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Determination of Selection Criteria for Tomato (*Solanum lycopersicum* L.) Yield Component in the Lowland Based on Path Analysis

AUTHORS INFO

Marlina Mustafa
Sembilanbelas Nopember Kolaka University
linamarlinamus@gmail.com
+628111072907

Muhamad Syukur
Bogor Agriculture University
muhsyukur@yahoo.com
+628129553633

Surjono Hadi Sutjahjo
Bogor Agriculture University
surjonohadisutjahjo@yahoo.com
+62811119038

Sobir
Bogor Agriculture University
ridwanisobir@gmail.com
+628128097381

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Abstract

The shifting of tomatoes cultivation from upland to lowland led to a significant decrease of tomatoes production, particularly on tomatoes varieties which are not able to adapt to lowland. Genotypes selection based on appropriate selection criteria is the most effective method to obtain tomatoes genotypes with high production in the lowland. The aim of this study was to determine appropriate selection criteria in the lowland based on high heritability value, high phenotype and genotype correlation to production component, and character relationship closeness with production component through path analysis. This study used a randomized block design with three replications. Selection criteria was chosen based on high heritability value, significant correlations in phenotype and genotype and its high direct impact on fruit weight per plant which were the number of fruits per plant and weight per fruit characters

Keywords: heritability, lowland, path analysis, selection criteria, tomatoes

A. Introduction

The average tomatoes production in Indonesia is still low arounds 6.3 ton/ha compared to Taiwan and India which are 21 ton/ha and 9.5 ton/ha, respectively. One of the reasons behind low tomato production in Indonesia is unsuitable varieties for specific environmental conditions. Most varieties of tomatoes are suitable only to be cultivated in the upland, thus yield and quality of the fruits produced become very low if cultivated in unsuitable envinronment such as lowland (Wijayani & Widodo, 2005).

Tomatoes cultivation in Indonesia is grown in upland with percentage of 60% while the remaining 40% in lowland. The average yield of tomato crops in lowland is about 6.0 ton/ha while in upland may reach 26.6 ton/ha (Purwati, 2007). Purwati (2009) reported that yield of tomato hybrid adaptive to lowland and upland grown on medium land (550 m asl) was only 1.95 kg plant^{-1}, while the yield potential could reach 3 kg plant^{-1} or 35% decrease in yield. Well adapted varieties in both medium land to upland grown in the medium land showed decrease in yield from 4-5 kg plant^{-1} to 1.95 kg plant^{-1} or 50-60%. Whereas, if these varieties are cultivated in the upland (800 m asl), it can achieve yield around 5.32 kg plant^{-1} (Soedomo, 2012).

The shifting of tomatoes cultivation area to lowland led to the risk of decreasing quality and fruit production. Lowland high temperatures impact fruit ripening and fruit growth rate of tomatoes (Adams, Cockshull & Cave, 2001). Increased temperatures of 2-4^{0}C from optimum temperatures affect gametes development and inhibit fruit formation thereby decreasing tomatoes production (Peet, Willits, & Gardner, 1997; Sato, Peet, & Gardner, 2001; Firon, Shaked, Peet, Pharr, Zamski, Rosenfeld, Althan, & Pressman, 2006).

The yield performance (production) is a complex character which is greatly influenced by yield component characteristics. Yield and the components characters are controlled by many genes whose expression is strongly influenced by the environment (Wirnas, Widodo, Sobir, Trikoesoemaningtyas, & Sopandie, 2006). The development of high-yielding varieties can be made through direct selection of the yield performance or indirect selection through several other characters related to yield performance (Falconer & Mackay, 1996). Indirect selection or simultaneous selection to improve yield based on index selection will be more efficient compare to selection by one character or two characters combinations (Moeljopawiro, 2002)

In order to perform simultaneous selection, the used character for selection criteria must be chosen based on heritability value and closeness relationship to the desired character (Yunianti, Sastrosumarjo, Sujiprihati, Surahman, & Hidayat, 2010; Mustafa, Syukur, Sutjahjo, & Sobir, 2017). Using the selected characters, it can be compiled to create effective selection index. In this study the relationship between yield character with other characters is known through correlation analysis and path analysis. The study aimed to select yield component characters based on the correlation, cross-coefficient, and heritability thus it can be used to develop selection index for the yield performance of 30 tomato populations in the lowland.

B. Methodology

The research was conducted in March-August 2012. Seedling was carried out in Plant Breeding Laboratory, Faculty of Agriculture, Bogor Agricultural University. Field plantingwasdone at Leuwikopo Experimental Field of Bogor Agricultural University .

The material used was 30 tomato genotypes collection of Tomato Breeding Team, Plant Genetics and Breeding Section, Department of Agronomy and Holticulture, Bogor Agricultural University (Table 1). Those genotypes originated from several locations in Indonesia and Bogor Agricultural University collections. The experiment was carried out using Completely Randomized Design (CRD) with single factor of tomato genotype consisting of 30 genotypes with three replications.

Activity implementation began with seeding. Watering was done every day in the morning. Fertilization was conducted once a week after seeds were two weeks old since seedling using NPK fertilizer (16:16:16) with water concentration of 10 g l^{-1} applied by leaching at seedlings base. Cultivation activity against plant-disturbing organisms attack were carried out when the attack symptoms on seedbed were seen by spraying pesticides.

Planting was conducted after tomatoes seeds were 30 days old since seedling. Garden plot was made with size of 5 m $\times$ 1 m for each experimental unit with spacing of 50 cm each. Furthermore, each plot was given 20 kg of manure and 0.5 kg of calcium. After calcium and manure addition for two weeks, the plot was covered with silver black plastic mulch then hole was made with distance of 50 cm x 50 cm. Planting was done in the afternoon with one plant per planting hole. Seeds embroidery was conveyed a week after planting. Crop maintenance conducted include watering,

fertilizing, giving pesticides, and weeding. Weeding was carried every once a week after the plants (WAP) were a week old since planting (1 WAP) using NPK fertilizer (16:16:16) with concentration of 10 g l^{-1} around 250 ml $plant^{-1}$. Pesticide spraying was conducted every two weeks using active Mancozeb 80% or Propinep 70% with concentration of 2 g l^{-1}, insecticide made of active Profenofos 500 g l^{-1} with concentration of 2 ml l^{-1} and miticide containing active ingredient Dikofol with concentration of 2 ml l^{-1}. Weed control was done manually. Harvesting activities conducted when fruit criteria was yellow reddish. Harvesting was done every two times in a week for five weeks.

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Table 2. List of genotypes used in this study

No	Genotype	Name/Originated	Fruit Characteristics
1	IPBT1	Intan/Balitsa Lembang	Round big fruit
2	IPBT3	G1-K/IPB	Round small
3	IPBT4	Pointed PSPT/IPB	Medium fruit (pointed)
4	IPBT6	SSH 3/IPB	Round medium
5	IPBT8	4974/IPB	Round medium fruit
6	IPBT13	Karina/PT. BCA	Round medium fruit
7	IPBT21	Mawar/PT.BCA	Rose type fruit
8	IPBT23	Rampai/PT.BCA	Round small
9	IPBT26	Kaliurang	Round big fruit
10	IPBT30	SSH 9/IPB	Round small
11	IPBT33	SSH 10/IPB	Round small
12	IPBT34	M4-HH/IPB	Round medium
13	IPBT43	Bogor1/IPB	Round small
14	IPBT53	Bogor2/IPB	Round small
15	IPBT56	Medan3	Medium, slightly oval, pointed
16	IPBT57	Medan4	Small fruit
17	IPBT58	Bukit Tinggi1	Round medium
18	IPBT59	Bukit Tinggi2	Round small
19	IPBT60	Kediri	Round medium
20	IPBT63	Brastagi3	Tomato fruit, big slightly oval
21	IPBT64	Papua2	Round medium
22	IPBT73	Maros 1	Rose type fruit
23	IPBT74	Maros 2	Medium, oval
24	IPBT78	Maros 6	Tomato fruit, big slightly oval
25	IPBT80	Mantero/PT.BCA	Round medium
26	IPBT82	Fatma/CV.One Tani	Round medium, pointed
27	IPBT83	Ratna/Panah Merah	Tomato fruit, medium, slightly oval
28	IPBT84	Dellana/Cv.Laksmi	Medium, slightly oval
29	IPBT85	Palupi/CV.Enno CoSeed	Medium fruit, sightly oval
30	IPBT86	Roma/Denmark	Rose type fruit

The characters observed in this study were plant height (cm), stem diameter (mm), leaf length (cm), leaf width (cm), day to Flowering (dap), day to harvesting (dap), fruit length (cm), diameter (cm), fruit size (mm), fruit flesh thickness (mm), number of locules (locule), fruit hardness (kg cm^{-1}), water content of fruit (%), total soluble solids (^{o}brix), number of fruits per plant (fruit), weight per fruit (g), fruit weight per plant (g).

C. Rsult and Discussion

1. Heritability

Characters showing high broad-sense heritability value are leaf length, leaf width, fruit length, fruit diameter, fruit size, fruit flesh thickness, number of locules, fruit hardness, number of fruits per plant, weight per fruit, weight per plant and fruit cracking index. While characters with

moderate heritability value are flowering age, harvest age, total soluble solid and water content of fruit (Table 2).

Tabel 2. Nilai Heritabilitas beberapa karakter tomat

Karakter	h^2bs	Kriteria	Karakter	h^2bs	Kriteria
Plant height	0.76	high	Fruit flesh thickness	0.82	high
Leaf length	0.75	high	Number of locules	0.97	high
Leaf width	0.75	high	Total soluble solids	0.35	Moderate
Day to flowering	0.39	Moderate	Fruit hardness	0.70	high
Day to havesting	0.41	Moderate	Water content of fruit	0.38	Moderate
Fruit length	0.92	high	Number of fruit per plant	0.85	high
Fruit diameter	0.91	high	Weight per fruit	0.93	high
Fruit size	0.89	high	Weight per plant	0.62	high

h^2_{bs}: Broad sense heritability

Traits of characters used as selection criteria are high heritability estimate value and correlate significantly with fruit rupture index. Heritability estimate value can be employed to select the characters for selection criteria (Tenaya, Setiamihardja, Baihaki, & Natasasmita, 2003; Lestari, Dewi, Qosim, Rahardja, Rostini, & Setiamihardja, 2006). Heritability estimate value with high criteria can be directly used as selection character in the early generations (Hadiati, Murdaningsih, Baihaki, & Rostini, 2003; Sudarmadji, Mardjono, & Sudarmo, 2007). Several studies on tomatoes indicated high heritability value for the characterof number of flowers per cluster (El-Gabry, Solieman, & Abido, 2014), the number of locules (Li, Li, & Wang, 2007), and the number of fruits per cluster (Hanson, Chen, & Kuo, 2002). High broad-sense heritability indicate that the observed characters are strongly controlled by genetic factors than environmental factors, the genetic variation expressed in plant phenotypic appearance.

2. Phenotype-Genotype Correlation

The phenotype-genotype correlation shows the closeness relationship between characters as presented in Table 3. The result of phenotypic correlation analysis indicated that fruit diameter, number of locules, number of fruits per plant and weight per fruit were positively and significantly correlated to fruit weight per plant. Total soluble solids and fruit hardness were negatively and significantly correlated to fruit weight per plant. Genotype correlations tended to show similar result except for fruit hardness and harvest age. Fruit hardness was significantly correlated to phenotypic weight per plant yet genetically not correlated, while harvest age was phenotypically not correlated with weight per fruit yet significantly genetically correlated. Characters of fruit diameter, number of locules, total soluble solids, number of fruits per plant and weight per fruit showed similar result which was significantly correlated to to weight per fruit in phenotype and genotype.

Positively correlated characters indicate that the addition of these characters will increase fruit weight per plant and vice versa, the addition of negatively correlated characters will decrease fruit weight per plant. It shows that genotypes with heavier weight per plant can be seen from genotypes with large fruit diameter, large number of locules, low total soluble solids, low fruit hardness, higher fruit per plant and heavier weight per fruit. Improvement of these characters will increase tomatoes weight per plant. This finding is supported by Wahyuni (2014) and Saputra (2014) studies that fruit diameter, number of locules, total soluble solids, number of fruits per plant and weight per fruit were significantly correlated to fruit weight per tomato plant. According to Hussien (2014), the character heavily correlated to fruit weight per plant (yield) is weight per fruit. According to Islam, Ivy, Rasul, & Zakaria, (2010), characters positively correlated to tomato yield per plant are number of fruits per plant, fruit length, fruit diameter, and fruit weight per plant.

3. Path Analysis

High correlation only shows the closeness of relationship between characters yet can not show cause-and-effect relationship (Yunianti *et al*., 2010). Path analysis can be used to identify cause-and-effect relationship and sort them into direct and indirect effects (Roy, 2000). Based on path analysis results (Table 4), characters with great direct effect on weight per plant were number of fruits per plant and weight per fruit with direct effect of 0.532 and 0.456, respectively. Fruit size,

total soluble solids, and fruit hardness have negative direct effect which indicates that indirect effect is the cause of the correlation (Singh & Chaudhary, 1979).

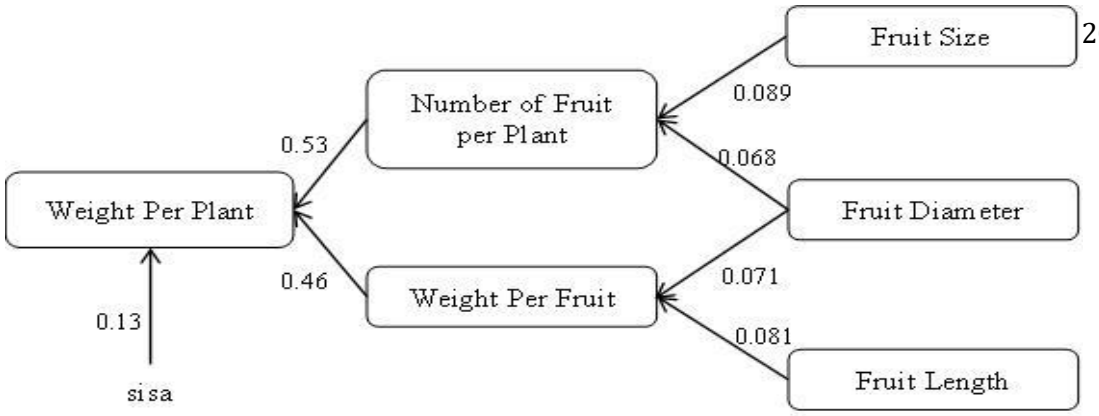

Figure 1. Path diagram of several characters on tomatoes weight per plant

Efforts in determining the characters which can be used as effective selection criteria may be seen from the magnitude of direct effect of fruit weight per plant, correlation between characters with fruit weight per plant and deviation of correlation between independent characters with its direct effect on fruit weight per small plant. If those three characters are fulfilled then the characters will be very effective as selection criteria (Yunianti *et al*., 2010). Based on this determination, the characters contributed to greatest direct effect and total of small indirect effect were the number of fruits per plants and weight per fruit. The relationship path scheme with fruit weight per plant is presented in Figure 1. Based on heritability value, correlation coefficient and cross coefficient, the characters can be used as selection criteria for resistance to fruit weight per plant were the number of fruits per plant and weight per fruit. Characters affecting weight per plant through the number of fruits per plant were fruit size and fruit diameter, while through weight per fruit was fruit diameter and fruit length. Hussien (2014) and Islam *et al.* (2010) reported similar finding that the characters of number of fruits and weight per fruit in tomato plants have great direct effect on tomato production.

D. Conclusion

Selection criteria based on high heritability value, significant phenotypic-genotype correlation and having high direct effect on fruit weight per plant were the number of fruits per plant and weight per fruit.

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Table 3. Phenotype and genotype correlation among character with weight per plant

Character	PH	LL	LD	DF	DH	FL	FD	FZ	FT	NL	TSS	FH	WC	NFP	WF	WP
PH	1	-0.11^{ns}	-0.25*	0.16^{ns}	-0.17^{ns}	-0.11^{ns}	0.39**	0.13 ^{ns}	0.00^{ns}	0.48**	0.05^{ns}	0.13^{ns}	0.06^{ns}	-0.20^{ns}	0.24*	0.20^{ns}
LL	0.08^{ns}	1	0.85**	0.15^{ns}	0.35**	0.56**	0.06 ^{ns}	0.41**	0.50**	-0.41**	0.25*	0.20^{ns}	-0.21*	-0.36**	0.28*	-0.18^{ns}
LD	-0.02^{ns}	0.97**	1	0.09^{ns}	0.27*	0.47**	-0.07 ^{ns}	0.29*	0.50**	-0.43**	0.16^{ns}	0.21^{ns}	-0.20^{ns}	-0.20^{ns}	0.15^{ns}	-0.11^{ns}
DF	0.43*	0.76**	0.67**	1	0.41**	0.47**	0.20 ^{ns}	0.43**	0.39**	-0.14^{ns}	0.19^{ns}	0.30**	-0.21^{ns}	-0.33**	0.37**	-0.01^{ns}
DH	0.29^{ns}	0.81**	0.67**	0.98**	1	0.55**	0.27*	0.52**	0.37**	-0.21^{ns}	0.25*	0.27*	-0.27*	-0.45**	0.44**	-0.16^{ns}
FL	0.08^{ns}	0.78**	0.69**	0.76**	0.76**	1	0.32**	0.86**	0.80**	-0.39**	0.33**	0.39**	-0.43**	-0.69**	0.54**	-0.12^{ns}
FD	0.65**	0.38*	0.22^{ns}	0.22^{ns}	0.63**	0.48**	1	0.76**	0.43**	0.65**	-0.06^{ns}	0.00^{ns}	-0.02^{ns}	-0.59**	0.71**	0.38**
FZ	0.38*	0.69**	0.55**	0.80**	0.80**	0.92**	0.84**	1	0.78**	0.08^{ns}	0.19^{ns}	0.27*	-0.31**	-0.79**	0.76**	0.12^{ns}
FT	0.19^{ns}	0.76**	0.71**	0.75**	0.70**	0.92**	0.61**	0.91**	1	-0.22**	0.16^{ns}	0.28*	-0.41**	-0.62**	0.46**	-0.02^{ns}
NL	0.63**	-0.27^{ns}	-0.33^{ns}	0.06^{ns}	0.04^{ns}	-0.30^{ns}	0.68**	0.15^{ns}	-0.13^{ns}	1	-0.25*	-0.28*	0.34**	-0.04^{ns}	0.25*	0.49**
TSS	0.39*	0.77**	0.66**	0.99**	0.95**	0.74**	0.49**	0.71**	0.65**	-0.04^{ns}	1	0.40**	-0.22*	-0.33**	0.16^{ns}	-0.38**
FH	0.25^{ns}	0.48**	0.55**	0.71**	0.70**	0.66**	0.32^{ns}	0.59**	0.61**	-0.20^{ns}	0.72	1	-0.37**	-0.31**	0.23*	-0.28*
WC	0.36*	0.57**	0.51**	0.87**	0.91**	0.41*	0.52**	0.50**	0.42*	0.25^{ns}	0.90**	0.44*	1	0.29^{ns}	-0.25*	0.07^{ns}
NFP	-0.22^{ns}	-0.49**	-0.29^{ns}	-0.57**	-0.80**	-0.78**	-0.66**	-0.91**	-0.72**	-0.04^{ns}	-0.67**	-0.46*	0.47**	1	-0.72**	0.37**
WF	0.26^{ns}	0.34^{ns}	0.15^{ns}	0.58**	0.67**	0.58**	0.76**	0.82**	0.51**	0.24^{ns}	-0.36*	0.33^{ns}	-0.41*	-0.81**	1	0.34**
WP	0.26^{ns}	-0.35^{ns}	-0.31^{ns}	-0.17^{ns}	-0.43*	-0.18^{ns}	0.47**	0.13^{ns}	-0.06^{ns}	0.62**	-0.64**	-0.33^{ns}	0.15^{ns}	0.47*	0.41*	1

*: significant, **: highly significant, ^{ns}:Not Significant, PH: Plant Height, LL: Leaf Length, LD: Leaf width, DF: day to flowering, DH: day to harvesting, FL: fruit lenght, FD: fruit diameter, FZ: fruit size, FT: fruit flesh thickness, NL: Number of locules, TSS: total soluble solids, FH: fruit hardness, WC: water content of fruit, NFP: number of fruit per plant, WF:weight per fruit, WP:weight per plant. Phenotype correlation vallue: upper right diagonal, genotype corralation value : lower left diagonal.

Table 4. Direct and indirect influence of each character on weight per plant

Character	Direct Effect	FL	FD	FZ	FT	NL	TSS	FH	NFP	WF	Total
FL	0.327		0.023	-0.059	0.000	-0.026	-0.020	-0.019	-0.121	0.081	0.186
FD	0.218	0.023		-0.035	0.000	0.029	0.003	0.000	-0.068	0.071	0.240
FZ	-0.211	-0.059	-0.035		0.000	-0.003	0.007	0.008	0.089	-0.073	-0.305
FT	-0.002	0.000	0.000	0.000		0.000	0.000	0.000	0.001	0.000	-0.001
NL	0.201	-0.026	0.029	-0.003	0.000		0.009	0.008	-0.004	0.023	0.236
TSS	-0.183	-0.020	0.003	0.007	0.000	0.009		0.011	0.033	-0.014	-0.153
FH	-0.148	-0.019	0.000	0.008	0.000	0.008	0.011		0.024	-0.016	-0.131
NFP	0.532	-0.121	0.068	0.089	0.000	-0.004	0.032	0.024		-0.175	0.446
WF	0.456	0.081	0.071	-0.073	0.000	0.023	-0.014	-0.016	-0.175		0.353

FL: fruit lenght, FD: fruit diameter, FZ: fruit size, FT: fruit flesh thickness, NL: Number of locules, TSS: total soluble solids, FH: fruit hardness, NFP: number of fruit per plant, WF:weight per fruit.