):402–408. https://doi.org/10.1590/S0100-204X2012000300012

Bizari, E.H., Val, B.H.P., Pereira, E.M., Mauro, A.O.D., & Unêda-Trevisoli, S.H. (2017). Selection indices for agronomic traits in segregating populations of soybean. *Revista Ciência Agronômica*, 48(1):110–117. https://doi.org/10.5935/1806-6690.20170012

Candido, W.S., Tobar-Tosse, D.E., Soares, R.S., Santos, L.S., Franco, C.A., & Braz, L.T. (2017). Selection of loose-leaf lettuce breeding lines based on non-parametric indexes. *African Journal of Biotechnology*, 16(40):1984–1989.

Carvalho, A.D.F., Nogueira, M.T.M., Silva, G.O., Luz, J.M.Q., Maciel, G.M., & Rabelo P.G. (2017). Selection of carrot genotypes for phenotypic root characters. *Horticultura Brasileira*, 35(1):97–102. https://doi.org/10.1590/s0102-053620170115

Cruz, C.D. (2006). *Programa GENES: biometria*. Viçosa: Editora UFV, 382 p.

Cruz, C.D. (2013). Genes: A software package for analysis in experimental statistics and quantitative genetics. *Acta Scientiarum. Agronomy*, 35(3):271–276. https://doi.org/10.4025/actasciagron.v35i3.21251

Cruz, C.D., Carneiro, P.C.S., & Regazzi, A.J. (2014). *Modelos biométricos aplicados ao melhoramento genético*. Viçosa: Editora UFV. 668 p.

Cruz, C.D., Regazzi, A.J., & Carneiro, P.C.S. (2012). *Modelos Biométricos Aplicados ao Melhoramento Genético*. Viçosa: Editora UFV. 514 p.

Dalbosco, E.Z., Krause, W., Neves, L.G., Araújo, D.V., Hiega, K.M.R., & Silva, C.G. (2018). Parametric and non-parametric indexes applied in the selection of sour passion fruit progenies. *Revista Brasileira de Fruticultura*, 40(1):1–8. https://doi.org/10.1590/0100-29452018282

DoVale, J.C., Fritsche-Neto, R., & Silva, P.S.L. (2011). Índice de seleção para cultivares de milho com dupla aptidão: minimilho e milho verde. *Bragantia*, 70(4):781–787. https://doi.org/10.1590/S0006-87052011000400008

Epagri - Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina. (2013). *Sistema de produção para a cebola*: Santa Catarina. Florianópolis: Epagri. 106 p.

Havey, M.J. (2018). Onion Breeding. In Goldman I (ed.). *Plant Breeding Reviews*. Hoboken: John Wiley & Sons Inc. p.39–85.

IBGE - Instituto Brasileiro de Geografia e Estatística. (2017). *Levantamento Sistemático da Produção Agrícola*: pesquisa mensal de previsão e acompanhamento das safras agrícolas no ano civil. Rio de Janeiro: IBGE. 81 p.

Kurtz, C., Pauletti, V., Fayad, J.A., & Vieira Neto, J. (2016). Crescimento e absorção de nutrientes pela cultivar de cebola Bola Precoce. *Horticultura Brasileira*, 34(2):279–288. https://doi.org/10.1590/S0102-053620160000200020

Leite, W.S., Unêda-Trevisoli, S.H., Silva, F.M., Silva, A.J., & Mauro, A.O.D. (2018). Identification of superior genotypes and soybean traits by multivariate analysis and selection index. *Revista Ciência Agronômica*, 49(3):491–500. https://doi.org/10.5935/1806-6690.20180056

Machado, D.L.M., Freitas, J.A., Luz, J.M.Q., Maciel, G.M., Nogueira, A.P.O., Finzi, R.R., & Oliveira, R.C. (2019). Genetic divergence between onion populations derived from three different crossing methods. *Genetics and Molecular Research*, 18(4):1–9. https://doi.org/10.4238/gmr18256

Maciel, G.M., Marquez, G.R., Aguilar, A.S., Beloti, I.F., Alves, I.M., & Momesso, M.P. (2019). Onion genotype skills in different planting systems. *Ciência Agrícola*, 17(2):35–41. https://doi.org/10.28998/rca.v17i2.5281

Mulamba, N.N., & Mock, J.J. (1978). Improvement of yield potential of the Eto Blanco maize *(Zea mays* L.) population by breeding for plant traits. *Egyptian Journal of Genetics and Citology*, 7(1):40–51.

Pedrozo, C.A., Benites, F.R.G., Barbosa, M.H.P., Resende, M.D.V., & Silva, F.L. (2009). Eficiência de índices de seleção utilizando a metodologia REML/BLUP no melhoramento da cana-de-açúcar. *Scientia Agraria*, 10(1):31–36. https://doi.org/10.5380/rsa.v10i1.11711

Peixoto, J.V.M., Maciel, G.M., Siquieroli, A.C.S., Pereira, L.M., Luz, J.M.Q., & Marques, D.J. (2020). Comparison between non-parametric indexes in the selection of biofortified curly lettuce. *Comunicata Scientiae Horticultural Journal*, 11(e3351):1–9. https://doi.org/10.14295/cs.v11i.3351

Ribeiro, N.D., Santos, G.G., Maziero, S.M., & Steckling, S.M. (2018). Phenological, plant architecture, and grain yield traits on common bean lines selection. *Revista Caatinga*, 31(3):657–666. https://doi.org/10.1590/1983-21252018v31n314rc

Santos, C.A.F., & Oliveira, V.R. (2011). Melhoramento genético de cebola no Brasil: avanços e desafios. *Horticultura Brasileira*, 29(2):S5727–S5743.

Santos, J.P., Grangeiro, L.C., Sousa, V.F.L., Gonçalves, F.C., Franca, F.D., & Cordeiro, C.J.X. (2018). Performance of onion cultivars as a function of spacing between plants. *Revista Brasileira de Engenharia Agrícola e Ambiental*, 22(3):212–217. https://doi.org/10.1590/1807-1929/agriambi.v22n3p212-217

Subandi, Compton, W.A., & Empig, L.T. (1973). Comparison of the efficiencies of selection indices for three traits in two variety crosses of corn. *Crop Science*, 13(2):184–186. https://doi.org/10.2135/cropsci1973.0011183X001300020011x

Terres, L.R., Lenz, E., Castro, C.M., & Pereira, A.S. (2015). Estimativas de ganhos genéticos por diferentes índices de seleção em três populações híbridas de batata. *Horticultura Brasileira*, 33(3):305–310. https://doi.org/10.1590/S0102-053620150000300005

Vidigal, S.M., Sediyama, M.A.N., Pedrosa, M.W., & Santos, M.R. (2010). Produtividade de cebola em cultivo orgânico utilizando composto à base de desejos de suínos. *Horticultura Brasileira*, 28(2):168–173. https://doi.org/10.1590/S0102-05362010000200005