Original Article

Climate and Cultivar of Tomato (*Licopersicum esculentum* L.) Affect the Lycopene Contents

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Abstract

The development and metabolism of tomato plants are influenced by climate and genetic diversity. However, it is still infrequently investigated how these two factors affect it. As a result, this study demonstrates that the lycopene concentration of tomato plants is affected by the environment and variances in tomato plant types. The Gustavo Cultivar and the Ros Cultivar of tomato plants were used in this study. The two types came from two separate climate zones in Central Sulawesi Province, Indonesia: The Napu Region and the Sigi Region. The Napu region has a temperate climate, while the Sigi region enjoys hot weather. Tomatoes from two distinct types and areas were then removed and tested for lycopene concentration with a 472 nm UV-Vis spectrophotometer. The results reveal that temperature and cultivar changes have a substantial effect on the lycopene concentration of the Ros Cultivar tomatoes. This climate variation, however, did not occur in the Gustavo Cultivar. The Ros Cultivar had the highest lycopene content. The warmer temperature raised the level of lycopene in the Ros Cultivar but not in the Gustavo Cultivar.

Keywords: Climate, Tomato, lycopene, *Licopersicum esculentum* L

Introduction

Central Sulawesi is an Indonesian province located in the center of the island of Sulawesi. Central Sulawesi has a total area of 61,841.29 km^2. The population will reach 3,822,241 people in 2021. Central Sulawesi has the most land area of any province on Sulawesi Island, as well as the second largest population after South Sulawesi. Central Sulawesi is located between 222 North and 348 South Latitude, as well as 1122 and 124.22 East Longitude. The equator that runs through Central Sulawesi makes the climate tropical. The temperature on the plains ranges from 25 to 36°C, while the humidity at sea level is 71-76%. The Central Bureau of Statistics estimates that in 2021, temperatures in hilly areas may reach 16 to 22 °C. In contrast to the previous quarter's growth of 5.37%, Central Sulawesi's GDP expanded by 6.77% in the first quarter of 2019. This was a surprise because Central Sulawesi only experienced a disaster; earthquake, tsunami, and liquefaction, in September 2018.

The agricultural sector in Central Sulawesi has a high potential. The agricultural sector is one of the most anticipated bases in supporting economic growth, especially after the 7.4 Richter earthquake that occurred in the Central Sulawesi region, which increased the demand for agricultural products, one of which was the demand for tomatoes to meet the demand. People from the Central Sulawesi Province, the Napu District, and Sigi Regency in Central Sulawesi Province are establishing tomato plants and have begun delivering tomatoes for sale in the market. The climates of the two regions are very different. Napu District has a cold temperature, which is ideal for soil and climatic conditions for producing tomatoes, whereas Sigi Regency has a hot environment, in which tomatoes can grow well, but not as well as in cold climates.

Tomato fruit is one of the vegetables that is commonly consumed by the community, either raw or processed. Tomato is a nutrient-dense horticultural plant [1]. The complete and good composition of nutrients makes tomatoes have many benefits for health [2], among which are as antioxidants [3, 4], heart health [5], cancer prevention [6, 7], bone health [8] and antibacterial [9, 10]. Tomatoes are a dietary group that provides protein and vitamins [1]. Tomatoes have substantial levels of vitamin C [11]. Tomatoes are also one of the best sources of lycopene [12, 13]. The amount of lycopene in tomatoes varies based on the cultivar, the location in which they grow, and how the tomato fruit is

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processed. There hasn't been much research on how lycopene content varies in tomatoes. As a result, this research is required so that individuals may choose the optimal tomato types to ingest that contain the most lycopene. It can even assist farmers in growing tomato plants that are high in lycopene.

The human body cannot produce lycopene. As a result, humans obtain lycopene from outside the body by consuming foods high in lycopene [13, 14]. When ingested by humans, lycopene has numerous benefits to the body, including the prevention of chronic diseases such as cancer and coronary heart disease [2, 7, 8]. Lycopene is also used to treat eye illness, male infertility, inflammation, and osteoporosis [1]. Lycopene has been shown in research studies to reduce cancer growth in cell culture, animal trials, and epidemiology [15].

Tomato plants that flourish under all situations can produce tomato fruit. As a result, the lycopene concentration in tomatoes fluctuates. Many elements influence it, including environmental circumstances, temperature, light, species genetic potential, and tomato growing maturity phase [16, 17]. The lycopene content of the fruit increases significantly during the ripening process [18]. Oboulbiga (2018) discovered that the lycopene concentration of tomatoes varies depending on the tomato cultivar [19]. Tomato cultivars include vulgare Bailey, cherry-shaped, pyriform aleph, robust Bailey, and grandifolium Baileys. Some of these arguments for tomatoes and lycopene suggest that tomato cultivar, in addition to tomato maturity, affects the amount of lycopene in the fruit. Furthermore, lycopene levels in tomatoes are impacted by the environment. As for the weather, it has been noted that Central Sulawesi Province has a different climate than other provinces, with hot and cold temperate circumstances occurring there. Studies on tomato cultivars from the Central Sulawesi region related to climatic conditions are necessary because lycopene research on many cultivars of tomatoes from various climates is currently rare and undocumented.

The following issues must be investigated, according to the description: What effect does climate have on the lycopene content of different tomato cultivars? Which tomato cultivar has the highest levels of lycopene? These solutions are critical because they are useful for determining the significant lycopene content in tomatoes between different cultivar and climates, as well as determining which tomato cultivar have the highest lycopene content and which climate is suitable for producing the highest lycopene content in tomatoes. As a result, the study's findings will be extremely useful to the community in terms of planting and consuming tomato cultivars with the highest levels of lycopene.

Materials and Methods

The lycopene analysis will take place at Tadulako University's Faculty of Teacher Training and Education's Biology Education Laboratory. Gustavo and Ros Cultivar were sampled from agricultural goods in Sigi Regency and Napu Regency. The research was carried out during August and October of 2022. A 472 nm ultraviolet-visible (UV-Vis) spectrophotometer was utilized to analyze the lycopene measurements.

The lycopene content of tomatoes is determined by washing 5 g of tomatoes. The fruits are separated from the seeds, then sliced and mixed before being placed in an Erlenmeyer glass. The fruit was then extracted by shaking for 30 minutes with 50 ml of extract solution containing 2:1:1 v/v hexane, acetone, and ethanol solutions. The solution was filtered before being mixed with 10 mL of distilled water. The solution was then agitated for 15 minutes to generate two polar layers (the bottom layer) and one non-polar layer (the top layer). The non-polar layer was collected and placed in a 100-ml volumetric flask. Up to the volumetric flask's mark, hexane solvent was added. Finally, the absorbance of the solution was determined using a 472 nm UV-Vis spectrophotometer. The formula for calculating lycopene concentration is:

$$\text{Lycopene (mg/kg w.w.)} = (\text{A472} \times 0{,}0288) / \text{kg sample w.w.} \quad (1)$$

Note: Kg Kilogram sample weight of material: Sample w.w. The constant 0.0288 is calculated by dividing the lycopene molar extension coefficient (18.6×10^4 /M/cm) by the lycopene molecular weight (536.9 g/mol).

Results and Discussion

Climate factors were assessed in two climate-differentiated locations in the study. The following table displays the climate data collected at the two research sites.

Table 1. shows climate data from the two research regions.

Region	Climate	
Napu	Humidity	54,3 %,
	Temperature	21,8 ºC
	Wind speed	3,1 mph
	Soil pH	5,9
Sigi	Humidity	60,7%,
	Temperature	32,8 ºC
	Wind speed	0,8 mph
	Soil pH	4,2

The Gustavo and Ros tomato types were sampled from the two places or regions using a sealed container packed with ice. A total of 100 g of tomatoes from each type and region were crushed to make tomato juice, which was then weighed to acquire the absorbance measurement findings and lycopene levels displayed in **Table 2**.

Table 2. shows the absorbance and lycopene levels of tomatoes from two areas and two kinds.

Tomato	Climate	Region	Replication	Absorbance	Lycopene (mg/kg)	Mean (mg/kg)	SD
Gustavo	Hot	Sigi	R1	0.266	15.35	15.40	0.547
			R2	0.258	14.89		
			R3	0.277	15.98		
	Cold	Napu	R1	0.288	16.62	14.73	2.259
			R2	0.266	15.35		
			R3	0.212	12.23		
Ros	Hot	Sigi	R1	0.537	30.99	30.99	0.000
			R2	0.537	30.99		
			R3	0.537	30.99		
	Cold	Napu	R1	0. 360	20.77	20.31	0.902
			R2	0.334	19.27		
			R3	0.362	20.89		

Figure 1 depicts the differences in lycopene levels (mg/kg) of tomato cultivars from different areas as presented in **Table 2**.

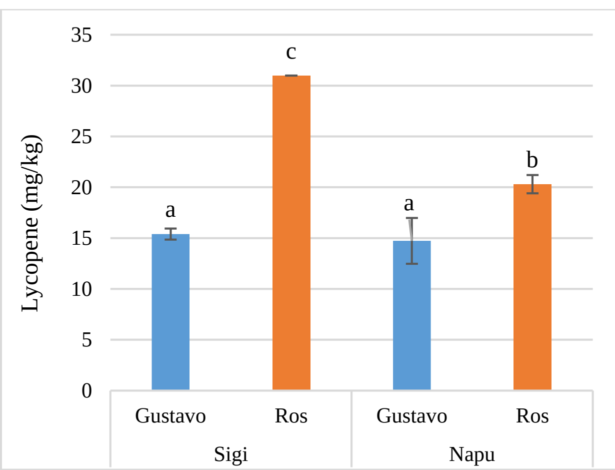

Figure 1. The differences in lycopene levels (mg/kg) of tomato cultivars from different areas.

Environmental factors and genetic differences between plant species or cultivars could theoretically influence the expression of plant components, including lycopene content. According to **Table 1**, Sigi has a warmer climate than the Napu region. In contrast, the wind speed and soil pH in Sigi are lower than in Napu. The lycopene content of tomato plants appears to be affected by the contrasting climatic conditions of the two locations. Nonetheless, the lycopene content of tomatoes appears to be influenced by factors other than climate change. The presence of genetic components in the tomato cultivar also plays a role. The lycopene content in various locations in the Sigi Region and the Napu Region was not statistically different, as was the case with the Gustavo Cultivar **(Table 2; Figure 1)**, but it was significantly different for the Ros Cultivar. Similarly, the lycopene concentration of numerous tomato cultivars, including the Gustavo Cultivar, varied marginally, whereas that of the Ros Cultivar was significantly different. Ros contains more lycopene than the other two cultivars.

Gustavo Cultivar has the same response to varied conditions as Ros Cultivar. Meanwhile, the Ros Cultivar is extremely sensitive to environmental changes. Interestingly, the study's findings suggest that the Ros Cultivar from the hot-climate Sigi Region had the highest lycopene level when compared to lycopene from tomatoes from the Napu Region. These findings show that the cultivar can respond to high temperatures, possibly through secondary metabolic regulation systems. Secondary metabolism, secondary lycopene metabolites [20-22], multiple sources claim that this is a method by which plants react to adverse environmental factors such as high temperatures [23], and other environmental stressors. The results of the study indicate that plants try to adjust to high conditions by producing lycopene. The Ros Cultivar from the Sigi Region had higher levels of lycopene than the Napu Region. The Ros Cultivar can acclimate to the scorching temperatures of the Sigi Region as a result of its ability to carry out secondary metabolism by generating lycopene.

Lycopene can combat free radicals produced by pollutants and UV radiation. Its ability to regulate free radicals is ten times that of vitamin E and two times that of beta-carotene [24, 25]. Apart from being anti-skin aging, lycopene also has benefits for preventing cardiovascular disease [5], osteoporosis [8], infertility [26, 27], and cancer, especially prostate cancer [6, 7, 15]. The most active molecule frequently discovered in red fruit, lycopene, plays a crucial role in health and has been shown in studies to have some advantages. The amount of research that has been done has expanded our understanding of lycopene's advantages. This is done to advance the field of medicine. Lycopene, which is found in tomato plants, is located on chromosome 4, which has a nucleotide arrangement of 1838 base pairs and 501 amino acids, as indicated by research that was presented on the website of the NCBI. There is no discernible difference between the levels of lycopene found in tomato plants and those found in other plants. As a consequence of this, it is quite likely that the two cultivars have the same nucleotide order, even though their DNA has differing degrees of lycopene gene expression to ensure the accuracy of the results. There is a need for additional research into both the genotype and expression of the lycopene gene in these two different tomato plant cultivars. According to the findings of earlier research [28], a cultivar of plants may adjust to high temperatures by altering the expression of genes that code for sucrose synthetase, cell wall invertase, peroxidases (APXs), and heat shock proteins. According to Catalá *et al*. (2006), temperature and other environmental conditions have a substantial impact on the physiology, biochemistry, and morphology of plants [29]. In the future, when it comes to the creation of new species, it will be vital to take advantage of genetic diversity to decrease the detrimental effects of high temperatures.

Figure 1 displays that tomatoes grown in the Sigi Region at a temperature of 32.8 degrees Celsius had the highest lycopene content. The findings contradict those of Zheng *et al.* (2020), who discovered that 20–27 ºC is the optimal temperature range for tomato development [30]. Meanwhile, temperatures between 15 and 30 degrees Celsius are optimal, according to Gosselin and Trudel (2022), because they allow red pigment to form on the surface of tomatoes [31]. Accordingly, the optimal temperature range for tomato growth and development is 15–30 ºC. At the Napu location, it falls within the range, but not at the Sigi location. 25% relative humidity is recommended for tomato plant growth. This moisture will promote the growth of immature tomato plants. Because 25% soil moisture enhances CO_2 absorption. Tomato plants with 25% humidity can produce fruit with a high lycopene content [30]. The relative humidity in the Sigi and Napu Regions exceeds 25% **(Table 1)**.

Soil acidity (pH) levels optimal for tomato growth range from 5.0 to 7.0 [32]. The Napu Region falls into the soil pH group suited for tomato growing, whereas the Sigi area does not **(Table 1)**. Several previous studies on lycopene in tomatoes have been conducted, but research on tomatoes related to climate in the Sigi and Napu Regions themselves has not yet been conducted. Thus, researchers assume that the Ros Cultivar, which has the most lycopene, is suitable for the conditions in Sigi. The weather is scorching. This is consistent with the findings of Gosselin and Trudel (2022), who discovered that tomato plants may thrive in hot climates [31].

In addition to the environment. the researchers assessed that the degree of ripeness of the tomatoes was also quite relevant because the tomatoes were analyzed at varied stages of ripeness at the time of the study. Ros tomatoes have a distinct red fruit color to Gustavo Cultivar's tomatoes. Therefore, they can produce a lot of lycopene. This assertion is consistent with Rivero's (2022) finding that in one cultivar of tomato, ripe and red fruit has more lycopene than less ripe tomatoes, which are less red [4]. As a result, the findings of this study are intriguing because they contradict prior findings by other researchers. Researchers previously theorized that tomatoes grown in cold climates developed better, resulting in tomatoes with a high lycopene concentration. However, the results revealed that tomatoes grown in hotter climates had the highest lycopene concentration.

In comparison to Setiawati's (2019) findings, she had 40.59 mg/kg of lycopene [33]. **Table 2** reveals that Sigi's tomatoes had the highest lycopene concentration at 30.99, while Gustavo's tomatoes had the lowest concentration at 14.73. Low amounts of lycopene in tomatoes were found in this study. This could be because the tomato cultivars studied were different. The study was also supported by research done by Bahanla Oboulbiga in 2018, She found that the amount of lycopene in tomatoes depends on the type, how old they are, and where they grow. In a hot area, the types that were looked at are likely to find a good place to grow. In another study, Vela-Hinojosa (2019) found that the amount of "lycopene" in fruit is affected by the genotype but not by the surroundings [34]. Lin *et al*. (2019) reported that the genetic variation in several species of *Solanum pimpinellifolium* L, *Solanum habrochaites* L, *Solanum chmielewskii* L, and *Solanum cheesmanii* L was resistant to heat and dehydration stress [35]. This indicates that the relationship between cultivars and genotypes is that a cultivar is a genetic expression caused by plants that allows it to be distinguished from other types or the same type. It is also possible that tomatoes of the Ros Cultivar, which are tolerant to high temperatures and climate, are listed in **Table 1** because relatively high temperatures are frequently a stress factor for tomato plants, which can affect plant growth by inhibiting the ability of flowers to grow and be pollinated to develop into drupes, inhibiting fruit ripening, and decreasing yield. The genes CBF, NHX1, DREB1, and HSP70, which make several cultivars of tomato plants tolerant to climatic stress, are the focus of research related to heat tolerance in tomatoes [28]. However, this is a limitation of the research, as it is challenging to obtain comparable data on tomato growth in the same region as the Sigi and Napu Regions.

As previously mentioned, the Ros tomato Cultivar in the Sigi region makes it possible to create a gene derivative that is resistant to high temperatures. However, this is difficult to determine because Ros and Gustavo tomato cultivars have not been studied. Another disadvantage of this study is that the research results have not yet yielded enough cultivars. Throughout the sampling interval, the researchers posed numerous queries to local tomato farmers. According to them, the number of tomato farmers in the Sigi region was declining, and by the time this research was entering the summer season, tomato farms had been displaced by corn fields. This is the factor that becomes an impediment, resulting in an imbalance between tomatoes grown in frigid and warm climates.

Conclusion

Climate and cultivar variables have a significant impact on the lycopene concentration of the Ros Cultivar. The Gustavo Cultivar, on the other hand, did not experience this climate variance. The Ros Cultivar contained the most lycopene. The warmer temperature increased lycopene levels in the Ros Cultivar but not in the Gustavo Cultivar.

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