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The selection of optimum selection index in tomato [*Solanum lycopersicum* L.] by comparing different economic coefficients

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Abstract
In the current study, five biometrical characters were used to construct selection indices in all possible combinations of characters: fruit yield per plant, days to initial flowering, plant height, average fruit weight, and number of fruits per plant. Thirty-one selection indices were constructed by using different weights like equal weight (W_1), genotypic correlation with fruit yield (W_2), phenotypic correlation with fruit yield (W_3), and path coefficients (direct effect) of the characters (W_4)**.** The selection index (I_{135}) having fruit yield per plant, plant height and the number of fruits per plant had the highest percent relative efficiency (PRE) among the rank correlation showed that ranks assigned to genotypes by all weight methods were more or less similar. It is concluded that as per the simplicity of arithmetic, the equal weight method is suitable for the development of the selection index compared to other weight methods.

Keywords: Selection index, percent relative efficiency, genetic gain, tomato, biometrical characters, correlation coefficient

Introduction
The *Solanaceae* family includes the tomato (*Solanum lycopersicum* L.) with the chromosome number 2n = 2x= 24. It is an annual, herbaceous plant with greyish green curled pinnate leaves. Tomato has off-white flowers and fruits are either red or yellow. It is a self-pollinated crop. The origin of tomatoes is Peruvian and Mexican region. It is a fruit that is often consumed as a vegetable, and is widely grown around the world. Tomato is categorized as a berry with lower sugar content compared to other fruits.
Selection plays a vital role in the variety development process. The construction and analysis of selection indices would give the most appropriate weightage to the phenotypic values of each of two or more characters to be used concomitantly for selection. Osei *et al*. (2014) [8] discovered that morphological traits help to determine genotype variability and genetic relationships. Tomato fruit yield is the end result of other yield-contributing traits, and these other traits are also interrelated among themselves (Islam and Khan, 1991) [5].
The objective of the selection index is to maximize the "genetic worth" of a population. The selection index technique was used to study crop improvement using different characters and assigning weights to each character.

Materials and Method
The fifty-six tomato genotypes used in the present study comprised forty-five F_1 hybrids developed in half-diallel fashion, ten parents and one standard check (Arka Rakshak) were collected from the Main Vegetable Research Station (MVRS), AAU, Anand. To create selection indices, five different biometrical characters were used: fruit yield per plant, days to initial flowering, plant height, average fruit weight, and number of fruits per plant.
The goal of most breeding programmes is to improve several characteristics at the same time. Smith's (1936) selection index, based on Fisher's (1936) discriminant function, was used to calculate the genetic worth (H, economic value) of genotypes using different biometrical characteristics of tomato. Because there is no standard weighting procedure, an attempt has been made to construct selection indices using weights such as equal weight [W1], genotypic correlation with fruit yield [W2], phenotypic correlation with fruit yield [W3], and path coefficients (direct effect) of the characters [W4]. To create selection indices, all characters

were given equal weight and a value of 1. The genotypic and phenotypic correlation coefficients between fruit yield and various biometrical characters estimated according to Hazel were calculated (1943). The Wright (1921) [14] path analysis was used to divide the correlation of different variables with fruit yield into direct and indirect effects of these variables on yield. SPAR1 and SPSS 21 software were used for the analysis.

For all four methods, the selection indices were built by using five single characters as well as all possible combinations of five different characters. Each method is made up of 31 selection indices. The genetic gain for fruit yield was used as the baseline to estimate percent relative efficiency (PRE) for all selection indices.

Results and Discussion

Genotype performance was found to be significant for all characters, including fruit yield per plant, days to initial flowering, plant height, average fruit weight, and number of fruits per plant. Fruit yield per plant had a highly significant and positive genotypic correlation with plant height (rg = 0.562) and number of fruits per plant (rg = 0.738), but it had a negative and highly significant genotypic correlation with days to initial flowering (rg = - 0.44). In the phenotypic correlation study for fruit yield per plant, a similar trend was observed (Table 2).

Plant height (rg = -0.427, rp = -0.283) and number of fruits per plant (rg = -0.380, rp = -0.305) correlated negatively and significantly. Plant height and the number of fruits per plant were found to have positive and highly significant genotypic and phenotypic correlation coefficients (rg = 0.518, rp = 0.421). There was no genotypic or phenotypic correlation between the average fruit weight and any of the characters studied.

The findings revealed that the genotypic correlation coefficient is generally greater than the phenotypic correlation coefficient. It is possible to conclude that there is a strong relationship between plant height, number of fruits per plant, and fruit yield per plant. De Souza *et al*. (2012) [2], Tasisa *et al*. (2012) [13], Chernet *et al*. (2013) [1], and Premalakshmi *et al*. (2014) [10] found a positive and highly significant genotypic and phenotypic correlation with plant height and number of fruits per plant in tomato genotypes.

The path analysis (Table 3) revealed that, among the causal variables, the number of fruits per plant had the greatest direct effect (0.609) on fruit yield per plant, followed by plant height (0.188), average fruit weight (0.188), and average fruit weight (0.188). (0.132). This suggests that directing the number of fruits per plant, plant height, and average fruit weight in the desired direction would be very effective for increasing yield. Days to first flowering had a direct negative effect on fruit yield (- 0.145). Characters with a high direct effect have a significant impact on fruit yield. Fruit yield per plant had a negative and non-significant correlation with average fruit weight, but it had a positive direct effect (0.132) on fruit yield per plant. The indirect effect of plant height on fruit yield per plant was 0.255, whereas the indirect effect of days to initial flowering on fruit yield per plant was negative (- 0.185). The other traits had a minor indirect impact on fruit yield. Premalakshmi *et al*. (2014) [10], Meitei *et al*. (2014) [6], and Monamodi *et al*. (2014) [7] all support this finding (2013).

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As Table 5 shows the top three ranking selection indices for various methods with different variable combinations. The results revealed that equal weight had the highest PRE compared to other weights, followed by the genotypic and phenotypic correlation coefficients and the path coefficient. As a result, it can be concluded that equal weight can be used to construct selection indices in order to achieve higher genetic gain.

The spearman's rank correlation study revealed that the equal weight with genotypic and phenotypic correlation except for path coefficients had a highly significant and perfect positive correlation (rs ≥ 0.92) which indicated that these weight methods had a more or less similar ranking of genotypes based on the selection indices (Table 6).

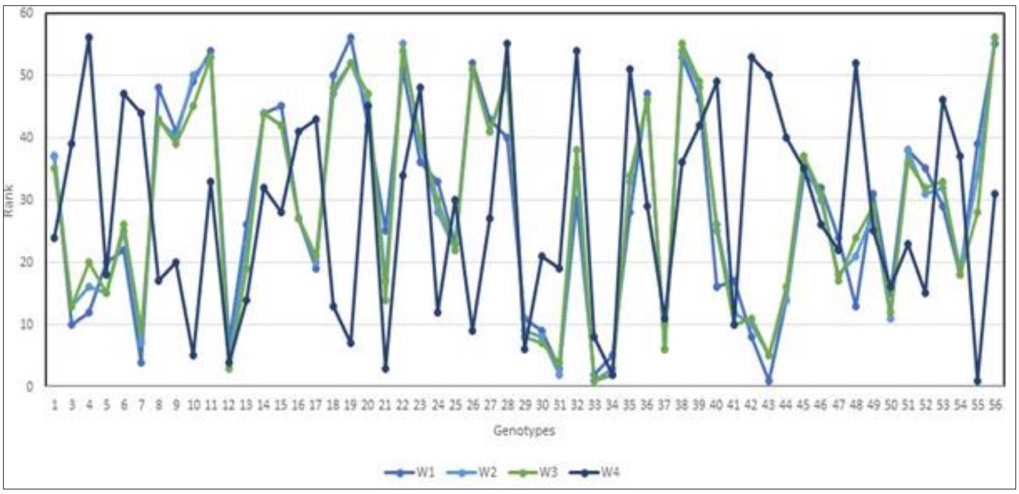

Fig 1: Rank of genotypes with different weight methods in the best selection index

Table 1: Different weights used in the construction of the selection index

Characters	Weights			
	Equal	Genotypic correlation coefficient	Phenotypic correlation coefficient	Path coefficient
Fruit yield per plant	1	1.000	1.000	1.000
Days to initial flowering	1	-0.448	-0.376	0.652
Plant height	1	0.562	0.472	-0.041
Average fruit weight	1	-0.036	-0.030	0.107
Number of fruits per plant	1	0.738	0.704	-0.193

Table 2: Genotypic and phenotypic correlation coefficients between fruit yield and its component characters in tomato

Character		Fruit yield per plant	Days to initial flowering	Plant height	Average fruit weight	Number of fruits per plant
Fruit yield per plant	Rg	1	-0.448**	0.562**	-0.036	0.738**
	Rp	1	-0.376**	0.472**	-0.030	0.704**
Days to initial flowering	Rg		1	-0.427**	0.003	-0.380**
	Rp		1	-0.283*	0.046	-0.305*
Plant height	Rg			1	-0.140	0.518**
	Rp			1	-0.120	0.421**
Average fruit weight	Rg				1	-0.232
	Rp				1	-0.221
Number of fruits per plant	Rg					1
	Rp					1

** - significant @ 1%, * - significant @ 5% level of significance

Table 3: Path coefficients of causal variables on fruit yield per plant in tomato

Character	Days to initial flowering	Plant height	Average fruit weight	Number of fruits per plant	Correlation with fruit yield
Days to initial flowering	-0.145	-0.052	0.006	-0.185	-0.376**
Plant height	0.040	0.188	-0.016	0.255	0.466**
Average fruit weight	-0.007	-0.023	0.132	-0.133	-0.031
Number of fruits per plant	0.044	0.078	-0.029	0.609	0.702**

** - significant @ 1% level of significance Residual effect = 0.433

Table 4: Selection indices having a high genetic gain and percent relative efficiency (PRE) among the different combination of characters in different weight methods

S. No	Selection Index	Genetic Gain	PRE
1.	**Equal weight as weight [W_1]**		
I_5	I = 0.934 X5	93.694	1672.086
I_{35}	I = 1.191 X3 + 0.755 X5	180.787	3226.374
I_{135}	I = -4.572 X1 + 2.000 X3 + 0.623 X5	188.457	3363.237
I_{1235}	I = -5.439 X1 - 0.753 X2 + 2.037 X3 + 0.540 X5	179.754	3207.940
I_{12345}	I = -6.192 X1-1.560 X2 + 2.038 X3 + 0.757 X4 + 0.515 X5	166.012	2962.686
2.	**Genotypic correlation taken as weight [W_2]**		
I_5	I = 0.689 X5	69.146	1233.999
I_{35}	I = 0.634 X3 + 0.624 X5	120.051	2142.474
I_{135}	I = -1.885 X1 + 1.052 X3 + 0.557 X5	129.375	2308.867
I_{1235}	I = -1.948 X1- 0.714 X2 + 1.045 X3 + 0.549 X5	133.225	2377.577
I_{12345}	I = -1.835 X1- 0.624 X2 + 1.045 X3+ 0.005 X4+ 0.551 X5	133.748	2386.902
3.	**Phenotypic correlation taken as weight [W_3]**		
I_5	I = 0.657 X5	65.961	1177.148
I_{35}	I = 0.516 X3 + 0.620 X5	109.439	1953.089
I_{135}	I = -1.308 X1 + 0.850 X3 + 0.566 X5	119.139	2126.192
I_{1345}	I = -1.227 X1+ 0.851 X3 + 0.014 X4 + 0.564 X5	119.594	2134.317
I_{12345}	I = -1.298 X1- 0.599 X2 + 0.844 X3 + 0.004 X4 + 0.558 X5	122.793	2191.393
4.	**Path coefficient taken as weight [W_4]**		
I_5	I = 0.569 X5	57.097	1018.969
I_{35}	I = 0.139 X3 + 0.620 X5	75.761	1352.064
I_{135}	I = 0.530 X1 + 0.205 X3 + 0.611 X5	86.647	1546.326
I_{1345}	I = -1.227 X1+ 0.851 X3 + 0.014 X4 + 0.564 X5	119.594	2134.317
I_{12345}	I = 0.328 X1- 0.627 X2 + 0.206 X3 + 0.122 X4 + 0.592 X5	85.929	1533.519

Table 5: Different combinations of variables in the top three ranking selection indices in different weights methods

Rank		Equal	Genotypic correlation coefficient	Phenotypic correlation coefficient	Path coefficient
Combination of two variables	1	I_{35} (3226.37)	I_{35} (2142.47)	I_{35} (1953.08)	I_{35} (1352.06)
	2	I_{15} (1889.73)	I_{15} (1449.38)	I_{15} (1392.07)	I_{15} (1232.31)
	3	I_{25} (1548.72)	I_{25} (1314.10)	I_{25} (1245.98)	I_{25} (1052.11)
Combination of three variables	1	I_{135} (3363.24)	I_{135} (2308.87)	I_{135} (2126.19)	I_{135} (1546.32)
	2	I_{235} (3102.35)	I_{235} (2217.68)	I_{235} (2016.04)	I_{235} (1376.64)
	3	I_{345} (2988.22)	I_{345} (2153.98)	I_{345} (1962.52)	I_{345} (1311.48)
Combination of four variables	1	I_{1235} (3207.94)	I_{1235} (2377.58)	I_{1345} (2134.32)	I_{1235} (1568.68)
	2	I_{1345} (3125.70)	I_{1345} (2318.54)	I_{2345} (2030.63)	I_{1345} (1510.52)
	3	I_{2345} (2922.88)	I_{2345} (2236.18)	I_{1245} (1459.33)	I_{2345} (1338.33)

Parenthesis value indicates percent relative efficiency (PRE)

Table 6: Rank correlations between different weight methods

Weight	Equal	Genotypic correlation coefficient	Phenotypic correlation coefficient	Path coefficient
Equal	1.000	0.975**	0.959**	-0.076
Genotypic correlation coefficient		1.000	0.994**	0.104
Phenotypic correlation coefficient			1.000	0.170
Path coefficient				1.000

**,*- Correlation is significant @ 0.01 & 0.05 level of significance.

Conclusion

The results of the present investigation can be concluded based on percent relative efficiency and genetic gain; the equal weight had the highest percent relative efficiency. The rank correlation showed that ranks assigned to genotypes by all weight methods were more or less similar. Compared to all other weight methods as per the arithmetic simplicity, equal weight method is most suitable for the development of the selection index. The following selection index, based on the equal weight method, may be used to select the best genotypes for increasing fruit yield per plant.

$$I_{135} = -4.572\ X_1 + 2.000\ X_3 + 0.623\ X_5$$

Where
X_1 = Fruit yield per plant (kg),
X_3 = Plant height (cm),
X_5 = Number of fruits per plant.

Future Scope

Yield is a complex character influenced by number of factors. So direct selection on the basis of yield may not be effective because many component traits affect it. To make an effective selection for higher yield, it is necessary to determine the relative efficiency of selection through the discriminant function technique over straight selection. The plant breeder has certain desired plant characteristics in his mind while selecting particular genotypes and for this, they apply various weights to different traits for arriving at decisions. A better way of exploiting genetic correlations with several traits having high heritability is to construct an index which combines information on all the characters associated with fruit yield. The above research will suggest the use of a selection index, which gives proper weight to each of the two or more characters to be considered and helps plant breeders in selecting characters for tomato improvement.

Author contributions

Dr. P. R. Vaishnav Sir has conceived and designed the analysis; Mayur Kumar Sonagara has collected and contributed the data; Dr. D. J. Parmar sir has performed the analysis; N. Vishnurekha and Unnati Vaghela both has wrote the paper.

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