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Lycopene, beta-carotene and productivity of tomato varieties at different shade levels under medium land of Indonesia

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Abstract

Lycopene and beta-carotene content of two antioxidants in tomatoes and productivity are strongly influenced by the intensity of solar radiation received by plants. The objective of this study was to elucidate the effect of shading on production, lycopene content and beta-carotene content of tomato varieties at medium land of Indonesia. The study was conducted in the area with an altitude of 515 meters above sea level, in Malang, East Java, Indonesia. Treatments tested in this study were arranged in a split plot design. The main plot was percentage of shading (0, 25 and 50 %). The subplot was tomato varieties (Juliet, Golden Sweet, Golden Shine and Betavila). The results showed that shading or lowering the level of solar radiation received by plants could improve the maximum air humidity but it did not change the minimum humidity. Minimum air temperature dropped by 1°C in the shade treatments of 25 and 50 % compared with no shade, while the maximum air temperature dropped by 4 °C in the shade of 25 % and by 5 °C under 50 % shade. Changes in the microclimate around the plants, especially the temperature and air humidity did not only increase the growth and productivity of plants, but also increased the chlorophyll content of leaves and lycopene of tomatoes. All varieties showed that the highest production was obtained when plants were shaded by 25 % compared with no shade or 50 % shade. In addition, lycopene in tomato varieties was also influenced by the microclimate around the plant, and the beta-carotene content was influenced by varieties of tomatoes and shaded level but not due to interaction.

Key word: Lycopene, beta-carotene, productivity, tomato, shade, medium land

Introduction

With increasing cancer cases in Indonesia, estimated annual cancer cases will increase from 14 million in 2012 to 22 million in the next two decades. More than 30 % of cancer deaths are caused by five factors of risk behaviours and eating patterns and less consumption of fruits and vegetables is one of the major associated factors (Infodatin, 2015). The high cancer disease is prompting many people to increase daily consumption of antioxidants in food and beverages. Numerous epidemiological studies have shown that eating large amounts of fruits and vegetables reduces the risk for some types of cancer in humans (Khachik *et al.*, 1995). Tomato is one of the fruits that has a fairly high antioxidant content. Lycopene also called alpha-carotene and beta-carotene are two types of antioxidants widely found in tomatoes. Other phytochemicals in synergy with lycopene from tomatoes provide a protective effect and helps to maintain prostate health. Tomato juice dose of 900 mg/20 g weight of mice administered for 14 days reduced pulmonary alveolar cell histological damage in mice caused by exposure to cigarette smoke (Stacewicz-Sapuntzakis and Bowen, 2005; Clara, 2010).

The content of antioxidants in tomatoes is dependent on types or varieties. Red tomato varieties have comparatively higher lycopene and beta-carotene is higher in orange tomatoes. Colour of the fruit is determined on the relative content of lycopene and beta-carotene. Fruit with high lycopene content lower content of beta- carotene show red appearance. Fruit with lycopene content together with the high beta-carotene have more orange appearance (Rosati *et al.* (2000). Tomato with a round shape and red colour (redness) is the most preferred cherry tomato. Genotype with limited preference are of unusual shape (oval and pear), colour (orange-yellow) and of larger size (Rocha *et al.*, 2013).

In addition to genotype, environmental factors may also affect the lycopene content in the fruit. The intensity of sunlight affects the temperature around the plant and temperature below 12 °C and above 32 °C can reduce the content of these antioxidants (Dumas *et al.*, 2003). Tomato plants given shade of black colour 25 % had the antioxidant content of lycopene and beta-carotene higher than the plants treated with 40 % shade of pearl, red and yellow colours (Tinyane *et al.*, 2013). Lycopene content of tomato fruit grown in greenhouse was 40 % higher than in the open field. Shade by foliage may be important to maximize the content of lycopene in tomato plants grown in warm areas with high solar radiation. Shade on fruit can be achieved by selecting cultivars with closed canopy, by changing the trimming technique with left lateral shoots up and with the setting of planting the crop rows north-south direction (Helyes *et al.*, 2007). Fruits that were stored at temperatures of 15 °C and 25 °C had higher lycopene content than stored at a temperature of 7 °C (Toor and Savage, 2006). Cox *et al.* (2003) reported that harvested greed-ripe tomato fruits exposed to light for 24 hours for maturation at 25°C in a growth cupboard had higher concentration of lycopene than green-ripe fruits exposed to light for 8 hours.

A research on lycopene conducted by Rosales *et al.* (2006) and Helyes *et al.* (2007) indicated that the air temperature affects

fruit lycopene content, especially in situations where the fruit is directly exposed to intense sunlight. When the fruit is directly exposed to the sunlight, the temperature of the surface of the fruit becomes higher, which leads toward the low lycopene content of the fruit. In the production parameters, tomato plant shaded 40 % by net had higher production than that shaded with 50 % net, and the highest production was obtained when shaded by net with pearl or red colour (Ilic *et al.*, 2012).

Sensitivity to shade is varietal character of tomato plant. The production of Bogor Rempai variety decreases when it is planted in a polyculture /multiple cropping system, while the production of Palupi variety is higher when it is intercropped (Khumairot, 2014). Microclimate similar to greenhouse is sufficient to accelerate plant growth, to increase dry weight of the leaves and to support the formation of the fruit compared to those grown under conventional climatic conditions.

Temperatures up to 25 °C can enhance the biosynthesis of carotene, especially lycopene. The 1-2 °C increase in temperature (18 to 19.8 °C or 22.4 to 23.6 °C) may increase the content of phenolic compounds (Dannehl *et al.*, 2012). The objective of this study was to elucidate the effect of shading on production, lycopene content, and beta-carotene content of tomato varieties in medium land conditions of Indonesia

Materials and methods

The study was conducted at the Experimental Garden of BPTP, East Java at Karangploso, Malang, Indonesia. The experiment used a split plot design. The main plot was plastic shade (0, 25 and 50 % shade). The sub plot consisted of four tomato varieties of (Juliet, Golden Sweet, Golden Shine, and Betavila).

The parameters observed were intensity of sunlight during experimentation, maximum and minimum temperature, maximum and minimum humidity. Solar radiation was measured using Actinograph, Meteorology Geophysics Karangploso, Malang, East Java, Indonesia, during 106 days of the plant growth, adjusted for Luxtron light meter LX 107. Measurement of the temperature and humidity inside and outside shade were conducted with a digital thermometer and a hydrometer HTC-1.

Plant growth was measured by plant height, leaf area index and crop growth rate (CGR) with equation: CGR= $1/Ga \times W_2-W_1 / T_2-T_1$ (g/cm^2/week) information: (Ga=Planting area, W_2=Dry Weight 2, W_1= Dry Weight 1, T_2=Time 2, T_1=Time 1), chlorophyll *a*, *b* and total chlorophyll, lycopene, and beta-carotene contents in the leaves were measured using the method of Nagata and Yamashita (1992) by extracting leaves in an acetone-hexane solution (10 mL) in a test tube with a ratio of 4: 6. One gram of tomato leaf sample was incorporated to the acetone-hexane solution, mixed and blended thoroughly with a homogenizer.

The mixed solution was then measured with a spectrophotometer at 453, 505, 645, and 663 nm wavelengths. The measurement results were calculated by the following equations:

Chlorophyll a = 0.999A663-0.0989A645

Chlorophyll b = -0.328A663 + 1.77A645

Lycopene = -0.0458A663 + 0, 204A645 + 0.372A505-0.0806A453

β-carotene = 0.216A663-1.22A645 -0.304A505 + 0.452A453

(A453, A505, A645, and A663 are absorbance at 453 nm, 505 nm, 645 nm, and 663 nm each other)

Results and discussion

Solar radiation, air temperature and humidity: Incoming solar radiation in 50, 25, and 0 % shade treatments were 33.938; 26, 434.65 and 17, 623.10 g cal/cm^2, respectively, for 106 days. Difference in solar radiation received by the plants led to differences in temperature and humidity around the plants. Minimum temperature of each shade treatment showed significant differences between the treatment of 0 % shade and the treatments of 25 and 50 % shade. For the maximum daily temperature, the 0, 25 and 50 % shade treatments showed significant differences. The minimum humidity around the plant did not show differences due to shade treatments, while the maximum moisture content showed significant differences for 0, 25 and 50 % shade treatments (Table 1).

Table 1. Differences in the daily minimum and maximum air temperature and humidity on 0, 25 and 50 % shade treatments

Level of shade	Temperature (°C)		Humidity (%)	
	Minimum	Maximum	Minimum	Maximum
0	20.94b*	40.01a	28.18a	73.00c
25 %	21.04a	35.85b	28.08a	77.24b
50 %	21.32a	34.52c	27.84a	82.52a
CV	1.68	2.21	11.87	4.35

*The numbers followed by different letters, differ significantly in the Duncan's test (α = 0.05).

The distribution of the daily minimum air temperature can be seen in Fig. 1 A), and the distribution of daily maximum air temperature is depicted in 1 B)

Leaf area index: There were interactions between shade treatment and tomato varieties affecting plant leaf area index at 9 weeks after planting. The leaf area indexes of Juliet and Golden Shine varieties with no shade did not differ with those treated with shading. The leaf area index of Betavila variety of 25 % shade was different from that of 0 or 50 % shade. The leaf area index of Golden Sweet variety, however, showed differences in all shade treatments. Golden Sweet variety had the lowest leaf area index followed by the Golden Shine variety, while Juliet and Betavila varieties had higher leaf area index than other varieties (Fig. 3).

Leaf chlorophyll (*a* and *b*): Levels of chlorophyll *a* in plants of 6 weeks age showed no difference in the shaded plants (25 and 50 %) with unshaded plants (Fig. 2). Chlorophyll *b* content, in shade treatment was high because of low radiation received by the plant. This was an adaptation of plants to streamline acceptance of solar radiation as reported by Sulistyawati *et al.* (2016). The content of chlorophyll *b* in the leaves of tomato at age of 6 weeks was influenced by shade and varieties of crops grown (Table 2). The highest chlorophyll *b* content was observed in leaves of Juliet variety planted with 50 % shade, and the low chlorophyll content was observed in leaves of all varieties with 0 % shade. Similar results on grasses resulted in similar conclusion (Sirait, 2008).

Plant height and stem diameter: The results of this study showed that the tomato plant height was strongly influenced by the shade level (Fig. 3). The larger the shade percentage, the higher the plant height. Golden Sweet variety had the highest growth followed by Juliet, Betavila, and Golden Shine varieties. Golden Sweet and Juliet varieties, cherry tomatoes had indeterminate growth, high-growth, and continued to grow despite the generative phase (Budijaya, 1997). Shade greatly affects plant height and stem

Table 2. Chlorophyll *b* content in leaves of tomato varieties at age of 6 weeks after planting, crop growth rate of generative phase (g/cm^2/3weeks), and production a plant (g) under shade treatments

Shade treatment	Chlorophyll *b* at 6 weeks after planting (mg/g fw)	Crop Growth Rate of Generative Phase (g/cm^2/3weeks)	Plant Production (g)
Juliet			
0	64.4de*	38.2e	555de
25 %	87.9bcde	59.1c	1043c
50 %	152.8aa	43.1cde	698d
Golden Sweet			
0	54.7ee	8.0f	416ef
25 %	100.9bcd	82.4b	395ef
50 %	73.0bcde	19.4ef	333efg
Golden Shine			
0	47.7e	38.1de	260fg
25 %	67.0cde	29.1ef	230fg
50 %	106.5bc	41.7e	137g
Betavila			
0	63.6de	90.7a	1322b
25 %	76.2bcde	121.3b	2306a
50 %	113.0b	46.8cd	1379b

*The numbers followed by different letters, differ significantly in the Duncan's test ($\alpha = 0.05$).

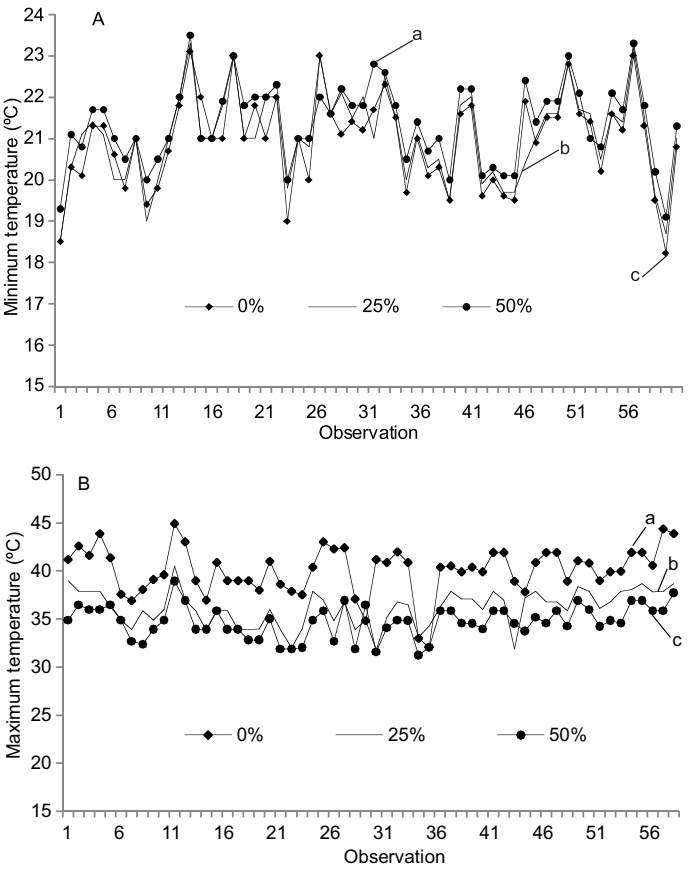

Fig. 1. A) Daily minimum air temperature in 0, 25 and 50 % shade treatments during the growth of plants. B) Daily maximum air temperature in 0, 25 and 50 % shade treatments during the growth of plants

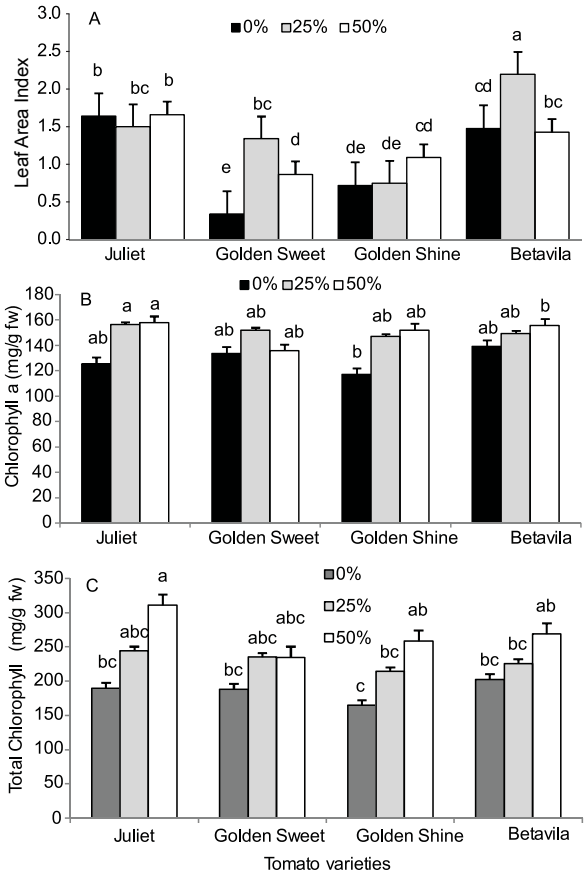

Fig. 2. A) The leaf area index of plant at 9 weeks after planting at different shade levels in 4 tomato varieties. B) The content of chlorophyll a in leaves of tomato varieties at age of of 6 weeks after planting under shade treatments. C) The total chlorophyll content in leaves of tomato varieties after 6 weeks of planting under shade treatments

diameter. The plants will be taller if the percentage of shade is higher because of the plant will grow towards light source, and it relates to the content of growth regulator auxin and gibberellin synergistically resulting cell elongation (Taiz and Zeiger, 2002; Hamdani *et al.,* 2016). The high plant growth due to the extension of the cell resulted smaller diameter of the shaded plants. Higher the shade percentage, the smaller the diameter of the plant stems has been reported by Taiz and Zeiger (2002). Golden Sweet variety had less stem diameter.

Production: The results of this study demonstrated that the production of each tomato variety was influenced by the intensity of sunlight received by the plants. Tested varieties showed that the highest production was observed when the plants were 25 % shaded compared with no shade or 50 % shade treatments. This is because of tomato plant is included in C_3 plant class and undergo photorespiration when receiving light higher than its optimal, because the cell sheath site of the Calvin cycle is directly related to the free air so respiration can happen in presence of higher solar radiation (Taiz and Zeiger, 2002). Tomato varieties having the highest production were Betavila and Juliet, while varieties having the lowest production were Golden Shine and Golden Sweet (Table 2). The study indicate that red tomatoes have a greater productivity especially at the altitude of 515 m above sea level in Indonesia

Crop growth rate: Crop growth rate illustrates low or high results of plant photosynthesis. Plant growth rate was lower under

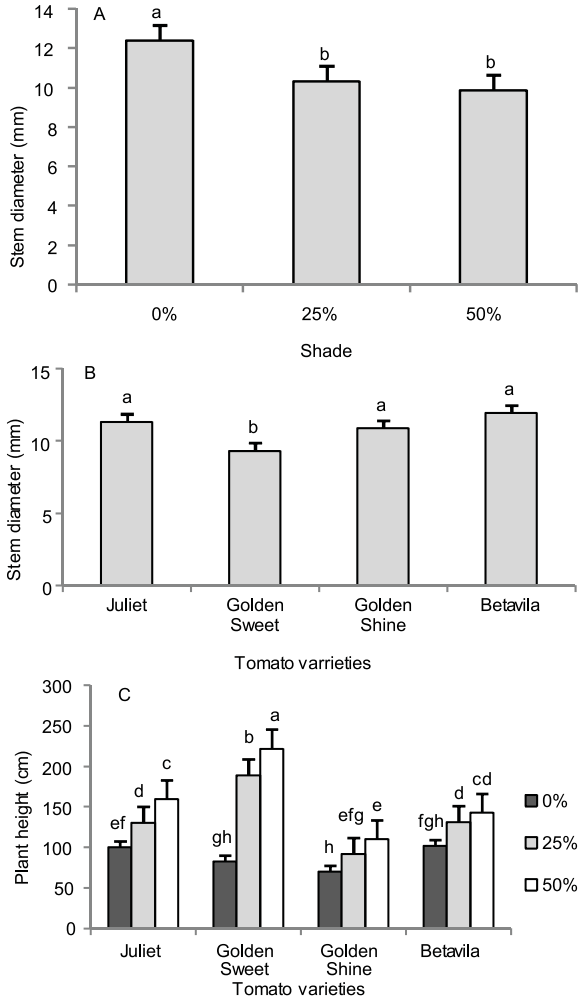

Fig. 3. A) Stem diameter at three levels of shade, age 12 weeks. B) Stem diameter of four tomato varieties, at 12 weeks. C) Plant height of four tomato varieties at several levels of shade, age 12 weeks.

50 % shade than that of cultivated in open. Generative phase can be categorized sensitive to shade, Betavila variety had growth rate of 46.8 g/cm^2/ 3 weeks when shaded by 50 %. The growth rate was moderate under 0 and 50 % of shade, although 25 % shaded plants showed the highest growth rate of 121.3 g/cm^2 / 3 weeks (Baharuddin *et al.*, 2014).

Beta-carotene: Beta-carotene of the fruit was affected by the shade and variety without significant interaction between factors (Fig. 5). Golden Shine tomato with orange colour had higher content of beta-carotene than red tomatoes of Golden Sweet, Juliet or Betavila varieties, and fruits under 25 % shade recorded highest beta-carotene contents. According to Rosati *et al.* (2000), the orange fruit have a high beta-carotene content. Golden Sweet tomato variety with yellow colour had lower beta-carotene content (Fig. 4 and 5).

Lycopene: Lycopene was greatly influenced by the microclimate around the plants, especially the temperature and humidity (Table 1). It was also influenced by the variety. In the red colour tomato fruit, the low temperature was associated with increased lycopene content of the fruit while the orange or yellow colour fruit had low lycopene (Fig. 4). The low temperature did not increased the lycopene content in the fruit (Figs. 1 and 5.). This was because the maximum temperature around the plant was low. Red fruits have characteristics such as chlorophyll in leaves, have higher levels of lycopene and beta carotene when getting lower light (Fig. 5 and Table 2). According to Helyes *et al.* (2007); Rosales *et al.* (2006), temperature around the plants affect the lycopene content in the fruit. this seems due to the increase in lipid peroxidation marked as lipoxygenase activity and malondialdehyde content at higher temperature (Rosales *et al.,* 2006).

Fig. 4. The colour of tomatoes in 25 % shade

Juliet and Betavila tomato varieties having red colour showed the highest productivity when they were grown in 25 % shade. Golden Sweet and Golden Shine varieties having yellow-orange fruit produced high yield when grown without shade. Lycopene in red tomatoes (Juliet and Betavila) was high when they were planted in high levels of shade percentages, but the productivity needs to be considered. The beta-carotene content was influenced by the variety and orange coloured variety had higher content of beta-carotene.

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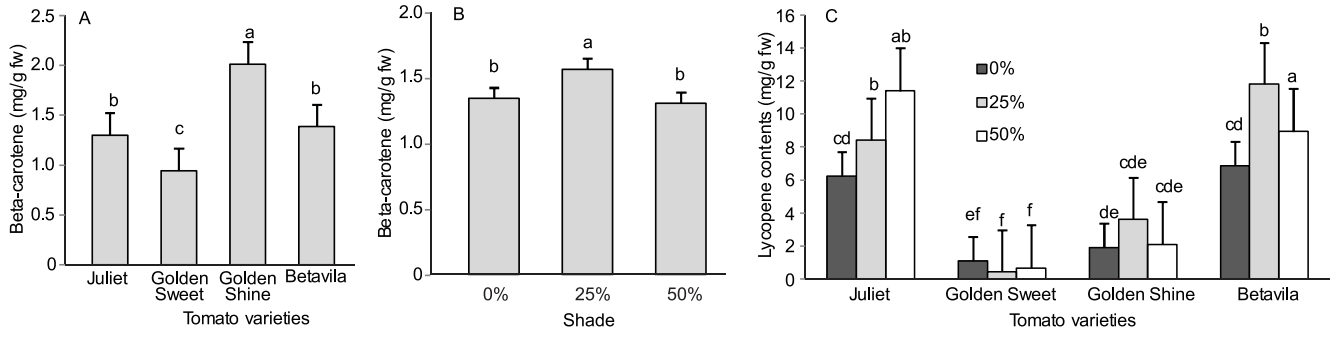

Fig. 5. A) Beta-carotene contents of fruits of four tomato varieties under different levels of shade. B) Lycopene contents of fruits of four tomato varieties under different levels of shade

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