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Short Communication: Genetic variability, heritability, correlation, and path analysis in tomato (*Solanum lycopersicum*) under shading condition

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Abstract. *Authors. 2018. Genetic variability, heritability, correlation, and path analysis in tomato (*Solanum lycopersicum*) under shading condition. Biodiversitas 19: 1527-1531.* Information on genetic variability, heritability and character association between quantitative characters with yield are crucial in crop improvement. Eighteen genotypes of tomato were evaluated to study the quantitative genetic of yield and various yield attributing character under shading condition at Pasir Kuda Station, Bogor Agriculture University, West Java, Indonesia from August 2016 until January 2017. The result showed that plant height, dichotomous height, fruit weight, fruit length, fruit diameter, number of fruit per plant, and the fruit set had broad genetic variability and high heritability. Characters with broad genetic variability and high heritability can be used as sources in shading tolerance tomato improvement. Fruit weight and fruit number per plant had significant positive correlation coefficient and direct positive effect on fruit yield per plant. It is, therefore, recommended that fruit weight and fruit of number per plant should be given due importance in selection to develop shading tolerance variety in tomato.

Keywords: Low light intensity, selection, shade tolerance

INTRODUCTION

Indonesia was known as an agrarian country. Most of Indonesia population worked in agriculture. However, the land area of more than 50% of Indonesia farmers was less than 0.5 Ha (Susilowati and Maulana, 2012). Therefore, it is necessary to optimize the utilization of agricultural land to increase the income of Indonesian farmers. One of the efforts that can be done is by the use of low light tolerance varieties in intercropping system. Intercropping systems gave substantially higher net income over mono-cropping with higher net income (Ullah et al. 2007), whereas Polthanee et al. (2011) state that intercropping system can be used by small farmers primarily to increase the diversity of their products and the stability of their annual output through effective use of land and other resources. However, lack of sunlight in plant cultivated under the tree stand or anything in the intercropping system leads to disruption of metabolism process that implicated to the decline of photosynthesis rate, carbohydrate synthesis and productivity of the plant.

Tomato (*Solanum lycopersicum*) has the potential to be developed in the intercropping system. Pranoto (2011) and Bahrun (2012) reported that tomato was a vegetable that usually used as a component of agroforestry, in headwater, middle stream, and downstream Cianjur watershed and one of four plants that suitable to be planted with agroforestry system in every agro-climate zone of headwater of Ciliwung watershed. Baharudin et al. (2014) and Sulistyowati et al. (2016 a) also reported that there were tomato genotypes that tolerant (shade-loving and shade tolerant genotypes of tomato) to low light intensity. However, there was no low light tolerant with high yielding varieties of tomatoes in Indonesia. The used of shade-loving genotypes under 50% shading condition could increase the productivity of tomato of up to 30% (Baharudin et al. 2014; Sulistyowati et al. 2016 a).

Information on the effect of shade on growth and yield tomato under shading condition including an increase of plant height, chlorophyll content and fruit quality and a decrease of a leaf area and productivity (Ilic et al. 2015; Baharudin et al. 2014; Sulistyowati et al. 2016b). However, information genetic variability and character selection that important for shade tolerance with high yielding improvement had not been reported in tomato. The objectives of the research were to estimate the extent of genetic variability, heritability, correlation, direct and indirect effect between yield and yield contributing characters on tomato under shading condition.

MATERIALS AND METHODS

Study area

The experiment was conducted under 50% shading condition at Pasir Kuda Station, Bogor Agriculture

University, West Java, Indonesia from August 2016 until January 2017. The station is located at an altitude of 250 meters above sea level. The soil type at the site is Latosols. SSH3 (shade-loving genotype), 4974 (shade-sensitive genotype) (Baharudin et al. 2014; Sulistyowati et al. 2016a), fifteen elite lines derived from "SSH3 and 4974" and TORA IPB (commercial open-pollinated tomato variety from Indonesia) were used in the experiment. The experiment was conducted arranged in a randomized complete block design (RCBD) with three replications with a plot size of 1 m x 5 m.

Procedures

Seeds of eighteen tomato genotypes were sown in the plastic seedling tray. The 21-day-old seedling (about 4-5 leaves) were then transplanted on the soil beds with a spacing of 50 cm x 50 cm (20 plants per plot). Black shade plastic net was used to reduce light intensity by up to 50% (the height of shade plastic net poles was 2 meters). Lime and manure were applied 2 weeks before planting with respectively 2 t ha^{-1} of dolomite and 0.5 kg per planting hole of manure. Organic fertilizer was applied every week using 250 mL per plant of NPK fertilizer solution. NPK (16-16-16) in a concentration of 10 g L^{-1} was employed at the vegetative phase, and NPK (16-16-16) in a concentration of 15-20 g L^{-1} was applied at the generative stage. Weeding was scheduled for two weeks, four weeks, and six weeks after planting. The irrigation was done every day to prevent drought or water shortages. The crop was protected from insect, pest, and diseases by using the recommended pesticide. The harvesting was conducted in the next three months after planting. The observation was recorded on five plants per plot for plant height, internode length, stem diameter, dichotomous height, fruit weight, fruit length, fruit diameter, percent of fruit set, the fruit of number per plant, and fruit yield per plant.

Data analysis

Average data were subjected to analysis of variance following Steel and Torrie (1981). Broad-sense heritability [Hbs] was estimated according to Lush (1949) and Johnson et al. (1955). Heritability values were categorized as low (<20%), moderate (20-50%) and high (>50%) following Syukur et al. (2010). The expected genetic advance (GA%) on 5% selection intensity was estimated and classified as low (<10%), moderate (10-20%) and high (>20%) following the method is given by Lush (1949). Phenotypic correlation coefficients were calculated by standard procedures (Johnson et al. 1955). Correlation coefficients were further partitioned into components of direct and indirect effects by path analysis (Saleem et al. 2013).

RESULTS AND DISCUSSION

Analysis of variance revealed highly significant mean all characters (Table 1) the existence of among the genotypes under shading condition in tomato as reported elsewhere (Baharudin et al. 2014; Sulistyowati et al. 2016a). The coefficient of variation (C.V) was less than 20% for almost all character indicating the precision in the data recorded (Table 1).

The phenotypic variance and phenotypic coefficient of variation (PCOV) were higher than the genotypic variance and genotypic coefficient of variation (GCOV). The results indicated that the apparent due to genetic factors but also due to the environmental condition. Therefore, selection for such traits sometimes might be misleading. Wide genotypic variance (Table 2) and high heritability (Table 3) for fruit height, dichotomous height, fruit weight, fruit length, fruit diameter, number of fruit per plant, and fruit set indicated influenced of genotypes higher than environment on variability of these characters under shading condition, whereas influenced of environment higher than genotypes on variability of internode length, stem diameter, fruit diameter and yield per plant.

According to Johnson et al. (1955), heritability estimates along with genetic advance were usually more helpful than heritability alone in predicting the genetic gain under selection. Fruit weight, fruit length, fruit set and a number of fruit per plant had high heritability and high genetic advance besides wide genotypic variation under shading condition. Similar findings were reported by various researchers (Meitei et al. 2014; Saleem et al. 2013; Ghosh et al. 2010; Rani and Anitha 2011; Mohamed et al. 2012) in normal condition.

The result indicated these characters were most likely to be influenced by additive gene effects and selection for the improvement of those characters would be effective in early generations (F2-F3) for the development of superior genotypes (Saleem et al. 2013). The yield of fruit had moderate heritability and genetic advance in this study, which is in contrast to various researchers earlier (Meitei et al. 2014; Saleem et al. 2013; Ghosh et al. 2010; Rani and Anitha 2011; Mohamed et al. 2012).

Correlation among characters is important in plant breeding program because it can predict the improvement a character through other characters (Kuswantoro 2017) and proffers a way forward for a simultaneous selection scheme in more than one trait (Izge et al. 2012). The result showed that plant height (0.24), internode length (0.48), dichotomous height (0.41), fruit weight (0.61), fruit length (0.49), fruit diameter (0.45), and number of fruit per plant (0.48) had significant positive correlation with fruit yield per plant (Table 4) under shading condition which indicated these characters were potential for a simultaneous selection scheme in more than one trait for shade tolerance of tomato with high yielding improvement. Similar results were also reported in normal condition (Meitei et al. 2014; Saleem et al. 2013; Rani and Anitha 2011; Mohamed et al. 2012; Islam et al. 2010; Mahapatra et al. 2013; Meena and Bahadur 2014; Hidayatullah et al. 2008) but contrast to Tiwari and Upadhyay (2012). According to Haydar et al. (2007), the positive associations of these traits may lead to yield increases. This phenomenon also can be explained in a way that total fluctuations in yield are governed principally by changes in one or more component.

Table 1. Estimates of mean, range and mean square for different characters of 18 tomato genotypes under shading condition

Characters	Means	S.E (±)	Range			Means square		CV (%)
Plant height (cm)	134.09	2.61	90.30	-	171.30	4.38	**	9.99
Internode length (cm)	4.45	0.05	3.80	-	5.30	3.15	**	6.80
Stem diameter (mm)	8.65	0.61	4.57	-	11.70	8.41	**	9.18
Dichotomous height (cm)	38.27	0.70	5.27	-	7.70	6.12	**	8.30
Fruit weight (g)	17.37	1.00	8.16	-	47.36	14.49	**	17.97
Fruit length (mm)	32.20	0.08	23.00	-	52.87	20.38	**	7.11
Fruit diameter (mm)	28.92	0.56	19.81	-	42.99	6.87	**	8.39
Number of fruit per plant	46.81	1.81	22.00	-	77.00	3.32	**	21.28
Fruit set (%)	59.02	2.09	25.00	-	88.89	7.99	**	14.40
Yield per plant (g)	780.49	39.40	263.12	-	1750.98	2.60	**	30.01

Note: ** Significant at level of 1%.

Table 2. Estimates of the phenotypic and genotypic coefficient of variation and variance of 18 tomato genotypes under shading condition

Characters	σ^2_p	σ^2_g	2 $\sigma_{\sigma 2g}$	Criteria	PCOV	GCOV
Plant height (cm)	381.98	202.48	180.42	Wide	14.58	10.61
Internode length (cm)	0.16	0.07	0.07	Wide	8.90	5.75
Stem diameter (mm)	2.55	1.82	2.36	Narrow	18.46	15.57
Dichotomous height (cm)	27.29	17.20	13.76	Wide	13.65	10.84
Fruit weight (g)	54.98	45.24	31.63	Wide	42.69	38.73
Fruit length (mm)	0.39	0.34	0.23	Wide	19.41	18.06
Fruit diameter (mm)	17.38	11.50	8.95	Wide	14.42	11.73
Number of fruit per plant	229.57	124.42	109.25	Wide	32.37	23.83
Fruit set (%)	240.63	168.40	127.20	Wide	26.28	21.99
Yield per plant (g)	89993.43	31931.28	38497.08	Narrow	38.44	22.90

Note: σ^2_p = phenotypic variance, σ^2_g = genotypic variance, $\sigma_{\sigma 2g}$ = standard deviation of genotypic variance, PCOV = phenotypic coefficient of variation, GCOV = genotypic coefficient of variation.

Table 3. Estimates of heritability and the genetic advance of 18 tomato genotypes under shading condition

Character	Hbs	Category	GA	%GA	Category
Plant height (cm)	53.01	High	10.08	7.52	Low
Internode length (cm)	41.72	Moderate	0.21	4.62	Low
Stem diameter (mm)	71.15	High	2.83	40.48	High
Dichotomous height (cm)	63.04	High	5.44	14.22	Moderate
Fruit weight (g)	82.29	High	9.37	53.96	High
Fruit length (mm)	86.59	High	0.76	23.61	High
Fruit diameter (mm)	66.16	High	3.75	12.97	Moderate
Number of fruit per plant	54.20	High	11.82	24.52	High
Fruit set (%)	69.98	High	12.02	20.36	High
Yield per plant (g)	35.48	Moderate	129.47	16.19	Moderate

Note: Hbs = broad sense heritability, GA = genetic advance.

Table 4. Correlation coefficient among different yield and yield attributing characters in tomato under shading condition

	PH	IL	SD	DH	FW	FL	FD	NFP	FS
IL	0.21								
SD	0.13	-0.10							
DH	0.01	0.39 **	-0.10						
FW	-0.04	0.45 **	-0.25	0.74 **					
FL	0.01	0.48 **	-0.31 *	0.75 **	0.94 **				
FD	-0.09	0.26	-0.13	0.55 **	0.78 **	0.74 **			
NFD	0.20	0.05	0.38 **	-0.28 *	-0.35 **	-0.44 **	-0.28 *		
FS	-0.05	-0.18	0.03	-0.31 *	-0.44 **	-0.43 **	-0.47 **	0.47 **	
YP	0.24 **	0.48 **	0.00	0.41 **	0.61 **	0.49 **	0.45 **	0.47 **	-0.01

Table 5. Direct (diagonal) and indirect effect of different quantitative traits on yield in tomato under shading condition

	PH	IL	SD	DH	FW	FL	FD	NFP	FS	rXY
PH	**-0.123**	0.051	0.032	0.003	-0.009	0.003	-0.023	0.048	-0.013	0.243
IL	0.100	**0.046**	-0.048	0.184	0.216	0.230	0.126	0.025	-0.086	0.478
SD	0.000	0.000	**-0.020**	0.000	0.000	-0.001	0.000	0.001	0.000	0.002
DH	0.005	0.156	-0.040	**-0.062**	0.298	0.303	0.224	-0.112	-0.126	0.406
FW	-0.021	0.275	-0.152	0.448	**0.879**	0.570	0.473	-0.214	-0.266	0.609
FL	0.007	0.234	-0.148	0.362	0.454	**-0.125**	0.358	-0.211	-0.210	0.485
FD	-0.043	0.119	-0.059	0.250	0.353	0.335	**0.013**	-0.128	-0.212	0.454
NFD	0.093	0.025	0.177	-0.130	-0.166	-0.205	-0.133	**0.756**	0.221	0.471
FS	0.000	0.001	0.000	0.002	0.003	0.003	0.004	-0.004	**0.047**	-0.008

Path coefficient analysis provides an effective means of partitioning direct or indirect causes of relationships. Since crop yield is affected by many factors, selection based on correlation alone may be misleading because it measures only the mutual association between two characters (Izge et al. 2012). Path coefficient analysis, however, specifically measures the relative importance of different yield components. Path coefficient analysis showed that fruit weight had highest direct positive effect (0.879) on yield followed by number of fruit per plant (0.756) which indicated that direct selection for these characters might be effective and there is a possibility of improving yield per plant through selection based on these characters (Ghosh et al. 2010) under shading condition. Internode length (0.046), fruit diameter (0.013), and fruit set (0.047) also expressed a positive direct effect on yield but in low magnitude. The direct selection for these characters would be beneficial for crop improvement since most of these characters also showed the significant positive coefficient of correlation on yield (Rani and Anitha, 2012). Fruit set had a high positive indirect effect (0.221) on yield via a number of fruit per plant. It, therefore, means that fruit set character contributed very much to fruit yield tomato in shading condition.

To conclude, wide genotypic variability and high heritability were found on fruit height, dichotomous height, fruit weight, fruit length, fruit diameter, number of fruit per plant, and fruit set which indicated influenced of genotypes higher than environment on these characters in tomato under shading condition. Fruit weight and a number of fruit per plant had a high positive direct effect on fruit yield, whereas fruit set had a high positive indirect effect on fruit yield via a number of fruit per plant which indicated that these characters contributed very much to fruit yield tomato in shading condition. In perusal to genotypic variability, heritability with high genetic advance, significant positive correlation and desirable direct and indirect effect of fruit weight, number of fruits per plant and fruit set on fruit yield per plant, it could be conclude that these characters could be used as selection characters for the development of inbred lines following pure line selection scheme in succeeding generation in tomato under shading condition.

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