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Flowering and fruiting phenology in two varieties of grapes (*Vitis vinifera*) in tropical regions, Indonesia

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Abstract. *Kamila S, Widodo WD, Santosa E, Suhartanto MR. 2024. Flowering and fruiting phenology in two varieties of grapes* (Vitis vinifera) *in tropical regions, Indonesia. Biodiversitas 25: 4593-4602.* Determining harvest time is a crucial phase in the production of high-quality grapes (*Vitis vinifera* L.). Traditional indicators, such as the number of days after pruning, the flowering period, and changes in skin color, are often unreliable. The variations in planting locations, particularly between lowland and highland areas, significantly influence temperature and climate conditions. These factors, especially in tropical regions with high rainfall, complicate the estimation of the harvest time, necessitating precise harvest handling. To determine grapes' ripeness level, a more accurate method, such as the heat unit method or accumulated heat unit, is required. This method considers the actual average temperature obtained by plants while in the field until they reach optimal maturity for harvest. Therefore, this study aimed to determine the heat units (°C per day) required from anthesis to harvest as a measurable criterion for assessing the ripeness of Jupiter and Transfiguration grape varieties. Additionally, it also focused on identifying the flowering and fruiting phenology of grapes in Indonesia, located in a tropical climate. The results showed that the two grape varieties can be harvested with a heating unit for Jupiter of 2521°C and Transfiguration of 2527°C. There was no difference between the two, but there was a significant difference in fruit diameter and metabolite compound content. These findings have significant practical implications for grape growers in tropical regions, providing them with a more accurate method for determining harvest time and improving the quality of their grapes.

Keywords: Fruit diameter, grapes, heat unit, life cycle of grapes, metabolite compound, phenology

INTRODUCTION

Growers often use simple methods to determine grape ripeness, such as counting the number of days after pruning, noting the flowering time, and measuring the skin color index. However, these methods are subjective and can lead to inconsistency in the quality of grapes during harvest. This inconsistency underscores the need for a more accurate alternative, which includes the heat unit method.

After ripening, harvesting at the right stage of ripeness is of the utmost importance regarding the desired fruit quality. The heat unit accumulation method during fruit growth and development has been used as a convenient, easy, and feasible criterion to determine fruit maturity. This method considers the actual average temperature experienced by the plant in the field until it reaches the optimum maturity for harvesting (Halepotara et al. 2019).

Phenology is the study of the timing of recurrent biological events (phenophase), the causes of this timing in the context of biotic and abiotic factors, and the relationships between phases of the same or different species. Additionally, phenology is defined by describing observable events and also by describing indirect relationships and the effects of phenological events on an ecosystem (Gray and Ewers 2021). Temperature is an important factor influencing the duration of phenophase. Meteorological conditions, including annual changes in air temperature, lead to variations in the phenophase length and quality of grapes (De Rességuier et al. 2020). Accurate information on plant phenology during the growing season is required for plant growth management and yield estimation, such as fertilizer scheduling, pest control, harvest operations, as well as predicting the impact of weather disturbances on grape vines (Gao and Zhang 2021). The phenology of flower and grapefruit development phases is based on Growing Degree Days (GDD).

The development of high-quality grapes requires planting materials and cultivation methods that are appropriate for the climatic conditions and adaptable to climate change. This approach ensures the maintenance of an optimal harvest period and the production of quality fruit (Tóth and Végvári 2016; Mihailescu and Soares 2020). Jupiter and Transfiguration varieties of grapefruit introduced from Ukraine (description attached) are in high demand and grown in Indonesia.

Grapes are a rich source of bioactive compounds, including phenolic acid, flavonoid, and anthocyanin. Phenolic content and composition are important indicators of the nutritional quality of grapes (Zhang et al. 2021) and critical determinants of quality and wine color (Chen et al.

2020). Anthocyanins, a class of secondary metabolites, contribute to the red, blue, and purple colors of flowers, fruits, and leaves (Van den Ende and El-Esawe 2014). Anthocyanins are responsible for the red and purple colors that accumulate during ripening on the skin of berries of red varieties. The red color of grapes, influenced by the quantity and composition of anthocyanins, is an essential factor determining market acceptance. However, the quantity and composition of anthocyanin in grapes are not fixed but rather influenced by a myriad of factors, including variety, maturity, post-harvest storage, and environmental factors such as location, light conditions, temperature, nutrition, water, micro-organisms, and viticulture practices (Chen et al. 2020; Colombo et al. 2020; Yang et al. 2020). This variability adds a layer of complexity to the study of grapes and their nutritional quality.

Bioactive compounds also benefit human health (Cosme et al. 2018; Xu et al. 2019), especially phenolics, including phenolic acids, stilbenes, flavonols, flavan-3-ols, and anthocyanin derivatives (Rodriguez-Casado 2016; Zhou et al. 2022). Phenolics act as antioxidants, anticancer, anti-inflammatory, and other properties for human health (Ky et al. 2014; Liu et al. 2018; Pexioto et al. 2018). These bioactive compounds are variably distributed in each part of the berries, especially in the skin and seeds (Pexioto et al. 2018; Zhou et al. 2022). The seeds showed the highest quantity of phenolic compounds and also the highest antioxidant, cytotoxic, and antibacterial activities (Pexioto et al. 2018; Zhou et al. 2022).

The growth potential of table grapes, particularly the differences between Jupiter and Transfiguration, is a key area that requires further investigation. More information is needed on the differences in growth, grape production, and metabolite content between these two varieties. This knowledge is essential for assessing the potential of these table grapes as fruit crops and antioxidant plants. The ultimate goal of this study aimed to determine the phenology and biology of flowering, including flower morphology and development, fruit morphology, and development, and to establish heat units (°C days) as a criterion for the grape harvest, which can be measured and compared for two varieties grown in tropical areas.

MATERIALS AND METHODS

Study area

This study was conducted from June 2022 to August 2023 at Cibubur, Ciracas Sub-district, East Jakarta District, Jakarta, Indonesia (6°21’25” S, 106°53’27” E) (Figure 1). The site is situated at an altitude of 66.61 m asl. Flower and fruit phenology observations were carried out visually and documented using a camera. Photo enlargement documentation of flowers was carried out at the Advance Laboratory of Institut Pertanian Bogor (IPB), Indonesia. The analysis of metabolite compound content was conducted at the Post-Harvest Research and Development Center Laboratory (*Laboratorium Balai Besar Litbang Pasca Panen*), Bogor, and the measurement of fruit diameter was conducted at the Post-harvest Laboratory Department of Agronomy and Horticulture, IPB. Observation of *Fusarium* and *Colletotrichum* diseases using a 400x magnification light microscope (Olympus) at the Laboratory of Pests and Plant Diseases P2BPT Cibubur Central Office of Seed Development and Plant Protection Jalan Jamboree, Cibubur, Ciracas Sub-district, East Jakarta District, Jakarta, Indonesia.

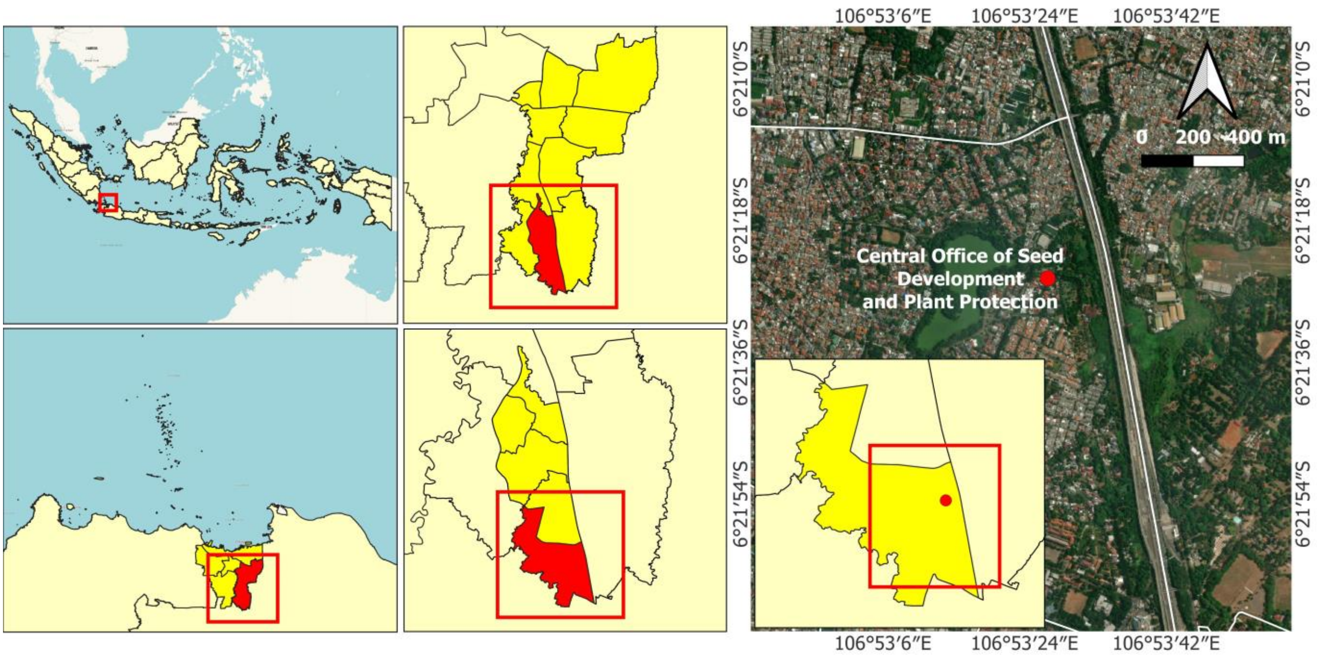

Figure 1. Location of the study area, in the garden of the Central Office of Seed Development and Plant Protection Jalan Jamboree, Cibubur, Ciracas Sub-district, East Jakarta District, Jakarta, Indonesia

Plant materials

Plants used for seed resources were collected from Kediri, Indonesia, after being propagated using the grafting method with 1-month-old Isabela grapes variety rootstock.

Procedures

In this study, 72 grapes were planted as tabulampot (planting fruit in pots) with a 1.5 m × 0.5 m spacing. Plant maintenance was carried out until they were ready to bear fruit by forming four tertiary branches per pot, which included flowers appearing on the vine. The average temperature at the study site during the flower emergence phase until harvest ranged from 26-31°C measured using a data logger thermometer (Elitech RC-5). All cultivation practices regarding fertilization, weed control, and plant-disturbing organisms (pests) were carried out according to standard regional cultivation practices during the trial, and pruning for flowering was performed in April of 2023.

The parameter observed was heat unit value (GDD°C). The determination of harvest days was based on heat units by calculating the daily average temperature from anthesis to harvest with a temperature data logger installed in the field at a height of 1.5 m from the ground, protected from direct sunlight and rain. The temperature data was recorded every 2 hours. Based on the guidelines by Umber et al. (2011), the heating unit is the sum of the maximum temperature of the day i (°C) plus the minimum temperature of the day i (°C) divided by two minus the base temperature of the plant (b = 10°C), as follows:

$$\textbf{Heat unit} = \Sigma\left(\frac{T_{Max\,i} + T_{Min\,i}}{2}\right) - b$$

Phenological study of flower and grape development

The flowering and fruiting phenology observations were made on four tertiary branches in each pot. The observation was carried out when flowers appeared in approximately 75% of the total experimental units from 07.00 to 09.00 am when the plants were fresh. Trees were marked with a red ribbon, and vigorous fruit bunches were selected, each with one flower cluster/treatment. Anthesis in grapevines after pruning begins with bud breakage (sprouted), blooming, pollination, fruit set, and color change (veraison) until harvest. Daily flower development is recorded with a data logger. The observation of fruit diameter was carried out with ten fruits proportionally, namely 3 at the base of the cluster, 4 in the middle of the fruit cluster, and 3 at the end of the fruit cluster. Measurement using a digital caliper was performed when the fruit was ripe.

The analysis of bioactive compounds, including phenol, flavonoid, and anthocyanin, was measured using the spectrophotometric method (Sims and Gamon 2002).

Data analysis

The data were analyzed using a T-test.

RESULTS AND DISCUSSION

Study phenology of grapes

The determination of grapes heat unit is the first study to test GDD in the tropics (Indonesia) on two types of grapevines, Jupiter and Transfiguration, about the timing of the flower emergence phase to ripe fruit ready for harvest. Next, 7 flower-to-fruit development phases were observed, including anthesis, cluster, blooming, fruit set, berry, veraison, and harvest.

Based on the T-test analysis results, there was no difference in heat unit values at each flowering and fruiting phase between the two varieties (tn). This study on grapes heat unit determination is to test GDD in the tropics on two varieties, Jupiter and Transfiguration. It focuses on the period from the flower emergence phase to fruit ripeness and readiness for harvest. The values of Jupiter and Transfiguration varieties were obtained on days 2521°C and 2527°C, respectively. Anthesis to fruit ripening occurs when rainfall in Indonesia is low due to the hot summer months of March, April, and May until August 2023. In these months, based on information obtained from the Meteorology, Climatology, and Geophysics Agency (BMKG), there was the influence of El Nino. The impact of El Nino feels more vital in the dry season, namely July, August to October 2023. Moreover, many regions in Indonesia have reached the peak of the dry season in these months. Mardianto and Setiyanto (2023) reported that El Nino was previously predicted to occur from early June 2023 to mid-2024.

Hot conditions do not adversely affect grape plants. In fact, these conditions stimulate accelerated flowering and earlier fruit ripening. Biasi et al. (2019) explained that grapes and berry ripening phenology indices are susceptible to climate change and are very sensitive to genotypes. Fraga et al. (2016) explained that the impact of climate change shows that plant phenological events in meeting their heat needs are shorter. The study of the degree days required for each flowering phase between the Jupiter and Transfiguration grape varieties is important. It shows that the growth and development times of these grapevines are the same, reinforcing the importance of this study in understanding grape and berry ripening phenology. No variety stands out as better or more advanced than the other (Table 1).

This similarity means that the two varieties can be cultivated with the same agronomic measures. Heat unit values obtained at each growth phase, from bud break to fruit ripening of Jupiter and Transfiguration varieties, are presented in Table 1 and Figure 2.

Genetically, both varieties have a similar number of harvest days; however, in this study, the Jupiter variety ripened more quickly, averaging 104 days from pruning, while the Transfiguration variety took longer, averaging 110 days; the description of Jupiter and Transfiguration grapes varieties as shown in Table 2.

Table 1. Cumulative GDD or thermal time requirement for different development stages of two varieties of grapes

Stages / Varieties	Anthesis (°C)	Cluster (°C)	Blooming (°C)	Fruit Set (°C)	Berry (°C)	Veraison (°C)	Harvesting (°C)
Jupiter	1054 ± 150	1214 ± 152	1476 ± 165	1598 ± 164	1734 ± 167	2264 ± 166	2521 ± 168
Transfiguration	1061 ± 275	1218 ± 263	1476 ± 277	1599 ± 275	1738 ± 280	2269 ± 277	2527 ± 275

Table 2. Description of Jupiter and Transfiguration varieties

Varieties / Characteristics	Jupiter	Transfiguration/ Preobrazhenie
Plant of origin	USA	Russia/ Ukraine
Patent	2002	2014
Breeder	John Reuben Clark, Fayetteville, (US), James Norrman Moore	Krainov VN, Kostrikin IA, Maistrenko LA, Troshin LP, Volynkin VA, Likhovskoy VA.
Mature stem diameter	20 mm	-
Color stem	Gray orange 177 B	-
Frost resistance	-23°C	-23°C
Leaf character		
Leaf shape	Oval	-
Upper leaf color	Green Group 137 B	-
Number of lobes	3	-
Lower leaf color	Green 138 B	-
Length of mature petiole	11.75 cm	-
Flower characters		
Flower type	Hermaphroditic	Hermaphroditic
Length	12.5 cm	-
Width	7.5	-
Number flowers per bunch	355	-
Duration blossom to fruit	110 days	110-120 days
Petal number	5	5
Sepal number	5	5
Fruit characters		
Fruit color	reddish-blue at early maturity	Yellow with pink
Texture	Semi-crisp	Juice
Fruit weight	5.5 g	10 - 20 g
Fruit peel	Medium thickness, non-slip, semi-crispy Slightly oval	-
Fruit shape	Sweet, mild-muscat rate high	Elongated oval, oval
Fruit flavor	19.8 %	
Soluble solids	257 g	-
Weight of mature bunch	Seedless	900 - 1200 g
Berries	-	1-2 seeds per fruit
Size berries	-	35 x 25 mm
Acidity	-	5-7 g/dm3
Sugar content	25-29 t/ha	19 %
Productivity		11-18 t/ha

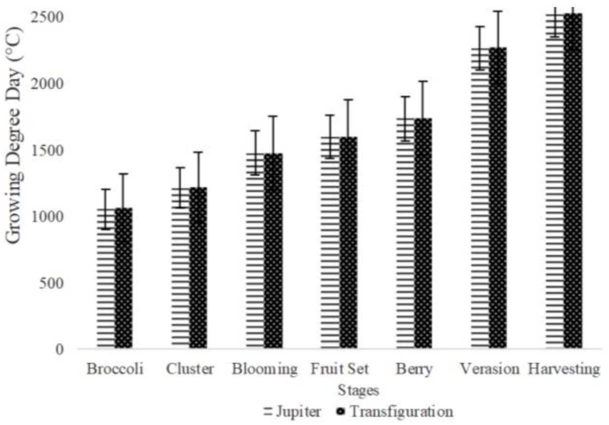

Figure 2. GDD requirement for two varieties of grapes at different stages of growth

Vine flower biology and growth phase

Grape flowers are considered compound because there are many flowers on each stalk. The flower consists of five sepals, petals, stamens, and a pistil that ends with a stigma. The reproductive organs of grapes flowers of Jupiter and Transfiguration varieties are presented in Figure 3.

There are no differences in reproductive organs between the flowers of Jupiter and Transfiguration. The blooming phase of the flower of the grapes is significant at +/-1 week. Most grape cultivars are hermaphroditic (containing both male and female reproductive structures) and self-pollinating. Anthesis (pollen release) occurs when the calyptra detaches from the base of the flower. The calyptra is the cap or covering of the male and female flowers, and when it is detached from the base of the grapes flower, it will reveal the stamens and pistil, as shown in Figure 4.

Cycle of grapes

Based on the degree of days of grapes growth in this study, the life cycle of grapes in 2023 in the tropical region (Cibubur-Indonesia) can be explained. The cycle is structured based on the development of the phenophase time of the current month, from pruning and flowering to maturity and back to pruning for the subsequent fruiting. Grapes' life cycle started with post-pruning in April, and in May, the growth response is already visible as the bud bursts (Figure 5).

The following week in May, the flowers enter the blooming phase after the bud bursts. This blooming phase clearly shows that the male and female flowers of the same tree are ready for pollination. Pollen with optimum pollen viability will insert the powder into the stigma, and pollination occurs then. Furthermore, in the same month (May), fertilization occurs (fruit set). This phase is characterized by the formation of berries and the remaining unfertilized flowers falling off. In June, there was a change in color (veraison) towards complete fruit ripening. The fruit reached the mature criteria in July and August and was harvested. After harvesting, the trees are pruned again in September, and if plant maintenance is carried out optimally and climatic conditions are conducive, grape will be harvested again in December.

This is unique and can be used as a guideline for grape cultivation in Indonesia as well as a differentiating factor from grape cultivation in the subtropical zone, which can only be harvested once a year due to the four seasons. In Indonesia, grapes are harvested 2 or 3 times a year. This is in accordance with the opinion of Camargo et al. (2012). In some tropical areas, due to the climate, grapes harvests are more than once a year, allowing pruning programs according to the demands of the wine industry. Flower and fruit phenology of Jupiter variety grapes, 5 days after pruning (HSP), are presented in Table 3.

Fruit diameters and metabolite content of the two grape varieties

The fruit diameters of Jupiter and Transfiguration varieties were significantly different; the Jupiter variety has larger fruits than Transfiguration. The average diameter of small fruit (S) in Jupiter and Transfiguration varieties is 2.31 mm; 1.21 mm; medium size (M) is 5.12 mm; 1.83 mm; and large size (L) is 6.47 mm; 2.2 mm. Morphologically, according to the description, the weight of the Transfiguration fruit is heavier than Jupiter, thereby the diameter of the fruit should also be larger. However, in this study, Jupiter had a larger fruit diameter than Transfiguration. This is believed to be related to the cultivation technique of tabulampot grapes in the open field where the environment directly influences plants. For example, climatic factors in fields that are covered by clouds can inhibit the interception of sunlight. This phenomenon is common in tropical areas that are hot but have high rainfall. Areas with high cloudiness are the cause of decreased biomass production because the radiation received does not match the needs of the plant.

In general, tropical regions according to Kok (2014), countries with tropical climates generally have a day length of 12 light hours per day for equatorial days and 8-12 light hours per day for short days. Although Cibubur is known as a cloudy area, and rainfall tends to be high. Subsequently, high and intense rainfall causes the length of sunlight to be reduced and shorter.

This study was conducted in the garden area of the Plant Protection Seed Center office, which is planted with a variety of vegetation that creates a relaxed and shady atmosphere, presumably affecting sunlight interception. Plants that did not receive sufficient sunlight (shaded) reduced berry color conversion, grape color, sugar content, single grain weight and soluble solids content, and berry efficiency. In addition, different levels of light transmission affected the accumulation of sugar content in grapes. There were 16 differentially expressed transcriptomic analyses of genes regulating PS I and PS II. These genes influence the accumulation of sugar content in berries through the photosynthetic pathway. The results showed that gene expression of the photosynthetic antenna protein pathway in berries was inhibited after cluster shading. This inhibition may decrease the sugar content in grape berries (Nan et al. 2024).

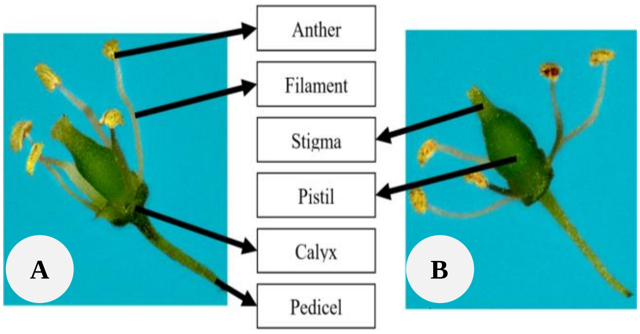

Figure 3. Reproductive organs: A. Var. Jupiter; B. Var. Transfiguration (photo by Seri Kamila, IPB, Bogor)

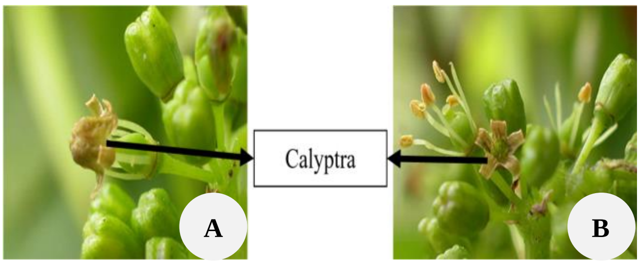

Figure 4. A. The cap separates from the base of the flower, becomes dislodged, and usually falls off, exposing the pistil and anthers; the anthers may release their pollen either before or after the cap falls. B. Pollen grains randomly land upon the stigma of the pistil, allowing pollination (Source: Giese et al. 2020)

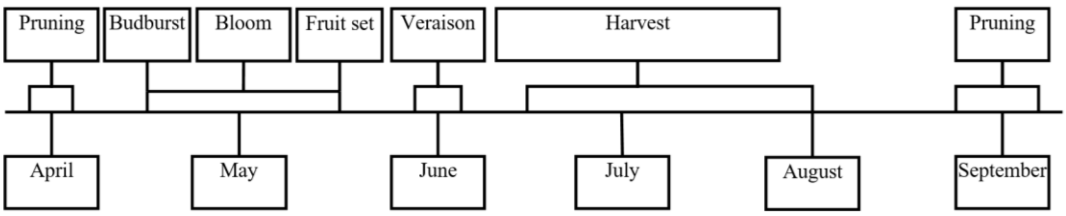

Figure 5. Grape growth cycle from April to September

Table 3. Flower and fruit phenology of Jupiter variety after pruning

Phenology	Phase	Phenology	Phase	Phenology	Phase
A. Bud Swell		B. Budburst		C. Anthesis (Flowering)	
D. Cluster		E. Pre blooming		F. Pollination	
G. Fruitset		H. Post Fruit Set		I. Berries	
J. Pre Veraison		K. Veraison		L. Veraison	
M. Veraison		N. Veraison		O. Harvesting	

Note: A. After fertilization pruning, the bud eyes look enlarged; B. Bud breaks, and a flower-bearing sprout emerges; C. Broccoli; D. Cluster formation; E. Clusters separate from each other; calyptra covers male and female flowers; F. The flower in a state of bloom. Anthesis occurs when the caliper detaches from the base of the flower; male and female flowers are visible and ready for pollination; G. Flowers that are successfully pollinated will become fruit. Otherwise, the flowers shrivel, dry, die, and fall off the bunch; H. The ovary will enlarge into a berry in female flowers, occurring 2-3 hours post-pollination; I. Berries start to grow in size; J. The size of the berries is increasing day by day, and they are shiny, bright green; K. Fruit phase starts to change color; L. Fruit discoloration is almost 50% red, and starting to soften; M. The fruit is almost completely red getting soft; N. All fruits are evenly red and soft; O. Red-black fruit, soft, sweet, and flavorful, ready for harvest

Shiraz grapes in Australia at 40°C and full sun were tested under various shading conditions with different Photon Flux Densities (PFD). In light shade, solar radiation was reduced by 10%, while medium shade radiation was reduced by 33%, and heavy shade was reduced by 55% compared to the control influence on fruit diameter (Abeysinghe et al. 2014).

Open-field grape cultivation faces many serious obstacles, such as plant-disturbing organisms (PEST) attacks. These are mainly caused by fungi such as Powdery mildew disease - *Uncinula necator* (Schwein.) Burrill, *Fusarium* wilt disease, *Colletotrichun*, Leaf rust disease, Stem base rot, Kutu Kebul (*Bemisia tabaci* (Gennadius, 1889)), Mite, Trip, and Shoot sucker pests. These attacks lead to stunted and suboptimal plant growth; some of the fungi, such as *Fusarium* and *Colletotrichum* (Figure 6). This figure shows that fusarium spores can be seen, causing the plant to wilt and the leaves to fall off, as leaves are essential for photosynthesis. If the leaves are reduced, the photosynthate produced will also be reduced. Fusarium is a species-rich genus that includes important plant pathogens that cause root and crown rot, wilt, blight, and blight in a wide range of perennials (Gordon 2017). In grapevines, one of the severe diseases is Grapevine Stem Disease (GTD), which causes grape and wine production to decline (Kaplan et al. 2016).

Table 4. Total phenol, total flavonoid, and total anthocyanin in the fruit of Jupiter and Transfiguration

Varieties	Total phenol (mg GAE g-1 dw)	Total flavonoid (mg QE g-1 dw)	Total anthocyanin (mg g-1 fw)
Jupiter	91.725 mg GAE/g	7.812 QE/100 g	57,167 mg/100 g
Transfiguration	87.983 GAE/g	7.116 QE/100 g	55.167 mg/100 g

Note: dw: Dry weight, fw: Fresh weight, GAE: Gallic Acid Equivalent, QE: Quercetin Equivalent

Brown spot (*Colletotrichum*)

Grape leaves affected by Fusarium wilt experience chlorosis, dryness, wilting, and fall

Preparation

Magnified cells of Fusarium and Colletotrichum fungi by microscopy

Figure 6. *Fusarium* sp. and *Colletotrichum* in leaf cell

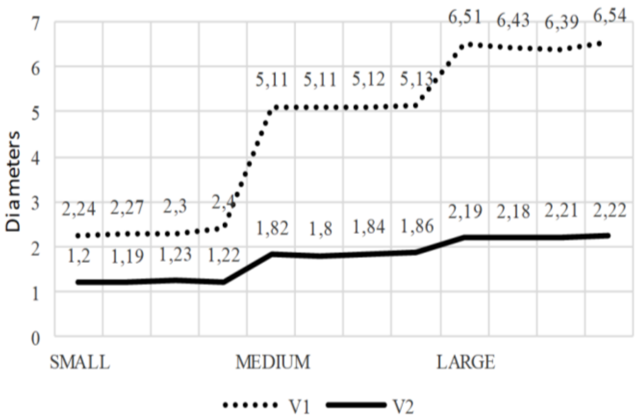

Figure 7. Fruit diameters of both Jupiter and Transfiguration: S (Small), M (Medium), L (Large)

The crop was cultivated in June 2022, before the rainy season. Unfortunately, the vegetative phase of the plant experienced poor climatic conditions due to heavy rainfall from August to January 2023. As a result, the growing medium tended to be waterlogged, resulting in anaerobic reactions that inhibited plant growth. In addition, some nutrients were leached because the growing media used were too porous, such as raw husks, burnt husks, and mashed goat manure. Nutrients that are not available to plants result in plant deficiencies.

A deficiency of nitrogen in grapevines results in the development of weak plants, shortened internodes, a reduction in leaf size, and light green to yellow coloration. This has been observed to affect the fruit set, long-term shoot fertility, yield (Guilpart et al. 2014), and the ripening process (Schreiner et al. 2018). The results showed that climate strongly influences soil erosion due to high rainfall, which impacts soil productivity. Less but more intensive rainfall in Mediterranean climates affects soil erosion (Grillakis et al. 2020). During the rainy season, sunlight intensity is low enough to inhibit photosynthesis. Carbohydrates from photosynthesis used for vegetative growth that are translocated to the generative phase are low. As a result, vine growth is inhibited. Nutrients used by plants are used more for recovery from pest and disease attacks so that the resulting growth biomass, such as fruit diameter, is not optimal.

The plant conditions will be different if cultivation is carried out in grape centers such as Probolinggo, Banyuwangi, Buleleng-Bali, and NTT, where climatic conditions are hot and rainfall is low leading to the production of grapes with better morphophysiological quality. Djufry (2022), in Indonesia, there are hundreds of varied soil types, 52 types of climate/rainfall patterns, 17 types of agro-climatic, and temperature variations related to topo physiography. Therefore, precision agriculture in the future is needed for grapes commodity development based on the dynamics of climate change and planting location. The difference in average fruit diameter of Jupiter and Transfiguration grapes is presented in Figure 7.

Total phenol, total flavonoid, and total anthocyanin in Jupiter and Transfiguration fruit measured in each of the introduced grape varieties of Jupiter and Transfiguration obtained total phenol 91.725 mg GAE/g; 87.983 mg GAE/g, total flavonoid 7.812 QE/100; 7.116 QE/100 g, and total anthocyanin 57.553 mg/100 g; 55.167 mg/100 g, respectively. The content of metabolite compounds is shown in Table 4. This table shows that the Jupiter variety has higher total phenolic, total flavonoid, and total anthocyanin content compared to the Transfiguration variety. Morphologically, red-colored grapes generally have higher carotenoid and anthocyanin pigment content. This is found in the Jupiter variety, which has a higher total anthocyanin; thereby it is dominantly red, compared to the Transfiguration variety with a lower total anthocyanin (Figure 8).

Table 5. Sunlight intensity (Lux meter)

Field \ Lux meter	The front (Lux)	Centre (Lux)	Backside (Lux)
TL	3442	4750	3053
BL	244.8	356.3	210.3

Note: TL: Top of the Leaf; BL: Bottom of Leaf

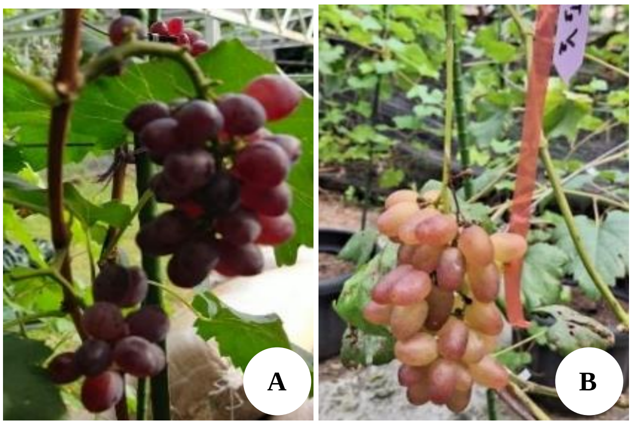

Figure 8. The color of ripe grapefruits of Jupiter and Transfiguration variety: A. Blackish red; and B. Yellow with a red tinge

Anthocyanin content mainly determines grapes' skin color. Anthocyanin is a flavonoid compound that is a secondary metabolite of plants and is synthesized during ripening (Kőrösi et al. 2022). The synthesis pathway of grape anthocyanins has been revealed clearly. Anthocyanins are synthesized via the phenylpropanoid pathway, starting with the amino acid Phe, through the flavonoid synthesis pathway to produce stable anthocyanins. Subsequently, cyanidin, delphinidin, peonidin, petunidin, and malvidin are the main anthocyanin inducers in grapes (Wang et al. 2022). Anthocyanin compounds are responsible for all the orange, red, blue, pink, and purple colors in grapes and their products, such as wine and juice (Mattioli et al. 2020). Anthocyanin is synthesized in the skin of red varieties and accumulates, while no anthocyanin is produced in the fruit of white varieties (Massonnet et al. 2017). The quantity and composition of anthocyanins in grapes primarily depend on varieties, environmental factors, and cultivation management (Guan et al. 2016).

Anthocyanin accumulation in berries was reported to be enhanced, especially in red to purple-skinned accessions, by combining post-harvest light irradiation (white light + UV light or blue LED light) with 15-25°C treatment. The optimal temperature (15-20°C) increased anthocyanin accumulation without a decrease in titratable acidity and berry weight. Coordinated induction of anthocyanin biosynthesis-related genes under these conditions may explain anthocyanin accumulation (Azuma et al. 2019).

Similarly, a temperature that is too high is not suitable for grapes. High temperatures can inhibit most phenolic accumulation in table grape varieties (Zhang et al. 2021). The effect of high temperature on grape composition affects various metabolite compounds, especially flavonoids, which are essential compounds for grape and wine quality. A decrease in total anthocyanins has been reported in many cases and is directly attributable to the effects of high temperatures. In climate change, in already warm and hot regions, such changes can be detrimental to grape growth and quality wine production, as high temperatures have been shown to affect berry composition critically (Gouot et al. 2018). The phenomenon of grapes being exposed to high heat stress in a short period, although the surface of grapes appears qualitatively normal, has led to a decline in nutrients.

The relationship between solar radiation and plant growth is known by light intensity, quality, and duration of irradiation. Light intensity and quality are the main factors in photosynthetic reactions, where atmospheric CO_2 is converted into carbohydrates, providing energy for all plant functions and structures (Shafiq et al. 2021). The plants' response to absorbing light will be different depending on their quality (Singh et al. 2015).

The effect of sunlight on anthocyanin accumulation and related gene networks in grape development has been investigated, and the results showed that sunlight is essential for anthocyanin accumulation in grapes. The gene network associated with anthocyanin biosynthesis showed higher activity in grapes exposed to sunlight. In gene expression analyses to identify genes involved in this process, new genes that may be involved in anthocyanin regulation were found. Sunlight is a crucial factor in shaping the color and quality of grapes through its effect on anthocyanin accumulation (Zou et al. 2019).

In this study, sunlight intensity in the field was measured using a Licor. Measurements were made by dividing the field into three parts, namely the front, center, and back. The light intensity tool is right above the Leaves (TL) and Behind the Leaves (BL). Sunlight intensity can be seen in Table 5.

According to Table 5, the light intensity reaching the canopy in the center of the field was 4750 lux, which is higher compared to the front and back areas, where the sunlight intensity was measured at 3442 lux and 3053 lux, respectively. This lower light intensity is thought to be due to the shading of trees around the planting site, which reduces solar radiation. Plant morphology in the field experienced changes due to low light intensity, such as the growth of vine internodes extending towards sunlight (etiolation), thin light green leaves, and the size of grapes not being optimal. Shade significantly decreased leaf size and lamina mass per unit area in rainforest plants (Meng et al. 2014).

Grapes grown under low light intensity have lower brightness values. Most of the genes related to anthocyanin synthesis are regulated by environmental factors (Qin et al. 2022). Anthocyanin content decreases under shaded conditions (Shinomiya et al. 2015). Light increases proanthocyanin and anthocyanin composition in grape skins by relative regulation of LAR1, LAR2, and ANR genes (Liu et al. 2016). In conclusion, heat unit accumulation of 2521°C days after anthesis can be used as a measurable harvest criterion for grapes of Jupiter and 2527°C Transfiguration varieties. In this study, there was no difference in the heat unit values required from anthesis to harvest maturity between the Jupiter and Transfiguration varieties. However, there were notable differences in fruit diameter and total phenol, flavonoid, and anthocyanin content, which were attributed to environmental influences related to microclimate. Based on these findings, Jupiter seems more adaptive to planting in open fields in Indonesia than Transfiguration. Therefore, Jupiter is recommended for cultivation by farmers and grape enthusiasts because of its flexibility in various planting environments and some of its associated advantages.

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REFERENCES

Abeysinghe SK, Greer DH, Rogiers SY. 2014. The interaction of temperature and light on yield and berry composition of *Vitis vinifera* 'Shiraz' under field conditions. Acta Hortic 1115 (18): 119-126. DOI: 10.17660/ActaHortic. 2016.1115.18.

Azuma A, Yakushiji H, Sato A. 2019. Post-harvest light irradiation and appropriate temperature treatment increase anthocyanin accumulation in grape berry skin. Postharvest Biol Technol 147: 89-99. DOI: 10.1016/j.postharvbio.2018.09.008.

Biasi R, Brunori E, Ferrara C, Salvati L. 2019. Assessing impacts of climate change on phenology and quality traits of *Vitis vinifera* L: The contribution of local knowledge. Plants 8 (5): 121. DOI: 10.3390/plants8050121.

Camargo UA, Mandelli F, Conceição MAF, Tonietto J. 2012. Grapevine performance and production strategies in tropical climates. Asian J Food Agro-Ind 5 (04): 257-269.

Chen H, Yang J, Deng X, Lei Y, Xie S, Guo S, Ren R, Li J, Zhang Z, Xu T. 2020. Foliar-sprayed manganese sulfate improves flavonoid content in grape berry skin of Cabernet Sauvignon (*Vitis vinifera* L.) growing on alkaline soil and wine chromatic characteristics. Food Chem 314: 126182. DOI: 10.1016/j.foodchem.2020.126182.

Colombo RC, Roberto SR, Nixdorf SL, Pérez-Navarro J, Gómez-Alonso S, Mena-Morales A, García-Romero E, Gonçalves LSA, da Cruz MA, de Carvalho DU, Madeira TB, Watanabe LS, de Souza RT, Hermosín-Gutiérrez I. 2020. Analysis of the phenolic composition and yield of 'BRS Vitoria'seedless table grape under different bunch densities using HPLC-DAD-ESI-MS/MS. Food Res Intl 130: 108955. DOI: 10.1016/j.foodres.2019.108955.

Cosme F, Pinto T, Vilela A. 2018. Phenolic compounds and antioxidant activity in grape juices: A chemical and sensory view. Beverages 4 (1): 22. DOI: 10.3390/beverages4010022.

de Rességuier L, Mary S, Le Roux R, Petitjean T, Quénol H, van Leeuwen C. 2020. Temperature variability at local scale in the Bordeaux Area. Relations with environmental factors and impact on vine phenology. Front Plant Sci 11. DOI: 10.3389/fpls.2020.00515.

Djufry F. 2022. Pengembangan Pertanian Cerdas Iklim Inovatif Berbasis Teknologi Budidaya Adaptif menuju Pertanian Modern Berkelanjutan. Kementan Bogor. IARD Press, Jakarta. [Indonesian]

Fraga H, Santos JA, Moutinho-Pereira J, Carlos C, Silvestre J, Eiras-Dias J, Mota T, Malheiro AC. 2016. Statistical modelling of grapevine phenology in Portuguese wine regions: Observed trends and climate change projections. J Agric Sci 154: 795-811. DOI: 10.1017/S0021859615000933.

Gao F, Zhang X. 2021. Mapping crop phenology in near real-time using satellite remote sensing: Challenges and opportunities. J Remote Sens 2021: 8379391. DOI: 10.34133/2021/8379391.

Giese G, Cruz CV, Leonardelli M 2020. Grapevine Phenology: Annual Growth and Development. College of Agricultural, Consumer And Environmental Sciences, New Mexico State University, New Mexico.

Gordon TR. 2017. *Fusarium oxysporum* and the *Fusarium* wilt syndrome. Ann Rev Phytopathol 55: 23-39. DOI: 10.1146/annurev-phyto-080615-095919.

Gouot JC, Smith JP, Holzapfel BP, Walker AR, Barril C. 2018. Grape berry flavonoids: A review of their biochemical responses to high and extreme high temperatures. J Exp Bot 70 (2): 397-423. DOI: 10.1093/jxb/ery392.

Gray REJ, Ewers RM. 2021. Monitoring forest phenology in a changing world. Forests 12 (3): 297. DOI: 10.3390/f12030297.

Grillakis GM, Polykretis C, Alexakis DD. 2020. Past and projected climate change impacts on rainfall erosivity: Advancing our knowledge for the eastern Mediterranean island of Crete. Catena 193: 104625. DOI: 10.1016/j.catena.2020.104625.

Guan L, Dai Z, Wu B-H, Wu J, Merlin I, Hilbert G, Renaud C, Gomès E, Edwards E, Li S-H, Delrot S. 2016. Anthocyanin biosynthesis is differentially regulated by light in the skin and flesh of white-fleshed and teinturier grape berries. Planta 243 (1): 23-41. DOI: 10.1007/s00425-015-2391-4.

Guilpart N, Metay A, Gary C. 2014. Grapevine bud fertility and number of berries per bunch are determined by water and nitrogen stress around flowering in the previous year. Eur J Agron 54: 9-20. DOI: 10.1016/j.eja.2013.11.002.

Halepotara FH, Kanzaria DR, Rajatiya JH, Solanki MB, Dodiya K. 2019. Effect of heat unit and time duration required for maturation of mango (*Mangifera indica* L.) CV. Kesar. J Pharmacogn Phytochem 8 (1): 537-541.

Kaplan J, Travadon R, Cooper M, Hillis V, Lubell M, Baumgartner K. 2016. Identifying economic hurdles to early adoption of preventative practices: The case of trunk diseases in California winegrape vineyards. Wine Econ Policy 5 (2): 127-141. DOI: 10.1016/j.wep.2016.11.001.

Kok D. 2014. A review on grape growing in tropical regions. Turkish J Agric Nat Sci 1: 1236-1241.

Kőrösi L, Molnár S, Teszlák P, Dörnyei Á, Maul E, Töpfer R, Marosvölgyi T, Szabó É, Röckel F. 2022. Comparative study on grape berry anthocyanins of various teinturier varieties. Foods 11 (22): 3668. DOI: 10.3390/ foods11223668.

Ky I, Lorrain B, Kolbas N, Crozier A, Peissedre P-L. 2014. Wine by-products: Phenolic characterization and antioxidant activity evaluation of grapes and grape pomaces from six different French grape varieties. Molecules 19 (1): 482-506. DOI: 10.3390/molecules19010482.

Liu M-Y, Song C-Z, Chi M, Wang T-M, Zuo L-L, Li X-L, Zhang Z-W, Xi Z-M. 2016. The effects of light and ethylene and their interaction on the regulation of proanthocyanidin and anthocyanin synthesis in the skins of *Vitis vinifera* berries. Plant Growth Regul 79: 377-390. DOI: 10.1007/s10725-015-0141-z.

Liu Q, Tang G-Y, Zhao C-V, Feng X-L, Xu X-Y, Cao S-Y, Meng X, Li S, Gan R-Y, Li H-B. 2018. Comparison of antioxidant activities of different grape varieties. Molecules 23 (10): 2432. DOI: 10.3390/molecules23102432.

Mardianto S, Setiyanto A. 2023. Analisis Dampak El Nino Terhadap Produksi Tanaman Pangan. Policy Brief, Kementrian Pertanian Republik Indonesia, Jakarta. [Indonesian]

Massonnet M, Fasoli M, Tornielli GB, Altieri M, Sandri M, Zuccolotto P, Paci P, Gardiman M, Zenoni S, Pezzotti M. 2017. Ripening transcriptomic program in red and white grapevine varieties correlates with berry skin anthocyanin accumulation. Plant Physiol 174 (4): 2376-2396. DOI: 10.1104/pp.17.00311.

Mattioli R, Francioso A, Mosca L, Silva P. 2020. Anthocyanins: A comprehensive review of their chemical properties and health effects on cardiovascular and neurodegenerative diseases. Molecules 25 (17): 3809. DOI: 10.3390/molecules25173809.

Meng F-Q, Cao R, Yang D-M, Niklas KJ, Sun S-C. 2014. Trade-offs between light interception and leaf water shedding: A comparison of shade- and sun-adapted species in a subtropical rainforest. Oecologia 174 (1): 13-22. DOI: 10.1007/s00442-013-2746-0.

Mihailescu E, Soares MB. 2020. The influence of climate on agricultural decisions for three European crops: A systematic review. Front Sustain Food Syst 4: 64. DOI: 10.3389/fsufs.2020.00064.

Nan X, Li W, Shao M, Cui Z, Wang H, Huo J, Chen L, Chen B, Ma Z. 2024. Shading treatment reduces grape sugar content by suppressing

photosynthesis-antenna protein pathway gene expression in grape berries. Intl J Mol Sci 25 (9): 5029. DOI: 10.3390/ijms25095029.
Pexioto CM, Dias MI, Alves MJ, Calhelha RC, Barros L, Pinho SP, Ferreira ICFR. 2018. Grape pomace as a source of phenolic compounds and diverse bioactive properties. Food Chem 253: 132-138. DOI: 10.1016/j.foodchem.2018.01.163.
Qin L, Xie H, Xiang N, Wang M, Han S, Pan M, Guo X, Zhang W. 2022. Dynamic changes in anthocyanin accumulation and cellular antioxidant activities in two varieties of grape berries during fruit maturation under different climates. Molecules 27 (2): 384. DOI: 10.3390/molecules27020384.
Rodriguez-Casado A. 2016. The health potential of fruits and vegetables phytochemicals: Notable examples. Crit Rev Food Sci Nutr 56 (7): 1097-1107. DOI: 10.1080/10408398.2012.755149.
Schreiner RP, Osborne J, Skinkis PA. 2018. Nitrogen requirements of Pinot noir based on growth parameters, must composition, and fermentation behavior. Am J Enol Viticult 69 (1): 45-58. DOI: 10.5344/ajev.2017.17043.
Shafiq I, Hussain S, Raza MA, Iqbal N, Asghar MA, Raza A, Fan Y-F, Mumtaz M, Shoaib M, Ansar M, Manaf A, Yang W-Y, Yang F. 2021. Crop photosynthetic response to light quality and light intensity. J Integr Agric 20 (1): 4-23. DOI: 10.1016/S2095-3119(20)63227-0.
Shinomiya R, Fujishima H, Muramoto K, Shiraishi M. 2015. Impact of temperature and sunlight on the skin coloration of the 'Kyoho' table grape. Sci Hortic 193: 77-83. DOI: 10.1016/j.scienta.2015.06.042.
Sims DA, Gamon JA. 2002. Relationships between leaf pigment content and spectral reflectance across a wide range of species, leaf structures and developmental stages. Remote Sens Environ 81 (2-3): 337-354. DOI: 10.1016/S0034-4257(02)00010-X.
Singh D, Basu C, Meinhardt-Wollweber M, Roth B. 2015. LEDs For energy efficient greenhouse lighting. Renew Sustain Energy Rev 49: 139-147. DOI: 10.1016/j.rser.2015.04.117.
Tóth JP, Végvári Z. 2016. Future of winegrape growing regions in Europe. Aust J Grape Wine Res 22 (1): 64-72. DOI: 10.1111/ajgw.12168.
Umber M, Paget B, Hubert O, Salas I, Salmon F, Jenny C, Chillet M, Bugaud C. 2011. Application of thermal sums concept to estimate the time to harvest new banana hybrids for export. Scientia Horticulturae. 129:52–57. DOI:10.1016/j.scienta.2011.03.005.
Van den Ende W, El-Esawe SK. 2014. Sucrose signaling pathways leading to fructan and anthocyanin accumulation: A dual function in abiotic and biotic stress responses. Environ Exp Bot 108: 4-13. DOI: 10.1016/j.envexpbot. 2013.09.017.
Wang C, Wang L, Ye J, Xu F. 2022. Fruit quality of *Vitis vinifera*: How plant metabolites are affected by genetic, environmental, and agronomic factors. Sci Hortic 305: 111404. DOI: 10.1016/j.scienta.2022.111404.
Xu C, McDowell NG, Fisher RA, Wei L, Sevanto S, Christoffersen BO, Weng E, Middleton RS. 2019. Increasing impacts of extreme droughts on vegetation productivity under climate change. Nat Clim Change 9: 948-953. DOI: 10.1038/s41558-019-0630-6.
Yang C, Xiao Y, Zhang Y, Sun Y, Han J. 2020. Heterogeneous network representation learning: Survey, benchmark, evaluation, and beyond. arXiv preprint arXiv 2004: 00216. DOI: 10.48550/arXiv.2004.00216.
Zhang L, Li X, Pang Y, Cai X, Lu J, Ren X, Kong Q. 2021. Phenolics composition and contents, as the key quality parameters of table grapes, may be influenced obviously and differently in response to short-term high temperature. LWT 149: 111791. DOI: 10.1016/j.lwt.2021.111791.
Zhou D-D, Li J, Xiong R-G, Saimaiti A, Huang S-Y, Wu S-X, Yang Z-J, Shang A, Zhao C-N, Gan R-Y, Li H-B. 2022. Bioactive compounds, health benefits and food applications of grape. Foods 11 (18): 2755. DOI: 10.3390/foods11182755.
Zou L, Zhong G-Y, Wu B, Yang Y, Li S, Liang Z. 2019. Effects of sunlight on anthocyanin accumulation and associated co-expression gene networks in developing grape berries. Environ Exp Bot 166: 103811. DOI: 10.1016/j.envexpbot.2019.103811.