Journal of Applied Horticulture, 18(2): 154-159, 2016

Selection of shade-tolerant tomato genotypes

D. Sulistyowati[1]*, M.A. Chozin[2], M. Syukur[2], M. Melati[2] and D. Guntoro[2]

*[1]Agronomy and Horticulture Study Program, Post Graduate School, Bogor Agricultural University (IPB), and Bogor Agricultural Extension Institute (STPP Bogor). [2]Department of Agronomy and Horticulture, Faculty of Agriculture, Bogor Agricultural University (IPB), Bogor, Indonesia. *E-mail: dwiwantisulistyo@yahoo.com*

Abstract

Tomato genotypes exibit different shade intolerance and shade-tolerant tomatoes have potential for vegetable-agroforestry system. To obtain shade-tolerant tomatoes, a study on several tomato traits were evaluated on their morphological and physiological characteristics and their yield as responses to low light intensity. This experiment was conducted at farmer's field, Bogor (October 2014-February 2015) using nested factorial design with three replications. Study was conducted on 50 tomato genotypes cultivated under 50 and 100% light intensity. Variables observed were: leaf number and area, flower number, fruit number, fruit weight and production, flowering and harvesting time. The tolerance levels of tested genotypes were classified based on plant relative productivity rate. Analysis of variance was used to differentiate between genotypes within response group; principal component analysis to define variance characters between genotypes; and cluster analysis using Euclidean distance method to determine relationship among tomato genotypes and similarity level . The 50 genotypes under shading condition were classified into 5 shade-loving genotypes, 16 shade-tolerant genotypes, 15 shade-moderately-tolerant genotypes and 14 shade-sensitive genotypes. First two principal components explained 57.19% variation. The first principal component was plant production and reproduction with the value of 37.69%; and the second one was plant morphological characters with the value of 19.50%. The dendrogram from cluster analysis separated 50 genotypes to 3 clusters with a distance of 20. There were 7 genotypes in the first cluster, 11 genotypes in the second cluster; and 32 genotypes in the third cluster.

Key words: Cluster analysis, euclidean distance, principal component analysis, relative productivity

Introduction

Tomato (*Solanum lycopersicum*), originally came from American Southwest namely Peru and Mexico (Peralta and Spooner, 2007). Although tomato needs cold and dry climate for its high quality and productivity (Nicola *et al.,* 2009), it is able to adapt in wide range of climates from temperate to hot and wet tropical areas. Tomato production in Indonesia (wet tropical) could be increased with the intensification in cultivation or increasing production area. It can be cultivated in multiple cropping systems such as intercropping, relay cropping, sequential cropping, interculture and agroforestry. Generally, farmers in Java Island cultivate the vegetable plants under full light condition, and have little knowledge in vegetable cultivation with intercropping or agroforestry system.

Lack of sun light in tomato plant cultivated under the tree stand (agroforestry) or anything as interculture (multiple cropping), leads to disruption of metabolism process that implicated to the decline of photosynthesis rate and carbohydrate synthesis. Low light intensity caused low growth rate and productivity of tomatoes. Manurung *et al.* (2008) showed that in agroforestry system with low light intensity at 32-174x1000 lux, there was a decrease (as much as 26.6%) in tomato yield per plant compared to those under full light condition. Tomato productivity in medium light-intensity (43-540 x 1000 lux) and full sun-light (482-540 x 1000 lux) were significantly not different (468 and 436 g/plant, respectively), but there was a significant difference with the productivity in low light (319 g/plant) conditions.

Tomato is a vegetable that usually used as a component of agroforestry, in headwater, middle stream, and downstream Cianjur watershed and one of four plants suitable to be planted with agroforestry system in every agro-climatic zone of headwater of Ciliwung watershed (Pranoto, 2011; Bahrun, 2012). Baharudin *et al.* (2014) found that under shade level of 50%, 20 tomato genotypes cultivated in polybags showed high variances in plant growth, yield and quality as responses to low light intensity. Based on relative productivity, tomato genotypes could be classified into 4 groups namely shade-loving, shade-tolerant, shade-moderately-tolerant and shade-sensitive plants. Plant growth response in polybags will not be the same as planting directly in the ground which is the actual growing condition. There are a lot of tomato genotypes for which information on performance under low light is limited.

Genotype/variety that could adapt in unfavorable condition (abiotic stress) had better stability and could be used in breeding program. An effort to develop shade-tolerant tomato could be done through plant breeding program. Identification of genotypes tolerance is the first step in developing tolerant cultivar (Zainal *et al.*, 2011). This research aimed to study plant morphological characters, production and reproduction of 50 tomato genotypes under low light intensity (50%) for identifying shade tolerant types.

Materials and methods

Fifty tomato genotypes from the collection of Plant Breeding Division, Department of Agronomy and Horticulture, Faculty of Agriculture, Bogor Agricultural University, were used. The descriptions of these genotypes are presented in Table 1. This experiment was conducted at farmer's field Bogor from October 2014 to February 2015. The experiment was arranged in nested design with 2 factors and 3 replicates. The first factor consisted of two levels of shading intensity, *i.e.* no shading (0%) as control and 50% shading. The observations were recorded on 5 plants from each genotype.

Seeds of 50 tomato genotypes were sown in seedling tray. The 25-day-old seedlings (about 4-5 leaves) were then transplanted on the soil beds with a spacing of 50 cm x 60 cm. Black shade net was used to reduce light intensity up to 50% (the height of shade net poles was 2 meter) and no shade net for control. Daily average of air temperature in 50% shading was lower (27 ^oC) than no shading treatment (27.5 ^oC). However, the humidity in 50% shading was higher (64.5%) than no shading (63.5%).

Lime and manure were applied 2 weeks before planting with 2 tons/ha dolomite and 0.5 kg animal manure, respectively to each planting hole. Fertilizer was applied every week using 200 mL plant^{-1} of NPK fertilizer solution. NPK (16-16-16) in concentration of 10 g L^{-1} was used at vegetative phase and NPK (10-55-10) in concentration of 2 g L^{-1} was applied at generative phase. The variables observed were leaf number and area, fruit number, fruit weight, fruit weight per plant, flowering time, flower number and harvesting time. These characters were also used to construct the dendrogram and clustering.

Genotypes were classified based on relative productivity rate, yield under shade against control in shade level (Djukri and Purwoko, 2003). The classification for shading intolerance were (1) sensitive genotypes (relative productivity <60%); (2) moderate genotypes (relative productivity (60-80%)); (3) tolerant genotypes (relative productivity >80-100%); (4) shade-loving genotypes (relative productivity >100%).

$$\text{Relative productivity} = \frac{\text{Productivity in 50\% shade}}{\text{Productivity without shade}} \times 100$$

Methods used for statistical analysis were (1) analysis of variance to differentiate between genotypes within group response, using orthogonal contrast test α = 5%, (2) principal component analysis to define characters variance between genotypes and to classify genotypes by 8 characters (production, reproduction, and morphological characters), and (3) cluster analysis using Euclidean distance matrix to determine relationship among tomato genotypes and its similarity level. Orthogonal contrast test was done using SAS software version 9.1.3, while principal component analysis and cluster analysis was done by using SPSS software version 16.

Results

Screening based on relative productivity: The tomato yield varied with genotypes; this indicated that tomato genotypes responded differently to shade. The highest productivity rate in plants that were not shaded obtained from genotype Brastagi 1

Table 1. Plant numbers and descriptions (fruit size and shape) of tomato genotypes

No.	Genotypes	Descriptions	No.	Genotypes	Descriptions
1.	Intan	Intermediate/indented	26.	Brastagi 4	Very small/flat
2.	GI-K	Very small/flat	27.	Kediri 2	Small/indented
3.	Pointed PSPT	Very small/flat	28.	Papua 1	Intermediate/indented
4.	SSH 3	Intermediate/indented	29.	Lembang 3	Small/indented
5.	4974	Intermediate/indented	30.	Brastagi 6	Intermediate/indented
6.	Karina	Small/indented	31.	Brastagi 7	Small/indented
7.	Gondol	Small/indented	32.	Maros 1	Small/indented
8.	Tuban 2	Small/indented	33.	Maros 3	Intermediate/indented
9.	Mawar	Very small/flat	34.	Maros 6	Small/indented
10.	Kaliurang	Small/indented	35.	Montero	Small/indented
11.	Tomat kecil 1	Very small/flat	36.	Ratna	Very small/flat
12.	Apel Belgia intermediet	Very small/flat	37.	Dellana	Intermediate/pointed
13.	SSH 9	Very small/flat	38.	Palupi	Intermediate/indented
14.	SSH 10	Small/indented	39.	Roma	Small/indented
15.	M4-HH	Small/indented	40.	Marglobe	Small/indented
16.	Bogor	Very small/flat	41.	Mirah	Intermediate/indented
17.	Medan 3	Very small/flat	42.	Tomat buah	Intermediate/indented
18.	Medan 4	Very small/flat	43.	Tora	Very small/flat
19.	Bukittinggi 1	Small/indented	44.	F 6003008-1-12-10-3	Very small/flat
20.	Bukittinggi 2	Very small/flat	45.	F 6003008-1-12-10-10	Very small/flat
21.	Kediri 1	Very small/flat	46.	F 6003008-1-12-16-2	Very small/flat
22.	Brastagi 1	Very small/flat	47.	F 6004001-8-16-14-12	Very small/flat
23.	Brastagi 2	Very small/indented	48.	F 6004009-6-4-10-10	Very small/flat
24.	Brastagi 3	Very small/flat	49.	F 6004009-5-7-10-10	Very small/flat
25.	Papua 2	Very small/flat	50.	F 6005001-4-1-12-5	Intermediate/indented

(1737.00 g/plant) and the lowest by Gondol variety (437.33 g/plant) (Table 2).

Based on relative productivity criteria by Baharudin *et al.* (2014), the 50 genotypes were classified into 5 shade-loving genotypes, 16 shade-tolerant genotypes, 15 shade-moderately-tolerant genotypes and 14 shade-sensitive genotypes. However, it seemed that the intolerance level to shading did not always represent the plant yield. Based on Table 2, there were varieties with low productivity (437.33 g/plant or 614.67 g/plant) but they were classified as tolerant or shade-loving plant.

Diversity in characters: Difference among genotypes (not presented) and variation between response groups (Table 3) can be seen in most morphological, production and reproduction characters. Genotypes of sensitive to shade loving group can be identified by lower leaf number, flower number, fruit weight and fruit weight per plant (productivity) as compared to genotypes of tolerant and shade-loving plant groups.

Principal component analysis (PCA): Table 4 presents eignvalues of 2 major components of 8 characters (morphological, production and reproduction) of tomato. These two major components accounted for 57.19% of the total variance. This

Table 2. Tomato yield per plant and response groups of tomato genotypes

No.	Genotypes	Yield fresh tomato (g/plant) 0%	100%	Relative productivity (%)	Shade tolerance categories
1.	Intan	1002.33	646.00	65	Moderate
2.	GI-K	1665.67	1453.67	87	Tolerant
3.	Pointed PSPT	1564.67	1121.33	72	Moderate
4.	SSH 3	819.67	1166.00	143	Shade-loving
5.	4974	1182.67	491.67	42	Sensitive
6.	Karina	1197.33	1012.67	84	Tolerant
7.	Gondol	437.33	400.00	91	Tolerant
8.	Tuban 2	877.00	628.33	72	Moderate
9.	Mawar	754.00	680.67	91	Tolerant
10.	Kaliurang	906.33	322.67	35	Sensitive
11.	Tomat kecil 1	867.67	712.00	82	Tolerant
12.	Apel Belgia intermediet	1239.33	1381.00	111	Shade-loving
13.	SSH 9	1108.00	1033.67	93	Tolerant
14.	SSH 10	1144.33	1070.33	94	Tolerant
15.	M4-HH	1004.67	954.00	95	Tolerant
16.	Bogor	894.67	761.67	85	Tolerant
17.	Medan 3	812.33	757.33	94	Tolerant
18.	Medan 4	1040.33	1294.67	124	Shade-loving
19.	Bukittinggi 1	1260.67	856.00	68	Moderate
20.	Bukittinggi 2	802.67	662.33	83	Tolerant
21.	Kediri 1	583.33	514.33	88	Tolerant
22.	Brastagi 1	1737.00	297.67	17	Sensitive
23.	Brastagi 2	1429.33	921.67	64	Moderate
24.	Brastagi 3	1074.67	410.33	38	Sensitive
25.	Papua 2	1139.67	1167.67	103	shade-loving
26.	Brastagi 4	821.67	756.67	93	Tolerant
27.	Kediri 2	1256.33	376.67	30	Sensitive
28.	Papua 1	1231.33	479.00	39	Sensitive
29.	Lembang 3	1325.00	308.33	23	Sensitive
30.	Brastagi 6	1029.67	464.33	45	Sensitive
31.	Brastagi 7	1321.33	816.33	62	Moderate
32.	Maros 1	1185.00	597.00	50	Sensitive
33.	Maros 3	614.67	676.33	111	shade-loving
34.	Maros 6	1007.00	756.00	75	Moderate
35.	Montero	1321.00	828.00	63	Moderate
36.	Ratna	1291.33	834.67	64	Moderate
37.	Dellana	1408.67	579.67	41	Sensitive
38.	Palupi	1048.67	865.33	83	Tolerant
39.	Roma	1012.33	644.67	34	Sensitive
40.	Marglobe	1135.00	352.67	31	Sensitive
41.	Mirah	1245.67	778.00	62	Moderate
42.	Tomat buah	1162.00	727.00	63	Moderate
43.	Tora	937.67	301.67	32	Sensitive
44.	F 6003008-1-12-10-3	1043.67	894.00	86	Tolerant
45.	F 6003008-1-12-10-10	1200.67	775.67	65	Moderate
46.	F 6003008-1-12-16-2	886.67	779.67	88	Tolerant
47.	F 6004001-8-16-14-12	1127.33	374.00	33	Sensitive
48.	F 6004009-6-4-10-10	1076.00	827.67	77	Moderate
49.	F 6004009-5-7-10-10	1163.67	890.67	77	Moderate
50.	F 6005001-4-1-12-5	1252.33	406.33	33	Sensitive

Table 3. Morphological characters of different groups of tomato genotypes in low light intensity (50%)

Characters	Groups			
	Shade-loving	Tolerant	Moderate	Sensitive
Leaf number	39.93a	40.07a	39.3a	33.33b
	(34.5-45.4)	(27.2-52.9)	(28.4-50.2)	(23.3-43.3)
Leaf area (cm^2)	53.68a	64.84a	66.38a	50.13a
	(40.19-67.17)	(42.39-87.29)	(32.93-99.83)	(17.22-83.04)
Flowering time (DAP)	42.5b	44.67a	43.33ab	44.67a
	(40.3-44.7)	(42.3-47.0)	(40.7-46.0)	(42.0-47.3)
Flower number	75.9b	79.36a	68.1c	74.4c
	(58.8-93.0)	(54.5-104.2)	(35.8-100.3)	(48.7-100.1)
Harvesting time (DAP)	65.5a	66.0a	67.0a	69.5a
	(63.3-67.7)	(62.3-69.7)	(61.7-72.3)	(63.0-76.0)
Fruit number	19.90c	26.72b	27.13a	9.45c
	(5.49-34.31)	(7.18-46.25)	(5.57-48.70)	(4.82-14.09)
Fruit weight (g)	71.53a	60.48a	60.09a	55.82b
	(36.0-107.1)	(19.7-101.3)	(17.3-102.9)	(21.7-89.9)
Fruit weight per plant (g)	1028.67a	926.83a	874.83b	447.33c
	(676.3-1381.0)	(400.0-1453.7)	(628.3-1121.3)	(297.7-597.0)

Notes : The numbers on the same line and followed by the same letter show no significant difference in the contrast test ($\alpha = 0.05$).

result also indicated that major variance of 8 characters can be explained by two principal components namely Z_1 and Z_2.

The first principal component (37.69%) was considered as factor of plant production and reproduction, because the flowering time, harvesting time and fruit weight have high negative eigenvalue, while flower number, fruit number and fruit weight per plant have high positive eigenvalue. Second principal component (19.50%) was factor of plant morphology, because leaf number has high negative eigenvalue and leaf area has high positive eigenvalue.

Scatter diagram (Fig. 1) explained component scores of 50 tomato genotypes based on Z_1 and Z_2 as its axis and indicated that there were 3 major genotype groups, different from each other. First group (A) was characterized by higher flower number, fruit number and fruit weight per plant, and faster flowering time and harvesting time. This group consisted of genotypes no 2, 3, 12, 13, 18, 25, 44, 45, 46, 48 and 49. Second group (B) consisted of genotypes no 7, 27, 37, 38, 40, 41 and 50. This group had traits of larger leaf area with less leaf number.

Cluster analysis: Cluster analysis explained grouping of 50 genotypes depicted by dendogram from 8 morphological, production and reproduction characters (Fig. 2). Consistency with the scatter diagram of 50 genotypes were separated into 3 clusters at a distance of 20 (indicated by 20% in level of inequality). First cluster consisted of genotypes no 2, 3, 12, 13,18, 25, 44, 45, 46, 48, 49 named as group A; second cluster consisted of genotypes no 7, 27, 37, 38, 40, 41, 50 named as group B; and the third cluster is composed by the rest of the other genotypes named as group C.

Table 4. Eigen vectors of first two principal components

No	Characters	Eigen vector (eigen value)	
		Z_1 (37.69)	Z_2 (19.50)
1.	Leaf number	0.215986	-0.52641
2.	Leaf area	-0.16206	0.906268
3.	Flowering time	-0.58438	-0.01771
4.	Flower number	0.662191	0.354863
5.	Harvesting time	-0.70554	0.401937
6.	Fruit number	0.864393	0.172858
7.	Fruit weight	-0.68525	0.12967
8.	Fruit weight per plant	0.669159	0.356037

Discussion

The experiment sucessfully identified 21 genotypes as tolerant and shade-loving genotypes based on relative productivity rate. So, these genotypes can potentially be used for multiple cropping or agroforestry system. The tolerant and shade-loving tomato genotypes that can be recommended for planting in agroforestry systems include 2, 4, 6, 12, 13, 14, 18, 25, which resulted in high productivity in shade conditions 50% (Table 2). Khumairot (2014) reported that the shade-tolerant tomato productivity increased three folds when intercropped with sweet corn.

There was phenomenon of high yielding yet shade-sensitive variety such as Brastagi 1 (1737.00 g/plant) and low yielding yet shade-tolerant or shade-loving (437.33 g/plant) or (614.67 g/plant) (Table 2). Breeding for abiotic stress (low light intensity) tolerant and high yielding genotypes will result in superior variety that could be used in agroforestry system. Tolerant traits in plant could be obtained from other variety, landrace, related wild species, or other species. The availability of genetic variation will determine the success of plant breeding program (Yunianti *et al.*, 2007).

Multivariate analysis results revealed that 50 tomato genotypes observed could be divided into 3 groups different from each other. Two principal components showed clearly separating groups (Table 4). First component (Z_1) consisted of higher flower number, fruit number and fruit weight per plant, and faster flowering time and harvesting time; while second component (Z_2) consisted of leaf number and area. This was supported by cluster analysis results that had separated A and B group. Group A consisted of genotypes no 2, 3, 12, 13, 18, 25, 44, 45, 46, 48 and 49, separated away from group B which consisted of genotype no 7, 27, 37, 38, 40, 41 and 50.

Shade-loving and tolerant genotypes can be identified with higher leaf number, flower number, fruit weight and productivity from sensitive genotype. Full sun is preferable at fruit initiation, but flower number and tomato fruit were usually larger when planted under shading condition (Calvert, 1959; Kinet, 1977). Additionaly, Khattak (2007) reported that, productivity of some exotic tomatoes was higher under shading condition.

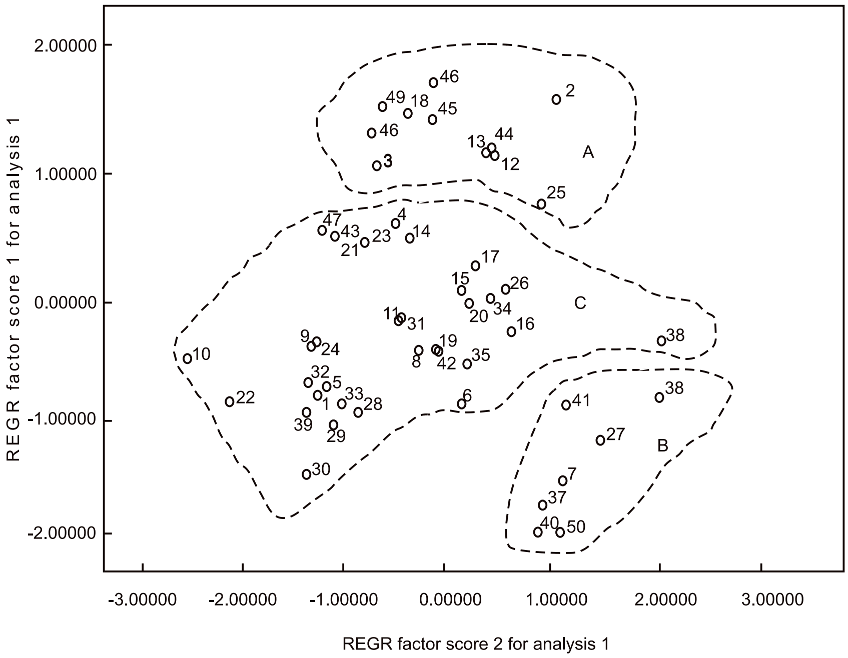

Fig. 1. Scatter diagram of component scores of 50 tomato genotypes

affecting grain size.

Screening results based on the relative productivity of plants and variability in characters (Table 3) showed the higher leaf and flower number, fruit weight, and productivity of tolerant and shade-loving plant group compared to sensitive genotypes. Flower number and fruit weight of the shade-tolerant and shade-loving groups were larger than those of the sensitive group. Plant production was affected by fruit size (Sandri *et al.,* 2003) and fruit number (Muhsanati *et al.,* 2009).

Leaf area of all tomato genotypes increased in shade than the control condition (data not shown), but in shading conditions, there was no difference in leaf area between tomato genotypes. The leaf number are larger with the same relative leaf area in shade tolerant genotypes group than sensitive and expected to produce higher assimilate to support higher productivity in shade tolerant tomatoes. Leaf is the main photosynthetic organ in plant, directly involved in light harvesting and converting light energy to chemical energy to form photosynthate (Taiz and Zeiger, 1991). Increase in leaf number and area in 50% shading condition was observed in ginger (Pamuji *et al.*, 2010), tomato (Khattak, 2007), and shade-tolerant rice (Cabuslay *et al.*, 1995).

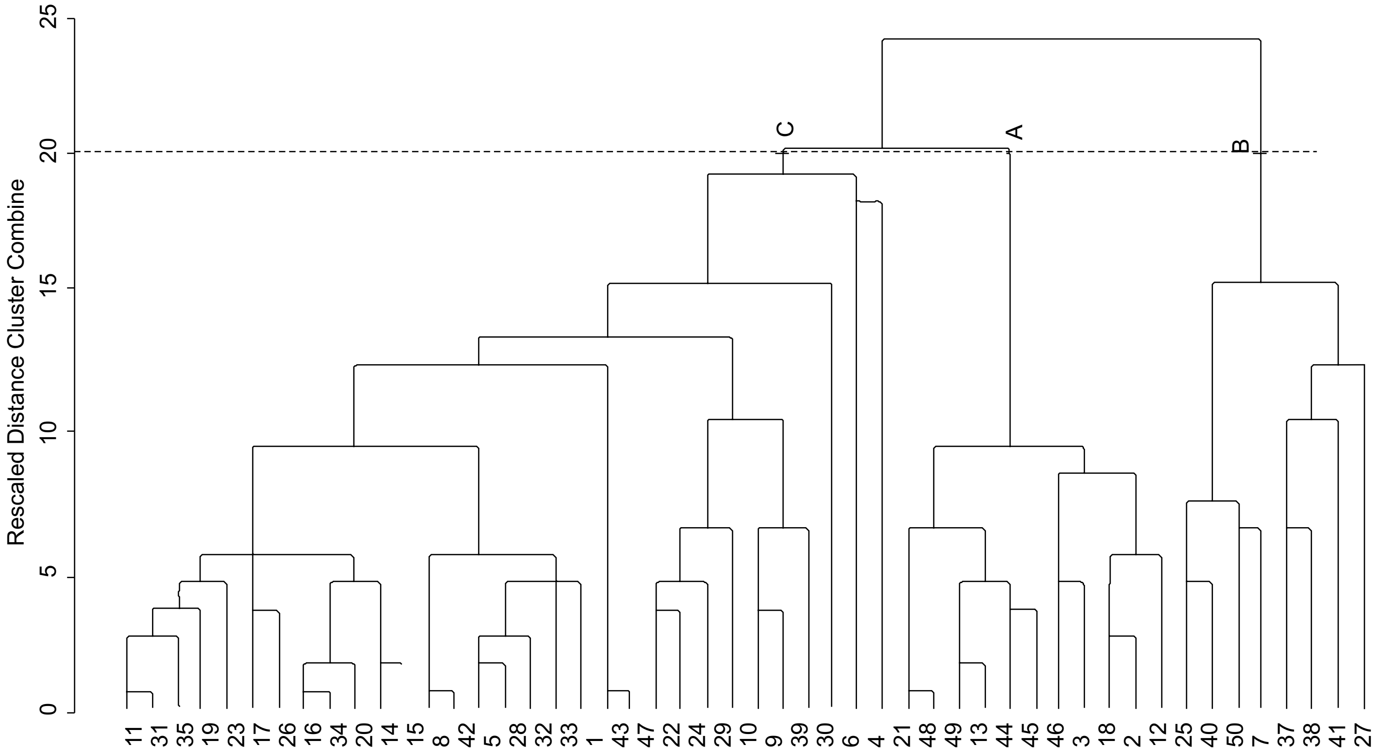

Fig. 2. Dendogram by cluster analysis based on 8 characters of tomato genotypes.

Classification based on tolerance to shade (Table 2), it generally can be shown that mostly in group A had tolerant and shade-loving genotypes (genotypes no 2, 12, 13, 18, 25, 44 and 46); whereas mostly in group B, genotypes were sensitive to shade. Based on this relationship, tolerant and shade-loving plant genotypes were generally characterized by higher flower and fruit number, fruit weight per plant, and early flowering and harvesting compared to shade sensitive group. Trikoesoemaningtyas (2008) reported that increase in soybean productivity was mostly affected by increase in number of grains rather than grain size, because grain/fruit size was more affected by genetic factor. Tang *et al.* (2010) stated that shading condition resulted in lower grain yield but not affecting grain size.

Selected single selection criteria on shade stresses soybean showed pod number per plant characteristic with higher heritability value than yield characters, morphological and other anatomical components (Trikoesoemaningtyas *et al.*, 2004). Seed weight per plant, leaf number and weight of dry grain tolerant upland rice were significantly larger than sensitive genotypes (Sopandie *et al.,* 2003).

Out of 50 genotypes, 5 shade-loving genotypes and 16 shade-tolerant genotypes indicate genetic difference is available in tomato varieties. This clearly demonstrate that tomato genotypes are different in shade-tolerance and thus opportunities are available for utilizing suitable types for developing new varieties or as such growing under low light conditions.

Acknowledgments

The authors would like to acknowledge the Indonesia Director General of Higher Education (DIKTI) for financial support (Strategic Research Superior with contract No 083/SP2H/PL/Dit.Litabmas/II/2015).

References

Baharudin, R., M.A. Chozin and M. Syukur, 2014. Shade tolerance of 20 genotypes of tomato (*Lycopersicon esculentum* Mill). *Indonesian J. of Agron*., 42(2): 132-137.

Bahrun, A.H. 2012. *An Eco-Physiological Study of Seasonal Crops that Form Agroforestry in Some Agroclimate Zones on the Upstream Watershed of Ciliwung*. Ph.D. Diss., Bogor Agriculture University, Indonesia, 2012. 126 pp.

Cabuslay, G.S., B.S. Velgara and R.U. Quintana, 1995. Low light stress: mechanism of tolerance and screening method. *Phillipine J. Crop Sci*., 16(1): 39-47.

Calvert, A. 1959. Effect of the early environment on the development of flowering in tomato: light and temperature interactions. *J. Hort. Sci*., 34: 154-162.

Djukri and B.S. Purwoko, 2003. Effect of paranets shade to tolerance characters of taro (*Colocasia esculenta* (L.) Schott). *Agr. Sci*., 10(2): 17-25.

Khattak, A.M., A. Salam and K. Nawab, 2007. Response of exotic tomato lines to different light intensities. *Sarhad J. Agr.,* 23: 927-932.

Khumairot, F. 2014. *Growth and Production of Shade Tolerant Tomato (Lycopersicon esculentum Mill.) in Intercropping System.* Script., Bogor Agricultural University, Indonesia, 2014. 17 pp.

Kinet, J.M. 1977. Effect of defoliation and growth substances on the development of the inflorescence in tomato. *Sci. Hort*., 6: 27-35.

Manurung, G.E.S., J.M. Roshetko, S. Budidarsono and I. Kurniawan, 2008. Dudukuhan tree farming systems in West Java: how to mobilize self-strengthening of community-based forest management? In: *Smallholder Tree Growing for Rural Development and Environmental Services, Snelder, D.J. and R. Lasco, (Eds.).* World Agroforestry Centre (ICRAF) ICRAF-Bogor, Indonesia.

Muhsanati, R. Mayerni and T.G.P. Sari, 2009. The effects of shadingnets on the growth and yield of strawberry (*Fragaria x annasa*). *Jerami*, 2: 31-34.

Nicola, S., G. Tibaldi and E. Fontana, 2009. Tomato production systems and their application to the tropics. *Acta Hort*., 821: 27-33.

Pamuji, S. and B.S. Akta, 2010. The effect of artificial shade intensity and fertilizer potassium dossage for the growth and yield of big ginger. *Agrosia,* 13(1): 62-69.

Peralta, I.E. and D.M. Spooner, 2007. History, origin and early cultivation of tomato (Solanaceae). In: *Genetic improvement of Solanaceous Crops*. Razdan M.K. and Mattoo A.K. (eds.). Enfield, USA, Sci. Publishers, 2: 1-27.

Pranoto, A.H. 2011. *Analysis Characteristic Agroecology of Agroforestry System in Cianjur Watershed*. Ph.D. Diss., Bogor Agricultural University, Indonesia, 2011. 138 pp.

Sandri, M.A., J.L. Andriolo, M. Witter and T.D. Ross, 2003. Effect of shading on tomato plants grown under greenhouse. *Hort. Bras*., 21: 642-645.

Sopandie, D., M.A. Chozin, Sastrosumarjo, T. Juhaeti and Sahardi, 2003. Shading tolerance in upland rice. *Hayati*, 10(2): 71-75.

Tang, Y., J. Liu, B. Liu, X. Li, J. Li and H. Li, 2010. Endogenous hormone concentrations in explants and calluses of bitter melon (*Momordica charantia* L.). *Interciencia,* 35: 680-683

Taiz, L. and E. Zeiger, 1991. *Plant physiology*. The Benyamin/Cumming Publishing Company Inc., Tokyo, Japan.

Trikoesoemaningtyas, D. Wirnas, D. Sopandie and T. Takano, 2004. Development and selection criteria for the selection of shade tolerant-soybean lines. In: *Proceeding of the 3rd seminar on toward harmonization between development and environmental conservation in biological production*. Serang, Banten, 3-5 Dec. 2004.

Trikoesoemaningtyas, 2008. Yield evaluation of shade-tolerant soybean lines from morphology and molecular marker selection. *Final Report of Research Grant LPPM and BPPP*. Bogor Agricultural University, Indonesia.

Yunianti, R., S. Sastrosumarjo, S. Sujiprihati, M. Surahman and S.H. Hidayat, 2007. Resistance of 22 pepper genotypes (*Capsicum* spp.) to *Phytophthora capsici* Leonian and their genetic diversity. *Bul. Agron*., 35: 103-111.

Zainal, A., A. Anwar, S. Ilyas, Sudarsono and Giyanto, 2011. Inoculation test and response of 38 tomato genotypes to Indonesian isolates of *Clavibacter michiganensis* subsp. michiganensis. *Indonesian J. of Agron.,* 39(2): 85-91

Received: November, 2015; Revised: January, 2016;
Accepted: February, 2016