

# Genetic gain according to different selection criteria for agronomic characters in advanced tomato lines

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**ABSTRACT.** Tomatoes are an important crop in Brazil. In advanced stages of breeding programs, the capacity to select or reject tomato lines becomes complex. We selected tomato lines comparing different selection strategies. We evaluated 115 advanced tomato lines from the Tomato Germplasm bank of the Federal University of Uberlândia. The following characteristics were evaluated: total chlorophyll content, foliar temperature, number of fruits, yield, distance between the first cluster and the soil, transverse and longitudinal fruit diameter, internode length and total soluble solids. Data was submitted to variance analysis, Scott-Knott's test of means, and selection gains estimates: direct and indirect selection, the classic Smith and Hazel index (SH), the Williams' base index (W), the genotype-ideotype distance index (GID) and the Mulamba and Mock's sum of ranks (MM). According to the Scott-Knott's test, the lines clustered in two groups for the variables number of fruits, yield, and distance between the first cluster and the soil. There was no consistency between the different selection indexes. Selecting 9% of the lines, total selection gains estimate for selection indexes were 12.57 (SH), and 38.57% (MM). With genetic gains more equally

distributed among the characters, the MM index is suggested as the most appropriate for advanced stages of tomato breeding programs.

**Key words:** *Solanum lycopersicum*; Selection indexes; Plant breeding

## INTRODUCTION

The tomato crop plays important social and economic roles in Brazil. In 2018, the harvested area in this country was about 51 thousand hectares, producing more than 4.1 million tonnes of tomatoes (Food and Agriculture Organization of the United Nations - FAO, 2018). In tomato breeding programs, several strategies are used by plant breeders in the selection of superior genotypes. Due to the existence of genetic correlations between characters, selecting is a big challenge. When the selection is practiced aiming at only one characteristic, there are usually favorable or unfavorable changes in the remaining characteristics. Whereas, when the selection is simultaneous, these changes tend to be more generalized within the characters. The possibility to predict gains of a specific selection strategy becomes essential for the success of a breeding program (Bhering et al., 2012).

Overall, performance per se is one of the main standards applied in the selection of superior tomato genotypes. For that matter, the univariate analysis using the Scott-Knott test of means (Scott and Knott, 1974) has been widely used by several authors (Araújo et al., 2016; Borba et al., 2017; Finzi et al., 2017; Maciel et al., 2018; Peixoto et al., 2018). Nevertheless, it is known that this type of selection can be inefficient, because it leads to a superior genotype in no more than one characteristic. In this sense, selection indexes are an excellent alternative, once they associate information from various agronomic characters and make possible to attribute selection weights to the most relevant characteristics.

Among the selection indexes, the following can be remarked: the classic Smith (1936) and Hazel (1943) index (SH), the Williams' (1962) base index (W), the genotype-ideotype distance index (Cruz, 2012) (GID) and the index based on the Mulamba and Mock's sum of ranks (1978) (MM). The SH and the W indexes differ mainly in the combination format and in the weighting between the characters. The GID index distinguishes itself for enabling the determination of desired values to each variable, while the MM index does not require establish economic weights and estimating variance and covariance (Rezende et al., 2014). All these indexes provide genetic gain estimations resulting from selection.

Selection indexes have been widely studied in diverse cultivated species, such as alfalfa (Vasconcelos et al., 2010), assai palm (Teixeira et al., 2012), passion fruit (Rosado et al., 2012), maize (Freitas et al., 2013), potato (Terres et al., 2015), and soybean (Leite et al., 2016; Bizari et al., 2017). According to Merk et al. (2012), selection indexes have potential for use in tomato breeding programs aiming at both yield and quality characteristics. However, there are few mentions in the literature regarding the comparison of different selection indexes in advanced stages of tomato breeding programs.

Therefore, our main goal of this article was to compare various selection indexes for determining superior tomato lines.

## MATERIAL AND METHODS

The experiment was carried out from May to July, 2018 at the Vegetable Research Station of the Federal University of Uberlândia, Monte Carmelo City, Minas Gerais State, Brazil (18°42'43,19" S, 47°29'55,8" W and 873 m above sea level). According to the Köppen's classification, the climate is Aw type, characterized by rainy and hot summers and dry winters (Da Motta et al., 2004). The open-air mean temperature in Monte Carmelo city varied from 23.2 (May 13) to 14.1°C (May 20) but, in general, it was close to 20°C during all the experiment.

The evaluated genetic material was 115 advanced tomato lines from the Tomato Germplasm Bank of the Federal University of Uberlândia. The lines were sowed in polystyrene trays (200 cells) on March 1, 2018.

Plants were grown in a hoop-style greenhouse (7 x 21 m), with 4 m ceiling height, covered by a 150-micron polyethylene roof, treated against ultraviolet rays, and white anti-aphid screens as lateral curtains walls. The lines were transplanted into the soil 31 days after the sowing. The soil presented the following characteristics: pH (H<sub>2</sub>O) = 5.9; P available = 30.1 mg.dm<sup>-3</sup>; K = 0.22 cmolc.dm<sup>-3</sup>; Ca<sup>+2</sup> = 2.8 cmolc.dm<sup>-3</sup>; Mg = 1.0 cmolc.dm<sup>-3</sup>; H<sup>+</sup> Al = 3.40 cmolc.dm<sup>-3</sup>; organic matter = 4.2 dag Kg<sup>-1</sup>; index SMP = 3.4; Al = 0.0 cmolc.dm<sup>-3</sup>; CTC pH 7.0 = 7.42 cmolc.dm<sup>-3</sup>; Copper = 2.3 mg.dm<sup>-3</sup>; Zinc = 6.6 mg.dm<sup>-3</sup> and Manganese = 6.6 mg.dm<sup>-3</sup>. Throughout the experiment, the cultural treatments followed the recommendations for tomato crops grown in protected environments (Heuvelink, 2018). The plants were supported by a stake using a string weave system.

The experiment was installed in the randomized block design with 115 treatments (advanced lines) and two replications. The experimental plots consisted of six plants, grown in the spacing of 0.2x1.0 m, totalling 1380 plants inside the greenhouse.

The harvests were performed weekly, from June 8 to July 27, 2018, totalling eight harvests. The fruits from each experimental plot were harvested in a full maturity stage (fully ripe fruit) and the following agronomic characters were assessed:

Total chlorophyll content (Soil Plant Analysis Development index-SPAD) (TC): obtained by five readings with a portable chlorophyll meter, Minolta SPAD-502 model (Jiang et al., 2017), in 2 central plants in the plot. The measurement was performed at a distance of 0.02 m from the edge and 0.05 m from the central leaves vein, followed by the calculation of means.

Foliar temperature (°C) (FT): obtained with an infrared pyrometer, B-max model, in 2 central plants in the plot. The measurement was taken in five leaves per plant, located in the median part of the tomato, with a 15 cm distance between the gadget and the leaves, followed by the calculation of the mean. The time of readings was between 12:00 and 14:30, and performed on a non-cloudy day.

Number of fruits plant<sup>-1</sup>(NF): ratio between the total number of fruits and the number of plants in the plot.

Yield (kg plant<sup>-1</sup>) (YLD): ratio between the weight of harvested fruits and the number of plants in the plot.

Distance between the first cluster and the soil (cm) (DC): distance between the first cluster and the soil, measured with a ruler (cm), in the two central plants in the plot, followed by the calculation of the mean.

Transverse fruit diameter (cm) (TD): measured with a pachymeter in the transverse median part of the fruit. Ten fruits from the central part of the plot were used, followed by the calculation of the mean.

Longitudinal fruit diameter (cm) (LD): measured with a pachymeter in the longitudinal median part of the fruit. Ten fruits from the central part of the plot were used, followed by the calculation of the mean.

Internode length (cm) (I): length between every node of the plant, since the beginning of the first fork in the stem until the first leaf below the last inflorescence. Internode lengths were measured with a ruler (cm) on the two central plants from each plot, followed by the calculation of the mean.

Total soluble solids (°Brix) (TSS): obtained as the mean of 15 fruits harvested from each cluster on the two central plants from each plot. After harvesting, the tomatoes were crushed in a blender and analyzed for total soluble solids using a Portable Digital Refractometer (Atago PAL<sup>-1</sup> 3810).

The obtained data was analyzed by two distinctive ways: univariate analysis (test of means) and selection indexes (selection gain estimation). For the univariate analysis, data was submitted to analysis of variance (F test,  $P < 0.05$ ) and the means were compared by the Scott-Knott test ( $P = 0.05$ ). For the selection gains estimations, 9% of the genotypes were selected with the direct and indirect selection methods; the classical index proposed by Smith (1936) and Hazel (1943) (SH), the Mulamba and Mock's sum of ranks (1978) (MM), Williams' base index (1962) (W); and the genotype-ideotype distance index (Cruz, 2012) (GID). The selection criteria were to reduce I and increase the remaining characters. For all the indexes, an economic weight equivalent to 1 was adopted for all characters, except for yield and total soluble solids, which adopted economic weight 2. Besides, for the GID index, the optimal values and the inferior and superior limits were determined as most desired for the crop. All the analysis were conducted using the software Genes (Cruz, 2013).

## RESULTS

According to the variance analysis (ANOVA), the advanced tomato lines could be weredifferentiated (F test,  $P < 0.05$ ) by foliar temperature, number of fruits, yield, distance between the first cluster and the soil, transverse fruit diameter, and internode length (Table 1). Total soluble solids, longitudinal fruit diameter, and total chlorophyll content in the leaves were statistically equal among the genotypes, with average values of 6.12 (°Brix); 5.4 (cm) and 58.2 (SPAD index), respectively. Using the Scott-Knott test ( $P < 0.05$ ), significant differences were identified only for the number of fruits, yield, and distance between the first cluster and the soil (Table 1).

Considering the variables with significant effect according to the Scott-Knott test (number of fruits, yield, and distance between the first cluster and the soil variables), the advanced lines were segregated in two groups (Table 1). Overall, the average values between the groups were 20.8 versus 14.3 for the number of fruits perplant (31% difference among groups); 1.5 versus 0.9 kilograms for yield (40% difference among groups); and 47.2 versus 58.6 centimeters for the distance between the first cluster and the soil (20% difference among groups).

Univariate analysis (Scott-Knott test) does not allow a conclusive visualization of the genetic variability among the genotypes. The non-detection of significant differences in some variables in the test may have occurred due to the large quantity of data, the amplitude proportion of the differences between treatments, as well as the small number of

replications. It is important to highlight that in breeding programs with a large number of treatments, it is occasionally necessary to reduce the number of replications by reason of the limited number of available seeds, time, space or other resources necessary to execution of the experiments. Thus, using alternative selection techniques is essential, especially considering an experiment with a large number of treatments. In this case, methods for estimating genetic gain can be excellent tools in the selection of superior genotypes.

**Table 1:** Means obtained for nine agronomic characteristics, evaluated in 115 advanced tomato lines.

Gen <sup>a</sup>	TC <sup>2</sup>	FT <sup>*</sup>	NF <sup>*</sup>	YLD <sup>*</sup>	DC <sup>*</sup>	TD <sup>*</sup>	LD	I <sup>*</sup>	TSS	Gen <sup>a</sup>	TC <sup>2</sup>	FT <sup>*</sup>	NF <sup>*</sup>	YLD <sup>*</sup>	DC <sup>*</sup>	TD <sup>*</sup>	LD	I <sup>*</sup>	TSS
1	52.3	21.5	11.6 b	0.9 b	62.0 a	5.1	5.8	11.2	4.6	38	62.8	22.0	20.3 a	1.9 a	42.8 b	6.5	4.3	8.5	8.6
2	48.5	21.9	21.5 a	1.7 a	66.3 a	5.2	5.6	9.6	4.9	39	60.0	22.3	19.6 a	1.2 a	44.3 b	5.6	4.4	8.2	5.2
3	48.2	22.0	22.9 a	1.3 a	53.3 a	4.8	4.8	8.6	5.0	40	59.2	22.1	14.0 b	1.4 a	47.3 b	6.3	5.0	9.2	5.7
4	51.5	22.3	24.8 a	1.6 a	56.8 a	5.4	5.4	9.1	4.8	41	54.6	21.6	29.0 a	1.2 a	56.8 a	4.4	7.9	8.2	6.3
5	53.1	21.4	14.2 b	1.0 b	51.3 b	4.5	9.2	9.8	5.6	42	52.3	21.5	20.4 a	0.7 b	64.0 a	3.7	9.8	8.3	7.7
6	57.6	22.1	14.9 b	1.2 a	59.8 a	5.4	5.3	7.1	5.7	43	54.0	21.9	8.1 b	0.5 b	68.8 a	5.6	5.0	9.5	6.8
7	52.5	22.1	17.5 b	0.9 b	51.0 b	4.2	4.9	10.0	6.7	44	55.6	21.8	13.0 b	1.1 b	50.8 b	5.5	4.9	8.7	5.5
8	50.3	22.3	15.7 b	0.7 b	56.8 a	4.8	4.7	8.5	4.9	45	50.0	22.1	12.0 b	0.8 b	49.8 b	5.0	5.1	7.4	6.2
9	50.7	21.9	15.5 b	1.4 a	53.4 a	6.0	8.2	8.8	4.9	46	54.3	21.6	13.4 b	1.0 b	48.8 b	5.8	5.2	8.7	5.4
10	63.3	21.3	16.5 b	1.2 b	50.0 b	5.3	4.2	8.6	4.9	47	54.1	21.5	17.9 a	1.1 b	54.0 a	5.4	5.4	8.0	5.9
11	62.5	21.5	15.0 b	1.2 a	59.0 a	6.0	5.1	9.0	5.5	48	48.8	22.1	15.6 b	0.9 b	48.8 b	3.7	5.7	10.4	6.0
12	56.8	21.5	23.4 a	1.2 a	56.1 a	6.3	5.2	7.7	6.7	49	59.6	22.0	20.3 a	0.9 b	54.3 a	4.5	3.7	7.5	6.0
13	52.8	21.5	19.2 a	1.4 a	54.8 a	5.5	5.2	10.3	5.9	50	111.9	21.9	10.9 b	0.6 b	57.5 a	6.4	5.4	10.4	6.4
14	59.4	21.2	17.0 b	1.1 b	43.6 b	5.9	4.9	8.7	4.9	51	59.7	22.1	12.7 b	1.0 b	46.5 b	5.1	4.4	7.6	6.0
15	55.7	21.4	23.8 a	1.4 a	47.0 b	5.1	4.0	14.4	4.7	52	57.4	22.2	13.9 b	0.9 b	48.8 b	6.2	5.3	8.1	6.5
16	57.8	21.7	20.2 a	0.8 b	56.4 a	4.5	3.8	8.9	6.4	53	56.1	21.6	17.5 b	1.5 a	46.3 b	5.7	4.7	7.7	5.9
17	57.7	21.4	18.8 a	0.9 b	62.6 a	5.0	4.6	9.6	5.9	54	57.3	22.0	18.9 a	1.4 a	49.3 b	6.7	5.1	8.5	6.4
18	47.7	21.3	20.0 a	1.5 a	54.0 a	4.7	5.6	10.7	6.4	55	57.9	22.2	27.7 a	1.2 a	44.3 b	5.7	4.7	8.3	5.0
19	51.4	21.1	15.6 b	0.6 b	46.3 b	3.9	4.5	11.5	7.1	56	54.3	22.3	13.9 b	1.1 b	43.5 b	5.4	5.0	9.4	5.4
20	48.7	21.3	14.9 b	0.6 b	58.5 a	4.5	5.3	12.5	6.2	57	56.7	22.3	19.9 a	0.9 b	34.8 b	4.9	4.2	7.7	6.8
21	44.6	21.8	13.3 b	0.7 b	71.0 a	4.9	4.6	11.0	6.1	58	58.2	22.3	18.9 a	1.8 a	68.0 a	8.9	7.7	9.3	6.5
22	45.1	21.4	15.7 b	1.1 b	59.5 a	5.1	5.6	9.2	5.5	59	55.6	21.7	15.2 a	1.1 b	53.9 a	6.1	5.1	8.1	6.3
23	54.1	21.5	14.5 b	0.8 b	55.6 a	5.7	5.1	8.1	6.3	60	53.5	22.3	21.0 a	1.5 a	55.5 a	7.2	6.3	8.5	5.9
24	57.5	21.3	20.9 a	0.8 b	64.3 a	4.1	7.3	9.6	6.0	61	53.5	22.2	18.1 a	0.8 b	47.8 b	4.8	4.1	9.0	7.0
25	59.5	21.8	15.3 b	0.7 b	47.0 b	4.9	4.1	8.0	7.1	62	65.5	21.6	22.6 a	1.9 a	55.0 a	5.8	4.8	8.0	6.2
26	118.0	20.5	11.4 b	0.9 b	68.5 a	5.3	4.9	9.2	5.6	63	57.0	21.7	12.5 b	1.5 a	61.0 a	7.5	6.2	8.0	6.2
27	61.2	21.5	13.6 b	0.8 b	55.8 a	6.3	5.3	6.8	7.1	64	61.3	21.5	17.1 b	1.0 b	58.0 a	4.7	4.0	9.5	6.5
28	53.3	21.8	17.0 b	1.2 a	56.3 a	6.0	5.0	8.6	6.2	65	68.0	21.2	21.8 a	1.6 a	51.8 b	5.4	4.4	9.0	5.6
29	57.4	21.8	12.4 b	1.0 b	62.5 a	5.4	4.5	7.8	5.4	66	57.4	21.4	11.9 b	0.7 b	56.6 a	5.9	4.8	8.6	7.6
30	60.0	21.7	19.0 a	1.7 a	63.5 a	6.0	4.8	9.1	7.2	67	53.1	21.7	10.3 b	0.7 b	59.5 a	5.4	4.3	8.3	6.4
31	57.9	22.2	12.6 b	0.8 b	55.3 a	5.2	3.8	8.4	6.5	68	62.6	21.5	12.7 b	1.0 b	49.5 b	6.7	6.3	9.4	5.8
32	61.9	21.5	14.3 b	1.2 a	41.5 b	6.0	5.1	7.5	6.7	69	59.3	21.3	12.8 b	0.9 b	51.8 b	8.2	7.6	8.2	6.4
33	63.0	22.1	14.4 b	1.3 a	52.3 b	6.7	5.6	7.7	6.9	70	55.5	21.4	16.9 b	1.3 a	47.0 b	7.0	9.7	8.1	6.7
34	59.3	22.2	26.1 a	1.9 a	51.3 b	5.2	4.1	8.1	5.3	71	61.0	21.9	18.0 a	1.0 b	45.8 b	5.2	4.5	6.4	5.1
35	60.6	22.3	19.5 a	1.7 a	56.8 a	5.8	4.7	7.6	6.7	72	66.4	21.7	16.7 b	1.5 a	61.8 a	6.3	5.3	8.4	6.5
36	63.3	21.7	20.9 a	2.6 a	54.0 a	7.2	5.4	8.5	6.9	73	63.5	22.2	13.3 b	1.0 b	50.5 b	6.1	4.7	7.6	7.8
37	62.2	22.0	13.0 b	1.2 a	48.0 b	5.1	4.3	7.1	7.4	74	55.2	21.9	17.2 b	1.4 a	55.0 a	8.4	7.4	7.7	6.0

<sup>1</sup>The numerals indicate the advanced tomato lines UFU-T. Means followed by distinct letters in the column differ by the Scott-Knott test at 0.05 significance. \* Significant by the F test (ANOVA) at 0.05 significance. <sup>2</sup>TC: total chlorophyll (SPAD); FT: foliar temperature (°C); NF: number of fruits (plant<sup>-1</sup> fruits); YLD: yield (kg plant<sup>-1</sup>); DC: distance from the first cluster and the soil (cm); TD: transverse fruit diameter (cm); LD: longitudinal fruit diameter (cm); I: Internode length (cm); and TSS: total soluble solids (°Brix).

Direct selection consists of the selection of only one important variable, aiming to obtain maximum genetic gains for such characteristic. Although, focusing in one single character may result on unfavorable gains for other important agronomic characteristics (Cruz, 2012). In this study, direct selection led to the greatest individual gains, but resulted in indirect losses for the remaining characters (Table 2). None of the direct selection led to

satisfying genetic gains estimations in all the evaluated characteristics. The greatest gain estimation was observed in yield (SG = 135.37%), by selecting 9% of the evaluated genotypes, but following a reduction in the number of fruits (SG = -37.65%) and an increased internode length (SG = 50.94%).

**Table 2.** Estimations of selection gain (SG%) on eight variables, by direct and indirect selection, in 115 advanced tomato lines.

Variables	SG%							
	TC <sup>1</sup>	FT	NF	YLD	DC	TD	LD	I
TC	<b>11.41</b>	-4.30	0.85	-1.56	-0.14	-3.90	-2.01	-2.87
FT	-6.89	<b>82.77</b>	-32.25	5.38	-17.74	24.06	-27.97	6.16
NF	-14.18	-7.19	<b>95.04</b>	-37.65	6.41	-9.73	7.41	0.63
YLD	-36.83	-17.35	-18.66	<b>135.37</b>	-44.26	13.54	-21.67	-40.68
DC	42.73	-42.66	-24.31	-10.19	<b>120.57</b>	-50.45	13.52	71.28
TD	-9.44	38.45	-26.01	-8.28	1.05	<b>93.58</b>	-36.29	-2.92
LD	-16.11	-5.82	2.79	-15.75	-6.05	-5.76	<b>48.55</b>	-4.27
I	23.62	-39.59	-6.47	50.94	-41.72	-21.97	-1.86	<b>-46.12</b>
Total	-5.69	4.31	-9.02	118.26	18.12	39.37	-20.32	-18.79

<sup>1</sup>TC: total chlorophyll (SPAD); FT: foliar temperature (°C); NF: number of fruits (plant<sup>-1</sup> fruits); YLD: yield (kg plant<sup>-1</sup>); DC: distance from the first cluster and the soil (cm); TD: transverse fruit diameter (cm); LD: longitudinal fruit diameter (cm); and I: Internode length (cm).

The increase of number of fruits and yield are essential goals in a tomato breeding program. Internode length is also relevant, since it can influence the number of clusters per plant (Finzi et al., 2017). Therefore, selection of superior tomato genotypes should be made considering several characters simultaneously, in order to maximize genetic gains for the greatest number of characteristics as possible (Vasconcelos et al., 2010; Rezende et al., 2014). The selection indexes represent an excellent alternative, allowing simultaneous selection with efficiency (Cruz, 2012; Rosado et al., 2012).

Selection gains estimations (SG%) obtained for all variables (significant or not according to ANOVA) vary among the selection indexes. Generally, by selecting only 9% of the superior genotypes (10 advanced lines), the SG varied from 0.30 to 1.57% for total chlorophyll content; -0.10 to 0.36% for foliar temperature; -6.83 to 6.31% for number of fruits; -0.59 to 26.64% for yield; 2.97 to 11.84% for distance between the first cluster and the soil; 5.50 to 9.41% for fruit diameter; -0.63 to 4.76% for fruit length; and -2.93 to 2.46% for internode length, among all selection indexes (Table 3). In all the selection strategies, total soluble solids did not show positive or negative estimations of SG, which grants the non-genetic variability of the characteristic among the genotypes. These results differ from the Merk et al. (2012) study: analyzing a processing tomato germplasm, these authors found significant genetic variation for soluble solids.

Considering the desirable characteristics in a tomato breeding program, the greatest estimations for selection gains were observed in the MM index (Table 4), especially for the number of fruits (SG = 6.31%) and yield (SG = 26.64%). Besides that, there was an estimation of reduction in the internode length (-2.93%), a favorable characteristic for tomato crops (Finzi et al., 2017).

Supporting these results, in other papers, when different indexes were compared, the MM index presented the most satisfying results for alfalfa, (Vasconcelos et al., 2010), assai palm (Teixeira et al., 2012), passion fruit (Rosado et al., 2012), maize (Freitas et al.,

2013), potato (Terres et al., 2015), and soybean crops (Bizari et al., 2017). Considering only the area under the disease progress curve of the tomato late blight (*Phytophthora infestans*) and fruit quality characteristics (total soluble solids and titratable acidity), Nick et al. (2013) also observed greater total estimated gain using the MM index. In the Leite et al. (2016) study, the W index was the most suitable for soybean advanced lines.

**Table 3.** Estimations of selection gain (SG%) obtained for eight variables, in 115 advanced tomato lines with the basic index proposed by Smith and Hazel (SH), the sum of ranks index of Mulamba and Mock (MM), Williams' base index (W), and the genotype-ideotype distance index (GID).

Index	SG% TC'	FT	NF	YLD	DC	TD	LD	I	Total
W	1.57	-0.10	1.96	14.53	7.00	5.20	0.08	0.72	30.96
SH	0.30	0.00	-6.83	-0.59	11.84	4.72	0.67	2.46	12.57
MM	0.35	0.36	6.31	26.64	2.97	5.5	-0.63	-2.93	38.57
GID	0.98	0.36	-0.78	14.70	4.21	9.41	4.76	-0.12	33.52

\*TC: total chlorophyll (SPAD); FT: foliar temperature (°C); NF: number of fruits (plant<sup>-1</sup> fruits); YLD: yield (kg plant<sup>-1</sup>); DC: distance from the first cluster and the soil (cm); TD: transverse fruit diameter (cm); LD: longitudinal fruit diameter (cm) and I: Internode length (cm).

The W and GID indexes were similar, allowing total gain of 30.96 and 33.52%, respectively, versus 38.57% from the MM index. On the other hand, the classical SH index presented undesirable selection gain values, for the characteristics evaluated. Selecting the ten best genotypes proposed by the index, the SG reached from -6.83, -0.59 and 2.46% for number of fruits, yield and internode length, respectively (Table 4).

Once the indexes with the greatest genetic gain estimates are established, it is possible to select the genotypes with agronomic potential. Overall, the greater genetic gains distributed equally within the evaluated characters (especially number of fruits, yield, and internode reduction) were obtained with genotypes selected by the MM index: UFU-T36, UFU-T58, UFU-T35, UFU-T72, UFU-T38, UFU-T30, UFU-T33, UFU-T83, UFU-T62, UFU-T100 (Table 4).

**Table 4.** Indication of ten superior genotypes of tomato selected by basic index proposed by Smith and Hazel (SH), the sum of ranks index of Mulamba and Mock (MM), Williams' base index (W), and the genotype-ideotype distance index (GID).

W	SH	MM	GID
UFU-T26	UFU-T58	UFU-T36	UFU-T88
UFU-T50	UFU-T43	UFU-T58	UFU-T58
UFU-T87	UFU-T63	UFU-T35	UFU-T87
UFU-T58	UFU-T97	UFU-T72	UFU-T79
UFU-T100	UFU-T21	UFU-T38	UFU-T72
UFU-T72	UFU-T92	UFU-T30	UFU-T36
UFU-T30	UFU-T93	UFU-T33	UFU-T112
UFU-T36	UFU-T29	UFU-T83	UFU-T63
UFU-T97	UFU-T2	UFU-T62	UFU-T74
UFU-T62	UFU-T26	UFU-T100	UFU-T50

Univariate analysis, such as direct and indirect selection, was not appropriate for efficient selection. The use of genetic gain (SG) can reduce significantly the time and

resources needed in the selection of potential genotypes in a breeding program (Heffener et al., 2011). Therefore, the use of selection indexes becomes an essential strategy.

There was no consistency between the different selection indexes and the SH index was not suitable for selecting the lines. The W and GID indexes presented inferior values of total SG estimations in comparison to the MM index. Thus, the MM index is suggested as the most appropriate to select advanced tomato lines.

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## CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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