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Selection in shade-tolerant genotypes of tomatoes

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Abstract

Genetically, tomato traits may have different shade intolerances. Shade-tolerant tomatoes are potentially developed, for instance, 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 yields as responses to low light intensity. This experiment was conducted at farmer's field Bogor in October 2014-February 2015 and used nested factorial design with three replications. Selection was conducted on 50 tomato genotypes cultivated under 50 and 100% light intensity. Variables to observe 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. Methods used for statistical analysis were analysis of variance to differentiate between genotypes within response group; principle component analysis to define variance characters between genotypes; and cluster analysis and Euclidean distance method to determine relationship among tomato genotypes and its similarity level . The 50 genotypes under shading condition were classified into 5 shade-loving genotypes, 16 shade-tolerant genotypes, 14 shade-moderately-tolerant genotypes and 15 shade-sensitive genotypes. Based on principal component analysis, the value of two principle components was 57.19%. The first principle 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 method, principle component analysis, relative productivity.

Introduction

Tomato 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 area to hot area and wet tropical area. Tomato production in Indonesia (wet tropical area) could be increased with the intensification in cultivation or increasing production area. Tomatoes might be able to 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 only few know and experience in vegetable cultivation with intercropping or agroforestry system.

Lack of sun light in tomato plant cultivated under the tree stand or anything as interculture, 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 under. Manurung *et al.* (2007) showed that in agroforestry system with low light intensity at 32–174*1000 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*1000 lux) and full sun-light (482-540*1000 lux) were not significantly different (468 and 436 g/plant, respectively), but there was a significant difference with the productivity in low light (319 g/plant).

Tomato (*Lycopersicon esculentum* Mill) 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 (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, tomato yield and quality as responses to low light intensity. Based on relative productivity, tomato genotypes observed 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 conditions. There are a lot of genotypes of tomatoes are unknown response in low light. Therefore it is necessary to conduct further research test planting directly in the ground in the form of screening tomato genotypes to try more genotypes at low light intensity.

Genotype/variety that could adapt in unfavorable condition (abiotic stress) had better stability and could be used in breeding program. An effort to produce shade-tolerant tomato could be done through plant breeding program. The activity started with collecting tomato germplasm and continued with screening. Identification for genotypes tolerance was the first step in developing tolerant cultivar (Zainal *et al.*, 2011). This research aimed to study the characteristics of 50 tomato genotypes based on their tolerance towards low light intensity (50%) for vegetable development and learn about the plant morphological characters, production and reproduction.

Materials and methods

The experiment used 50 tomato genotypes, they were collection of Plant Breeding Division, Department of Agronomy and Horticulture, Faculty of Agriculture, Bogor Agricultural University. The descriptions of those genotypes are presented in Table 1. Seeds of 50 tomato genotypes were sown in seedling tray. The 25-day-old seedlings were then transplanted on the soil beds with a spacing of 50 cm x 60 cm. As treatments, black shade net was used to reduce light intensity up to 50% and no shade net for control. The observations were conducted on 5 plants from each genotype. The variables to observe were leaf number and area, fruit number, fruit weight, fruit weight per plant, flowering time, flower number and harvesting time. Those characters were also used to construct the dendrogram.

The tolerance levels of tested genotypes were classified based on plant relative productivity rate, namely percentage of yield under shading against yield of control in shade level which resulted the highest variance (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%).

Methods used for statistical analysis were (1) analysis of variance to differentiate between genotypes within response group, (2) principle component analysis to define variance characters between genotypes, and (3) cluster analysis utilizing Euclidean distance matrix to determine relationship among tomato genotypes and its similarity level.

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* (1737.00 g/plant) and the lowest by *gondol* variety (437.33 g/plant) (Table 2). Referred to relative productivity criteria by Baharudin *et al.* (2014), the 50 genotypes under shading condition were classified into 5 shade-loving genotypes, 16 shade-tolerant genotypes, 14 shade-moderately-tolerant genotypes and 15 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.

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

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

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

No.	Genotypes	Yield fresh tomato (g/plant)		Relative productivity (%)	Shade tolerance Categories
		0%	100%		
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

Principal component analysis (PCA): Table 4 presented eigenvalues of 2 major components from 8 characters (morphological, production and reproduction) of tomato. Those two major components accounted for 57.19% of the total variance. This result indicated that major variance of 8 characters can be explained by two principle components namely Z_1 and Z_2.

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

Scatter diagram in 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 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 2, 3, 12, 13, 18, 25, 44, 45, 46, 48 and 49. Second group (B) consisted of genotypes 7, 27, 37, 38, 40, 41 and 50. This group had traits of higher leaf area with less leaf number.

Cluster analysis: Cluster analysis (Figure 2) explained the several characters variables of 50 genotypes by dendogram from 8 morphological, production and reproduction characters. Consistency with the scatter diagram (cluster analysis) of 50 genotypes were separated into 3 clusters at a distance of 20. First cluster consisted of genotypes 7, 27, 37, 38, 40, 41, 50; second cluster consisted of genotypes 2, 3, 12, 13,18, 25, 44, 45, 46,

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

Characters	Groups			
	Shade-loving	Tolerant	Moderate	Sensitive
Leaf number	39.93a (34.5-45.4)	40.07a (27.2-52.9)	39.3a (28.4-50.2)	33.33b (23.3-43.3)
Leaf area (cm^2)	53.68a (40.19-67.17)	64.84a (42.39-87.29)	66.38a (32.93-99.83)	50.13a (17.22-83.04)
Flowering time (DAP)	42.5b (40.3-44.7)	44.67a (42.3-47.0)	43.33ab (40.7-46.0)	44.67a (42.0-47.3)
Flower number	75.9b (58.8-93.0)	79.36a (54.5-104.2)	68.1c (35.8-100.3)	74.4c (48.7-100.1)
Harvesting time (DAP)	65.5a (63.3-67.7)	66.0a (62.3-69.7)	67.0a (61.7-72.3)	69.5a (63.0-76.0)
Fruit number	19.90c (5.49-34.31)	26.72b (7.18-46.25)	27.13a (5.57-48.70)	9.45c (4.82-14.09)
Fruit weight (g)	71.53a (36.0-107.1)	60.48a (19.7-101.3)	60.09a (17.3-102.9)	55.82b (21.7-89.9)
Fruit weight per plant (g)	1028.67a (676.3-1381.0)	926.83a (400.0-1453.7)	874.83b (628.3-1121.3)	447.33c (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 ($\alpha = 0.05$).

Table 4. Eigenvalues and eigenvectors of the two principal components analysis

No	Characters	Eigenvector (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

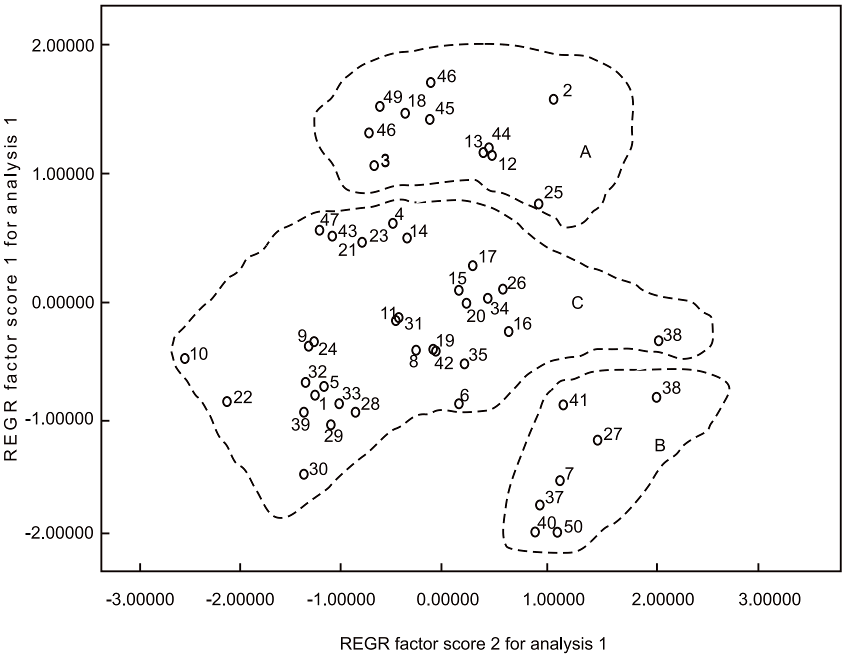

Fig. 1. Scatter diagram of component scores of 50 tomato genotypes

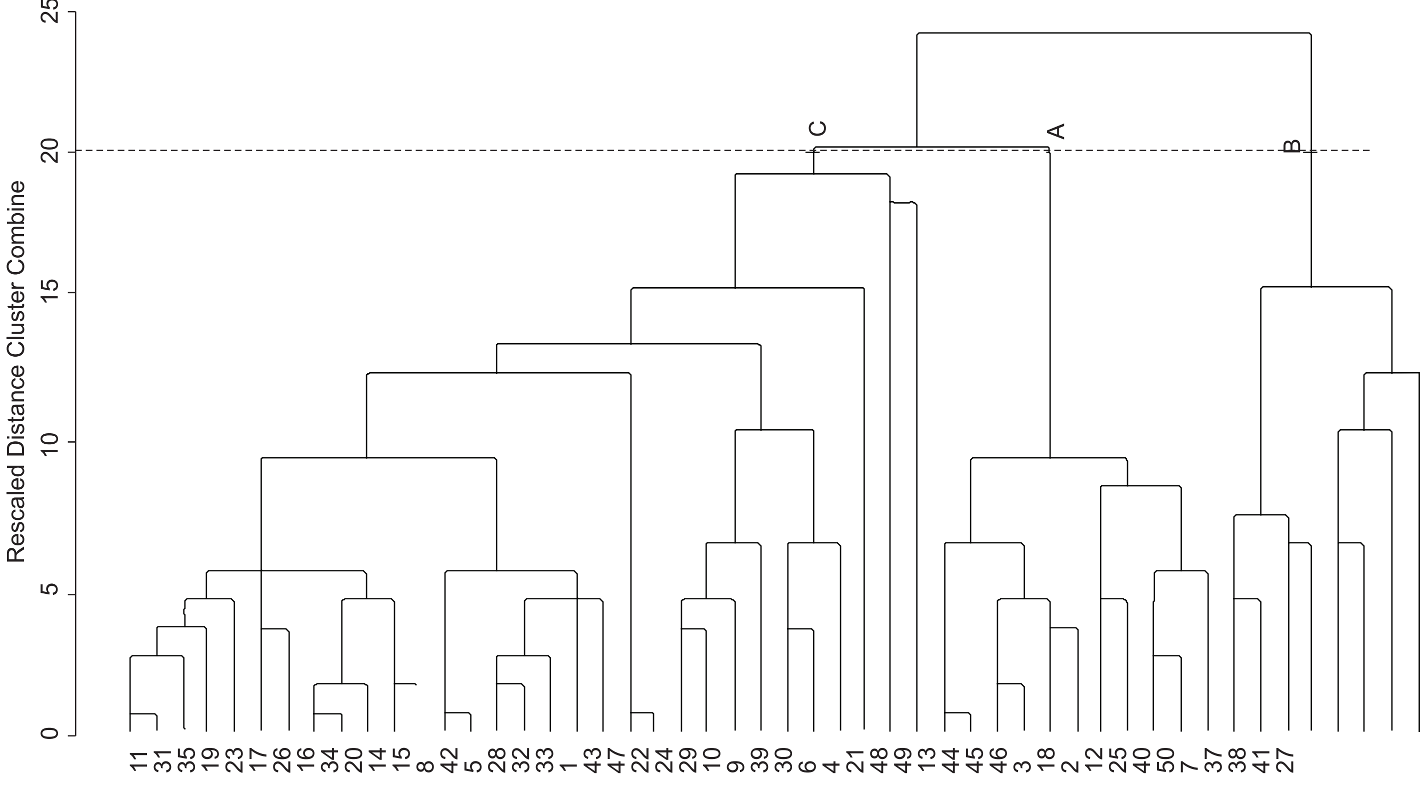

Fig. 2. Dendogram by cluster analysis based on the distance of 8 characters of tomato genotypes.

48, 49; And the third cluster composed by the rest of the other genotype.

Discussion

Based on relative productivity in shade level of 50% (Table 2), 50 tomato genotypes screening resulted 4 groups, namely shade-loving plant (5 genotypes), tolerant (16 genotypes), moderate (14 genotypes) and sensitive (15 genotypes), which is similar to Baharudin *et al.* (2014). This study has been sucessfully identified 21 genotypes as tolerant and shade-loving plant genotypes that are potential for multiple cropping or agroforestry system.

The tomato genotypes tolerant and shade-loving plant (Table 2) that can be recommended for planting systems mentioned above are genotype number 2, 4, 6, 12, 13, 14, 18, 25, which resulted in high productivity in shade conditions 50%. Khumairot (2014) reported that the shade-tolerant tomato productivity increased when intercropped with sweet corn so that the productivity of these varieties increased threefold. Important information regarding to production rate and response variance towards each variables are quite influential for plant breeding improvement.

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). Important information about productivity variance and response variance on each variable was very useful for genetic refinement in plant breeding. Breeding for abiotic stress (low light intensity) tolerant and high yielding genotypes will resulted 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. Genetic variance availability will determine the success of plant breeding program (Yunianti *et al*., 2007).

Multivariate analysis result revealed that 50 tomato genotypes observed could be divided to 3 groups different from each other. Two principle components showed clearly separating. First component (Z_1) consisted of larger 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 result that had separated between group A and B. Group A consisted of genotype 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 from larger leaf number, flower number, fruit weight and productivity from sensitive genotype. Full sun is preferable at fruit initiation, but flower number and fruit usually larger when planted under shading condition (Calvert, 1959; Kinet, 1977). Additionaly, Khattak (2007) reported thatproductivity of some exotic tomatoes was higher under shading condition.

Referred to classification based on tolerance to shade (Table 2), it generally can be shown that mostly in group A were tolerant and shade-loving plant genotypes (genotypes no 2, 12, 13, 18, 25, 44 and 46); whereas mostly in group B were genotypes sensitive to shade. Based on this relation, tolerant and shade-loving plant genotype generally was characterized by higher flower number, fruit number and fruit weight per plant, and faster flowering time and harvesting time compared to sensitive to shade 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.

Screening results based on the relative productivity of plants on the characters variance observation (Table 3) showed the higher leaf number, 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 (not shown), but at 50% shading condition there was no difference in leaf area between tomato genotypes. The leaf number are larger with the same relative leaf area on 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, 1995). 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).

Selected single selection criteria on shade stresses soybean were pod number per plant characteristic with higher heritability value than yield characters, production, 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 higher than sensitive genotypes, thus would be beneficial as interculture for production enhancement (Sopandie *et al.,* 2003). Information obtained from research above and other research regarding the relation between plant morphological, production and reproduction properties, and tolerance of shade properties; were basic information to learn about plant adaptation mechanism towards shade like on upland rice (Santosa *et al*., 2002; Sasmita *et al*., 2006) and soybean (Soepandie *et al.,* 2001; Muhuria *et al*., 2006; Kisman *et al.,* 2007).

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