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Effect of climatic conditions on the productive and biochemical characteristics of grape varieties grown on sierozem soil

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Abstract

The aim of this study was to evaluate the effect of climatic conditions on phenological observations, yield components and biochemical characteristics of grape varieties grown on sierozem soil of Turkestan region, Southern Kazakhstan. A total of 13 different medium and late grape ripening varieties known, loved and widely used by the local people for many years in cultivation were chosen. The phenological observations (date of budding and removable maturity date of grape) yield components (yield of grape, weight of bunch of grape, number of bunch of grapes, as well as productivity) and the biochemical characteristics (titratable acidity, glucoacidimetric index, glucose content, fructose content) of grape varieties were evaluated in three seasons (2018-2020). During the vegetation period, date of budding and removable maturity date observations were made and recorded as day/month. As a result of the study, differences were found among local genotypes in terms of phenological stages. On the average of years, the earliest date of budding was recorded on 21 March with Children's early and the latest date of budding was observed on 02 April Moldova and Victory. The highest yield and productivity were obtained from varieties Husayn kelin barmak and Chocolate grape varieties. Titratable acidity range was between 5 g/L – 8g/L, in average of years, the highest titratable acidity in late ripening grape varieties was found in Victory (7.3 g/L) while Moldova (6.0 g/L) had the lowest. Titratable acidity of Husayn kelin barmak (7.3 g/L) was determined also higher than the medium ripening grape varieties while Guzal Kara had the lowest, only 5.3 g/L. Glucose and fructose contents were determined as 8.58% and 11.04 in different grape varieties, respectively.

Keywords: Sierozem soil, grape, climate, sugar, phenological observations.

Introduction

Grapes are one of the world's most commonly produced fruit crops. In addition to the increasing consumption of fresh grapes, in recent years, interest in products made from grapes has greatly increased, particularly in grape juices (FAO-OIV Focus, 2016). The numerous health benefits may be part of the reason because these products are rich sources of phenolic compounds (phytochemicals with potential anti-oxidant activity) (Granato et al., 2016). A brief characterization of the global viticulture and winemaking sector is provided upfront to better understand its relevance in the world economy. As detailed in the report of the FAO-OIV Focus, (2016), it is estimated that the world vineyards cover an area of approximately 7.449 million ha (2018). (Santos et al., 2020)

Although the suitability of a region for grapevine cultivation is largely controlled by growing season mean temperature that should range between 12 and 22^{0}C, other atmosphere-driven conditions, such as growing

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season length, radiation levels, winter minimum temperatures, spring and fall frosts or soil water balance, among others, are also important limiting factors (Jones et al., 2012). Air temperature plays a central role in determining grapevine phenology (Bonada et al., 2015), influencing the onset of phenological stages like budbreak, flowering and veraison and the phenophase intervals (Fraga et al., 2016). Temperature also affects grapevine yield (Bock et al., 2010), wine production (Santos et al., 2013) and quality (de Orduña, 2010). Relatively constant and moderate temperatures during ripening favour the biochemical processes of colour, flavour and aroma development in grape berries. For rainfed grapevines, the water balance is mainly determined by precipitation, atmospheric humidity and soil water holding capacity. The amount of annual precipitation and its seasonal distribution are also crucial to the evolution of the plant water status, with subsequent effects on berry quality. Moreover, under extremely dry atmospheric conditions, stomata can close to preserve moisture, ceasing photosynthesis (Ashenfelter and Storchmann, 2014). Nevertheless, some reported effects of water stress on grape berry quality attributes are contradictory, being strongly dependent on the local conditions, on the degree of water stress and on the period in which it occurred (Costa et al., 2020)

In Southern Kazakhstan fruit and grapes are cultivated with seed-fruits covering 70% of the planting area. Stone-fruits occupy 20%, and nut plantations and berries take up to 10%. In the South-eastern zone of Kazakhstan, with an abundance of solar heat and the availability of irrigation water, the vineyards make it possible to get a good harvest and can be highly profitable. With a high potential opportunity, the productivity of a modern vineyard in Kazakhstan remains low. It is known that the main factor for increasing the productivity of grape plantations is the assortment, which is improved both by introducing varieties based on soil-climatic analogues, and by breeding and introducing genotypes created by methods of combinational selection on a genetic basis. Today, in our country, the planting area of vineyards is about 15 000 ha, new territories are being developed, and serious research work is being done by scientific research institutes.

The aim of this study was to evaluate the effect of climatic conditions on phenological observations, productive and biochemical characteristics of grape varieties grown on sierozem soil of Turkestan region, Southern Kazakhstan.

Material and Methods

Study sites

The experiment was performed at Saryagash district of the Turkistan region, South Kazakhstan (Figure 1). The experimental fields had been in grape growing regions of South Kazakhstan from 2015. Grape (*Vitis vinifera*) is the fruit crop in this region. This region is characterized by a semi-arid climate. Most of the precipitation occurred in October to May.

Figure 1. Study area

Soil

The main soil type, which is typical for the region, is sierozem soils. The sierozem soils are found in arid regions which characterized by a brownish-gray surface on a lighter layer based on a carbonate or hard-pan layer (USDA, 1999). Ordinary sierozems develop on loess-like loams and have fully developed profile with a rather noticeable division into genetic horizons. Sierozems are marked by good water-physiological properties, high biological activity, and adequate fertility; they produce high yields when irrigated. There are various subtypes: light, conventional (standard), dark, and northern (Saparov, 2014; Absatova et al., 2022). The soil belongs to the general soil type of dark sierozem. The soil pH was 8.05 in 0-30 cm soil dept, 7.86 in 30-60 cm soil dept, soil organic matter was 1.50% in 0-30 cm soil dept, 0.55% in 30-60 cm soil dept, mineral-N was 54.2 mg/kg in 0-30 cm soil dept, 41.5 in 30-60 cm soil dept, available phosphorus was 10 mg/kg in 0-30 cm soil dept, 8 in 30-60 cm soil dept, and exchangeable potassium was 401 mg/kg in 0-30 cm soil dept, 228 in 30-60 cm soil dept.

Grape varieties (Vitis vinifera)

A total of 13 different grape varieties including 8 medium ripening varieties (Guzal Kara, Akhtamar, Globus, Children's early, July, Queen of the Vineyards, Husayn kelin barmak and Husayn red) and 5 late ripening varieties (Taifi pink, Zebo, Moldova, Pobeda and Chocolate) which is known and widely used by the local people for many years used in this study (Figure 2).

Figure 2. Medium and late ripening grape varieties at Saryagash district of the Turkestan region, South Kazakhstan

Experimental pilot

The study was conducted in an experimental site located at Saryagash district of the Turkistan region, South Kazakhstan, during three consecutive seasons performed within three years (2018–2020). Grape plants were cultivated in 2015, using trellis culture and dragon-shaped pruning. Row spacing was 3m, plant spacing was 1.5m. During the field experiment (2018-2020), every year same agricultural practices used in same plot of field experiment. During the trials, all the cultural practices regarding fertilization, irrigation, weed control, and pest and disease management were conducted as standard regional cultivation practices.

Harvest and measurements

During the maturity period of these grape cultivars in the pilots, we picked 3-5 clusters from 3 plants of every grape variety, 10 grape berries were randomly collected from the head, middle and bottom of grape clusters. During the vegetation period, date of budding and removable maturity date of grape were recorded as day/month. The plots were harvested at full maturity stage of the grapes. At harvest, the number of bunches per vine and their masses were recorded to estimate the yield of grape (t ha^{-1}), weight of bunch of grape (gr) and number of bunch of grape (pics/branch). The harvested all grape samples were placed in plastic bags with dry ice and immediately transported to our laboratory for biochemical characteristics of.

For the biochemical characteristics of the each grape varieties, titratable acidity, glucoacidimetric index and sugars (glucose and fructose) were determined. The titratable acidity of each grape cultivar was analyzed by titrating the grape juice pH to 8.2 with NaOH and was expressed as gram tartaric acid equivalents per liter of juice (AOAC, 2000). The reducing sugars were determined according to the Somogy-Nelson colorimetric method (Nelson, 1944). Glucoacidometric index was calculated as the ratio of sugars (%) and titratable acidity.

Results and Discussion

Climate conditions

Analyzing the weather conditions in Turkestan region of the south of Kazakhstan during the study periods, it was noted that the average annual air temperature in the long term period from 2009 to 2020 relative to the period 2018-2020 increased by 2°C. The average annual maximum and minimum temperatures also increased, and in absolute terms, the change in temperature was 2°C and 3°C, respectively. At the same time, the absolute minimum temperature decreased by 6°C, from -4 to -10 °C (Figure 3). During the period of active growth and ripening of grapes (July), the greatest changes in air temperature were noted. Thus, the average temperature increased by 3° C in 2019, and the maximum and minimum temperatures increased by 3° C. At the same time, moisture supply during the period of active growth and ripening of grape varieties decreased in July 2019, although the annual amount of precipitation increased in August 2020.

Temperature is considered a fundamental driver of plant development and phenological cycles. It can modify profoundly the timing of cycles and such changes have been documented in many studies for different plant species under increasing temperatures in the past. During the ripening period, the air temperature plays a determinant role for grape maturation, including the aroma and the coloration, having an important effect on the characteristics of the wines (Jackson and Lombard, 1993). The day temperatures influence the coloration, but the effect of conditions of cool nights temperatures on it is even stronger (Kliewer, 1973). Several studies have indicated that increased temperatures have been associated with earlier phenological development of many wild and cultivated plants (Chmielewski et al., 2004; Cleland et al., 2007; Gordo and Sanz, 2009; Menzel et al., 2006; Schwartz et al., 2006), however, delays have also been documented for specific events, notably leaf colouring and leaf fall (Menzel et al., 2003; Estrella and Menzel, 2006; Gordo and Sanz, 2009). Phenology is modified by a complex interaction of (i) the sensitivity of the species phenology to climate drivers such as temperature but also photoperiod and water stress and (ii) the phenological stage in question.

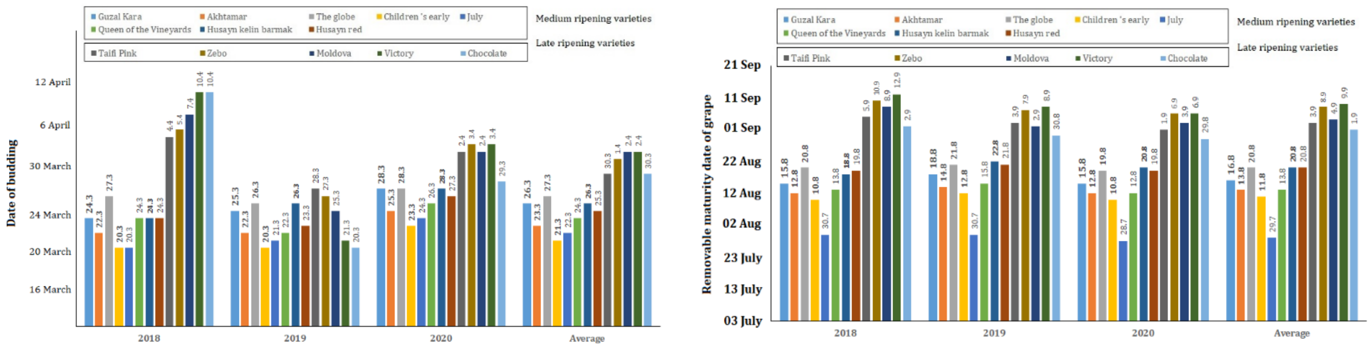
Meteorological conditions differed between harvests, especially insolation (Figure 3). In the final stage of grape maturation, rainfall was higher in the 2018 harvest. From January to March, the cumulative rainfall was 76.97 mm in 2018, 72.30 mm in 2019 and 90.00 mm in 2020. The largest difference occurred in the first 30 days of the year. In 2018, rainfall was better distributed, while in 2019 and 2020, one periods of lower water availability occurred in the March (Figure 3), which resulted in lower soil water storage. The total hours of annual insolation (uv index) in vineyards influence the photosynthetic and metabolic activities of vines and, considering the quality of grapes, insolation has direct relation with temperature. In the 2019 harvest, insolation was higher (uv index is 9 in June and July), but in the other harvests studied in 2018 and 2020, uv index was lover (8 in June 2018 and 2020, 7 in July 2018 and 2020).

Phenological observations

According to results, some differences were found among grape varieties in terms of phenological stages (Figure 4). On the average of years, the earliest date of budding was recorded on 21 March with Children's early and the latest date of budding was observed on 02 April Moldova and Victory. A difference of about 13 days was found between grape varieties in terms of the bud burst and full bloom dates depending on the direction and elevation of the vineyard. Changes in the phenology of several grape cultivars in recent decades are particularly in connection with the change of temperature (Figure 4). The beginning of all phenological stages in grape varieties in the period (2018–2020) occurred in earlier parts of the year, compared to the historical data. One of the most important phenological stages, date of budding, has been shifted ten-twenty days in the earlier part of the year. However, cultivars differently react to climate change. The biggest change in date of budding was observed in late ripening varieties (Taifi Pink, Zebo, Moldova, Victory and Chocolate). Medium ripening varieties (Guzal Kara, Akhtamar, The globe, Chilren's early, July, Queen of the Vineyards, Husayn kelin barmak, Husayn red) were less affected by the weather conditions compared to the late ripening varieties (Figure 4). Date of budding of late ripening varieties, in contrast to medium ripening varieties in 2018 happened 7-20 days ago than in 2019. However, date of budding of late ripening varieties, on average of 2018-2020, occurred 2-3 days earlier, compared to 2020. Phenological development stages differed in the same ecology but in different vegetation years due to changes in climate data (Cangi and Bekar, 2017). Different results were obtained from previous studies carried out in different regions regarding phenological characteristics. Budburst times of cultivars were 4-20 April (Kose, 2014).

Figure 3 Climate conditions of the experimental area, Turkestan region, Southern Kazakhstan

As a result, genetic factors and ecological conditions may be the cause of the different results in the studies performed in different regions. Different varieties within a species can have marked differences in date of budding. In the context of climate change, a deeper understanding of varietal differences in date of budding for agriculture is critical to select varieties that are adapted for production under future climate conditions.



(a) (b)

Figure 4. Phenological observations of grape varieties grown on sierozem soil (a) Date of budding (b) Removable maturity date of grape

Yield and yield parameters

Yield of medium and late ripening grape varieties and its components have been assessed at harvest (Figure 5). In all varieties, yields for the 2018 were higher compared to 2019 and 2020 due to a greater weight and number of bunch of grape per plant. The highest yield and productivity were obtained from varieties Husayn kelin barmak (239.1 t/ha) and Chocolate (231.7 t/ha), with an average of 183.9 t/ ha, respectively (Figure 5). Under subtropical conditions, Hernandes et al. (2010) recorded higher yields for IAC 138-22 'Máximo' than the values reported in this study for the same variety, with an average of 4.28 kg/vine and 22.5 bunches per vine. The increase in yield can be explained by the greater bunch mass found by those authors (195.8 versus 134 g). However, the productivity of 'Isabel Precoce' in the present study was higher than that found for the variety in temperate climate conditions, which produced 6.71 t/ha (Botelho et al., 2011).

The Akhtamar (medium and ripening grape variety) and Moldova (late ripening grape variety) varieties presented low yield and productivity at 148.1 t/ ha and 157.7 t/ha, respectively. This result was related to the low weight and number of bunches (Figure 5), which might be related to several factors, e.g., difficulty in budburst and low bud fruitfulness in the first few nodes at the base of the shoots (da Silva et al., 2018). According to Camargo et al. (2008), BRS Carmem vines should be pruned to leave six to eight nodes because the first ones are less fruitful. Thus, the pruning management of this variety must be adjusted to increase its potential yield.

Biochemical characteristics

Titratable acidity (TA) range and distribution of medium and late ripening grape varieties are shown in Figure 6. Titratable acidity (TA) range was between 5 g/L – 8g/L, in average of years, the highest titratable acidity in late ripening grape varieties was found in Victory (7.3 g/L) while Moldova (6.0 g/L) had the lowest. Titratable acidity of Husayn kelin barmak (7.3 g/L) was determined also higher than the medium ripening grape varieties while Guzal Kara had the lowest, only 5.3 g/L (Figure 6). The typical titratable acidity (tartaric acid equivalent) (TA) of unripe grapes is around 40 g/L, but this falls to below 10 g/L in ripe grapes. Grape acidity is inversely related to carbohydrate content; in the course of ripening, grape glucose and fructose concentrations increase while acid concentrations fall (Saxton et al., 2009). In present study, titratable acidity was measured all medium and late ripening grape varieties and low concentration.

Based on the established content of sugars and total acids in the grapes of the studied medium and late ripening grape varieties the glucoacidimetric index for each one of them was determined. Its rates were indicative of the grapes quality and its use in winemaking. The calculated rates for 2020 harvest were higher than 2018 and 2019, proving that the grapes were suitable for the production of wines of optimal quality with regard to the chemical composition and the tasting features. For 2020 harvest, the rates were within the range from 2.6 (Taifi Pink and Husayin kelin barmak) to 4 (July), i.e. the grapes not from all varieties, had good enough indicators for the production of quality wines (Yoncheva et al., 2019). Glucoacidimetric index for average of years was from 2.6 (Taifi Pink and Husayin kelin barmak) to 3.7 (July), showing the good characteristics of the grapes to obtain wines with optimal composition and organoleptic profile.

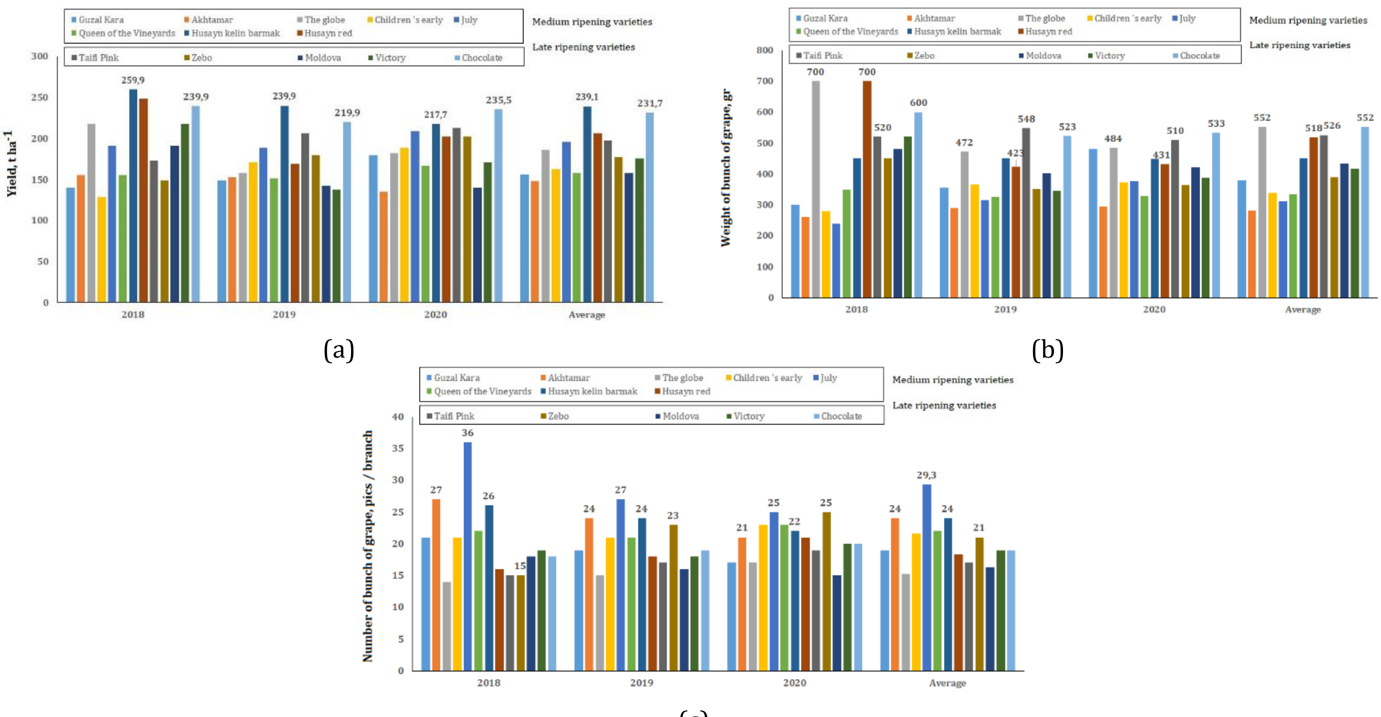


Figure 5. Yield and yield parameters of grape varieties grown on sierozem soil (a) Yield (b) Weight of bunch of grape (c) Number of bunch of grapes

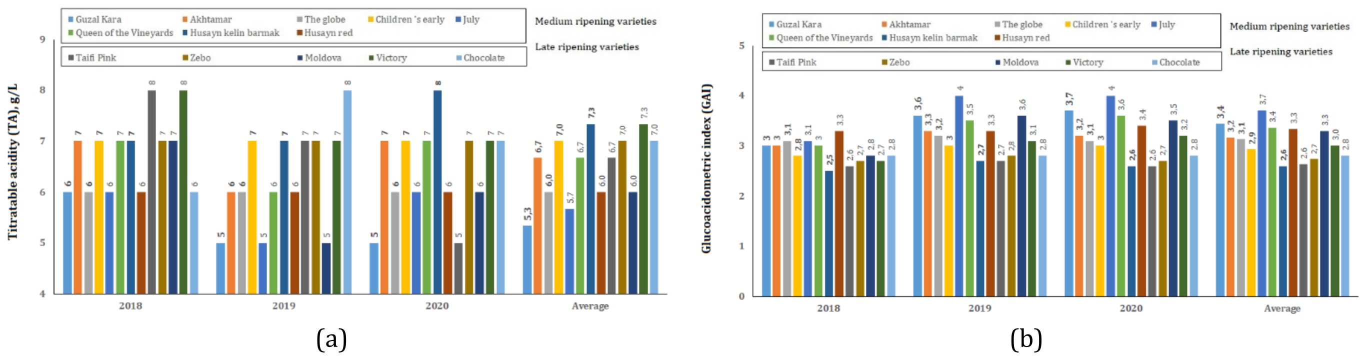


Figure 6. Biochemical characteristics of grape varieties grown on sierozem soil (a) Titratable acidity (b) Glucoacidimetric index

Quantitative data (%) of major carbohydrates such as glucose and fructose, along with the ratio glucose/fructose in the different grape varieties studied, are given in Figure 7. In this study, intervarietal comparison of results showed that the glucose variables were significantly different. Among analyzed samples glucose content of medium ripening grape varieties varied from 6.20% (Guzal Kara in 2018 and 2019) to 10.8% (July and Victory in 2018) (Figure 7). Glucose contents of Victory was determined also higher than the late ripening grape varieties. Guzal Kara and Moldova also lower glucose content among the varieties. Sugar accumulation, especially the concentration of high level of fructose, is a very important physiological process that determines the dessert fruit quality (Kafkas et al., 2006). The mean glucose value of grape varieties was determined as 8.58%. The fructose content in the analyzed varieties was ranged between 8.20 % (July in 2018) and 13.70 % (Chocolate in 2019). According to Average data, Akhtamar (medium ripening variety) and Victory (late ripening variety) were found as highest varieties. July also found the low fructose content. The mean fructose content was determined as 11.04 % in different grape varieties (Figure 7).

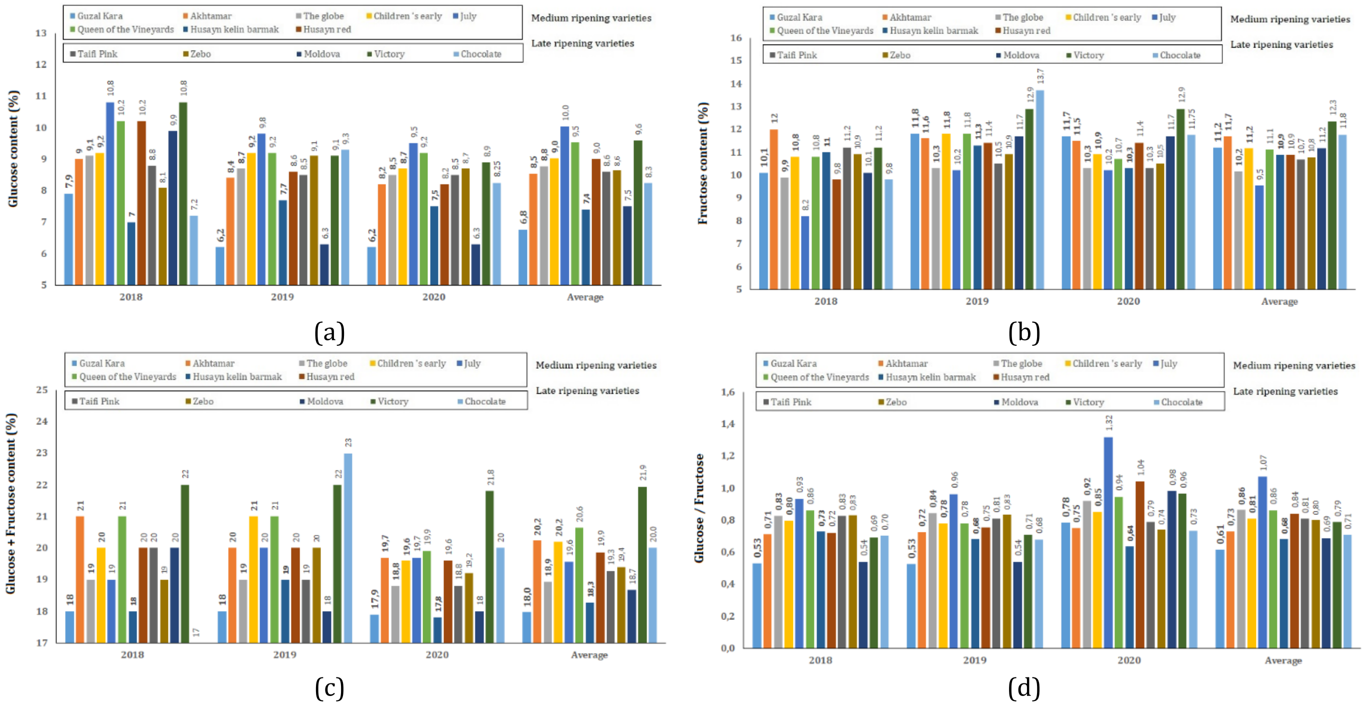


Figure 7. Reducing sugars of grape varieties grown on sierozem soil (a) Glucose content (b) Fructose content (c) Glucose + Fructose content (d) Glucose / Fructose ratio

No additional literature is found regarding the glucose and fructose contents of these varieties, therefore the total sugar content of some varieties were compared. Pérez-Magariño and González-San José (2006) determined the sugar content of Cabernet Sauvignon grapes, between 22.5 and 24.4 g/100 in Spain at the two studied vintages. In this study, the glucose and fructose contents of all varieties found to be lower their findings (Figure 7). The glucose and fructose value of Victory was obtained as 21.9 % in this study. Nurgel et al. (2002) found the sugar content of Kalecik karasi as 220 g/L, which is similar to the present result.

The values for glucose and fructose are low with a ratio near one, in grape varieties except with July. The most of the varieties showed that the fructose content higher than glucose content even though the July showed that glucose content almost always had higher than the fructose. Intervarietal comparison of glucose/fructose ratio showed that the July had higher glucose content than the other varieties. On the other hand, Victory had the higher fructose content among the varieties. Varandas et al. (2004) observed the glucose content higher than the fructose content in 5 grape varieties at harvest stage.

Conclusion

This paper presents recent research highlighting the impacts of climatic factors on droughts and yields of medium and late ripening grape varieties in Turkestan region, Southern Kazakhstan. Drought is one of the major manifestations of climate change in Kazakhstan and exerts a considerable pressure on the agricultural sector, which is the most vulnerable sector to drought in the economy. To mitigate its impact, a warning system to deliver timely information about the possible occurrence of droughts is needed. This is possible only if the influence of large-scale atmospheric processes, formed due to the impact of cosmic-geophysical conditions and interdependent factors in the ocean–glacier–land-atmosphere systems with direct and reverse links, is taken into account. Climatic change is clearly a process determined by the complex interaction of natural and anthropogenic causes. Without explaining the exact mechanism of anthropogenic impacts on the climatic system, we explore the impact of a range of indicators, some of them experiencing clear anthropogenic pressures, to explain the variability in productive and biochemical characteristics of grape varieties grown on sierozem soil in Turkestan region, Southern Kazakhstan. The results can be summarized as follows.

In this study, it has been determined that date of budding in medium and late ripening grape varieties depending on the cultivars and years. According to the meteorological data, the average annual max and min temperatures also increased, and in absolute terms, the change in temperature was 2°C and 3°C, respectively. At the same time, the absolute min temperature decreased by 6°C, from -4 to -10 °C. While climate patterns can differ radically from one year to another (climate variability), climate change is more concerning, because a significant shift in the long-term climatology would make the wine business unsustainable. Adaptation measures are most probably needed to adapt the current grape varieties to warmer climate conditions and the presence of more frequent and more intense extreme events such as heat waves, heavy rainy or long dry spells.

The grape composition is influenced by climatic conditions and consequently by interannual variability. The 2018 harvest presented better productive and physicochemical grape characteristics. The varieties Husayn kelin barmak and Chocolate presented high fruit yield of grape. Physicochemical grape characteristics were significantly different among the varieties. Husayn kelin barmak and Victory grapes had highest titratable acidity. This study yielded information about the major sugars which are glucose and fructose contents of grape varieties grown in Kazakhstan. The results showed that, there were significant differences in the glucose and fructose content in selected different grape varieties. Akhtamar and Victory were found as highest varieties while July also found the low fructose content. The results reflect that there must be genetic variation among the grape varieties according to their individual sugars.

Even though grapevines have an array of survival strategies, their development is strongly controlled by weather and climate, over a wide range of processes and timescales. Future suitability of a certain viticulture region highly depends on the change on the mean patterns on temperature and precipitation in the coming decades, but also on the impact of extreme temperature and precipitation. For that reason, estimation regional changes in temperature and precipitation and the derived impacts on the suitability of grape cultivation are of paramount importance for the business of gives critical information for making strategic decisions and investments in the near future, which will make the industry more resilient and adapted to climate change.

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