Table grape breeding programs and new cultivars

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Abstract

Table grapes are grown in almost every continent and the cultivars grown according to consumer demands may differ over the years. For this reason, table grape breeding studies are carried out in many countries. These breeding studies are carried out in public Universities and Research Institutes, as well as in recent years, different private sector representatives have come together and started to carry out breeding studies by forming a consortium or company. Especially companies such as Sun World, IFG, SNFL and Grapa are the most notable among these table grape breeding organizations. In parallel with the developments in biotechnology, it has become possible to develop table grape cultivars with the desired properties in a much shorter time. Especially with the Vitisgen1 and Vitisgen2 projects, which resulted in the participation of many research institutions in the USA, many gene regions of grapes were mapped, and as a result, grape breeding studies are expected to yield results in a much shorter time. Although there is a demand for table grapes with different characteristics in world markets, the demand for seedless, larger berry and disease-tolerant or resistant cultivars is much higher. Especially seedless table grape breeding studies are still continuing in many countries such as USA, Italy, Spain, Chile, Japan, Korea, China and Turkey. However, in line with the rapidly changing consumer demands, the number of grapevine genetic resources is being increased in many countries and conserved to meet these future demands and use in breeding studies.

Keywords: *Vitis*, high quality, seedless, consumer demands, biotechnology

INTRODUCTION

Along with viticulture, the cultivation of table grapes has become one of the most important agricultural income sources of local people in different countries of the world. Vineyard areas in the world cover an area of approximately 6.7 million ha and a total production of 73.5 million t (OIV, 2021; FAOSTAT, 2023). Although there is a general decrease in grape areas in the world, there is an increase in the amount of production and this can be explained by the increase in the production areas of table grapes and the higher yield of new cultivars (Dry et al., 2022).

37.2 million t of 73.5 million t of grapes are consumed as pressed grapes and 35.5 million t as unpressed grapes. About 30 million t of unpressed grapes are produced as fresh grapes (Figure 1). In particular, China ranks first in both total grape production and table grape production (Figure 2). Table grape production, which was 15 million t in 2000, has doubled in recent years (Figure 3). In addition, India, Turkey and Egypt are the countries with the highest table grape production after China (Figure 4).

In recent years, while grape production has decreased in Europe, production has increased in Asia and Africa. Thanks to the new table grape cultivars that represent an important revival in table grape production in this continent. Table grape areas, especially in Morocco, Egypt, India and China, have increased significantly. Especially in recent years, with the demand for seedless grape cultivars, almost all of new grapes entering the market are seedless cultivars (Ibáñez et al., 2015). Although controlled grape breeding studies have a history of more than a century, studies on breeding high quality cultivars with breeder's rights started about 50 years ago. Breeding programs have been initiated in different countries to develop new grape cultivars with different characteristics, especially in line with changing

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consumer demands. In these breeding programs, especially seedless, large berry, distinctive flavoured grape cultivars that are resistant/tolerant to different stress conditions are developed (Puglisi et al., 2022). Although *V. vinifera* grapes are grown the very large part of the world market, they are often quite susceptible to different diseases. With the interest in organic and sustainable viticulture, the demand for disease-resistant cultivars is increasing rapidly (Reisch et al., 2012).

In this study, general information about table grape breeding programs carried out in different countries of the world and in Turkey and the prominent cultivars are given.

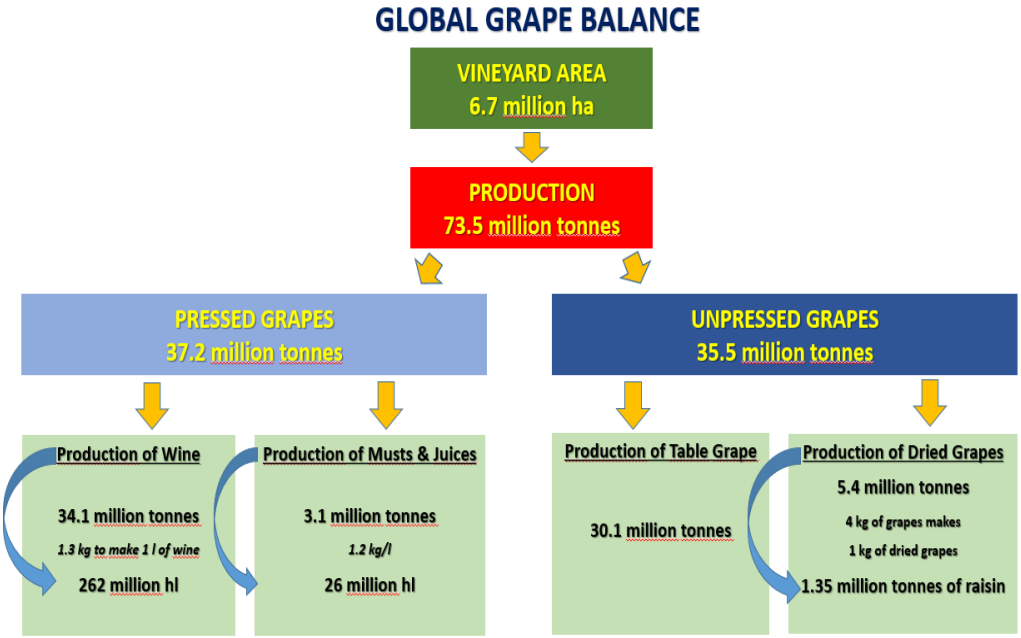


Figure 1. Diagram showing the balance of grapes on a global scale in the world.

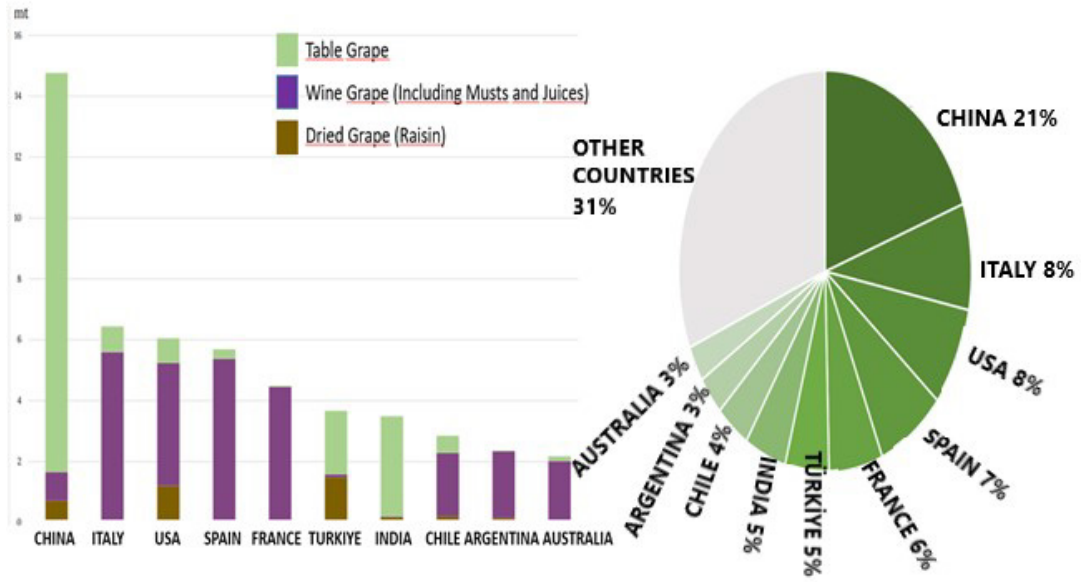


Figure 2. Fresh grape production in major countries in 2021 (left). Breakdown of global fresh grape production in 2021 (right) (OIV, 2021).

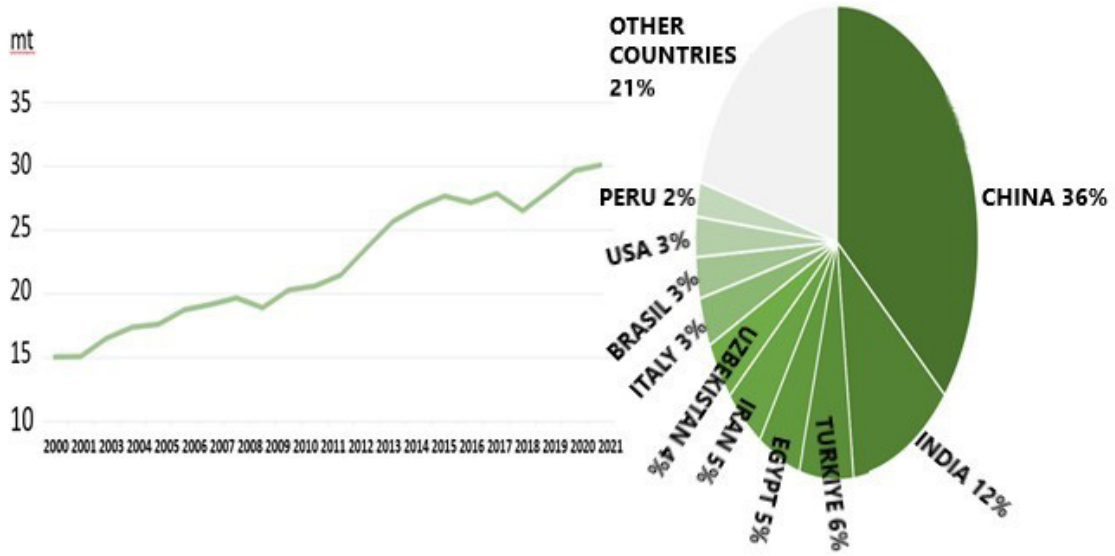


Figure 3. Total table grape production from 2000 to 2021 (left). Breakdown of the table grape production (right) (OIV, 2021).

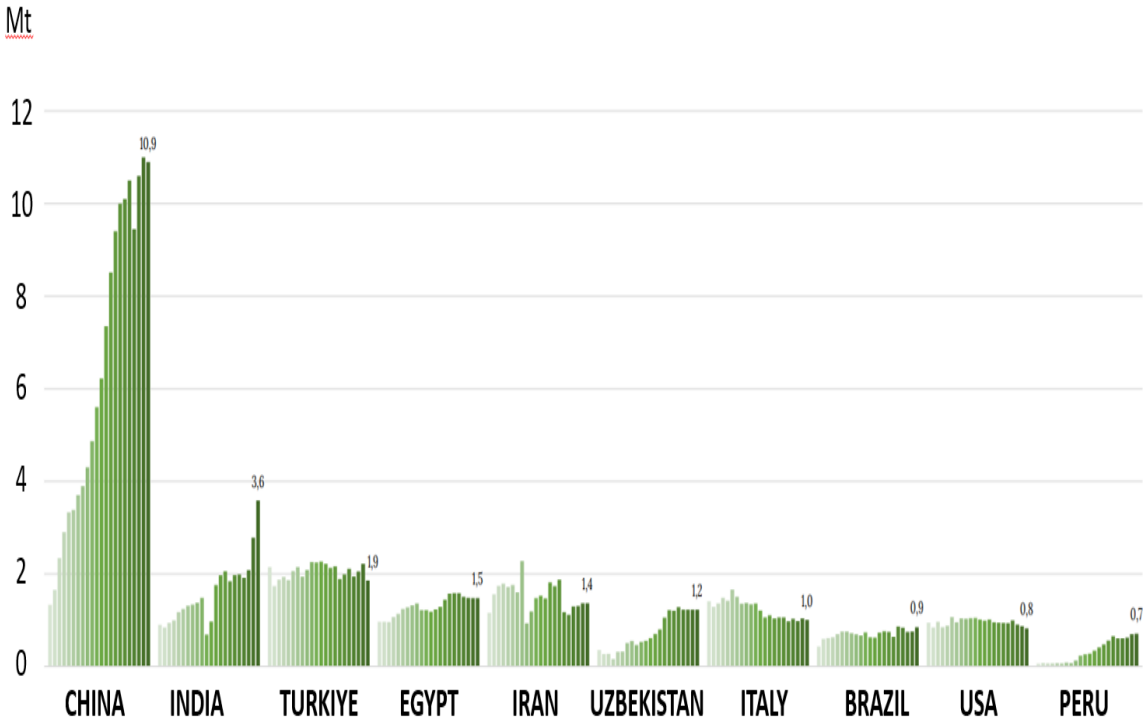


Figure 4. Total table grape production in major countries, 2000-2021 (OIV, 2021).

TABLE GRAPE BREEDING PROGRAMS IN THE WORLD

Table grape breeding studies continue in different countries of the world and in Turkey for different purposes (Figure 5). While these breeding studies initially aimed to develop large-berry grape cultivars that ripen out of season, today more focus is on developing new cultivars that are resistant or tolerant to different stress conditions, especially with the

negative effects of climate change. In new breeding studies, it is tried to develop new cultivars with larger beery, seedless, harvestable out of season, resistant to road/storage, special aroma, crispy and low production cost. In addition, in recent years, very successful breeding studies have been carried out on the development of cultivars that are more resistant to fungal diseases and the transfer of resistance genes from wild species to *V. vinifera* cultivars (Foria et al., 2019, 2022). These studies, especially in wine cultivars, are also applied in table cultivars with different breeding programs (Bavaresco et al., 2015; Yamada and Sato, 2016).



Figure 5. Countries with table grape breeding programs.

In addition, important breeding studies have been carried out on cold resistance and crossings with cold resistant wild species have been made to transfer resistance genes to new cultivars. The first studies in this field were started in the USA. In order to reduce the production risks and costs in cold regions, local wild species such as *V. labrusca*, *V. ripari* and *V. rupestris* are crossed with *V. vinifera* and developed some cultivars that can withstand low temperatures exceeding -30°C (Fennell, 2004; Hatterman-Valenti et al., 2016; Wang et al., 2021). Embryo rescue technique, which has been developed with the demand for seedless cultivars in recent years, has been very useful in table grape breeding studies. With this technique, two seedless parents are selected and the seeds formed by crossing each other are taken into tissue culture medium between 6 and 10 weeks and kept alive there. The first use of embryo rescue in grapes was reported in Emershad and Ramming (1982) also it is used by the USDA in seedless grape breeding programs in the USA (Ramming, 1990). It has since been used as a standard procedure in many table grape breeding programs. The success rate of this technique can vary greatly depending on the combination chosen and ambient conditions (Puglisi et al., 2022). In addition, many hybrid genotypes developed in parallel with the advances in biotechnology in recent years are determined by the MAS technique to determine whether they have the relevant genes, and for many genotypes that do not have the desired characteristics, no expense is incurred by planting them in the field (Zhu et al., 2020). In addition, in these studies, markers developed to identify seedless cultivars have been used successfully in recent years (Amato et al., 2022).

As a result of breeding studies in different countries, especially in the USA, Italy, Spain, Turkey, Chile, South Africa and Australia, new table grape cultivars have been developed and

these cultivars have begun to be used in production. Cultivars developed by different institutions or private companies in these countries have started to be produced in limited quantities (Plant Breeder's Rights – PBR) in different countries of the world. Among the companies that carry out breeding studies in table grapes, companies such as SNFL, IFG, Sun World, Grapa and ITUM constitute an important part of the table grape market with many new grape cultivars they have developed (Lund, 2015; Izcara et al., 2021). In Figure 6, there are photographs of some grape cultivars developed by these companies and grown in different countries of the world.



Figure 6. Some table grape cultivars developed by different institutions/companies.

Table grape breeding programs carried out all over the world primarily focus on developing new seedless cultivars. Developing genetically larger berry seedless cultivars that do not need plant growth regulators, in particular, also reduces production costs (Atak and Şen, 2021).

Although different table grape breeding programs around the world are currently introducing new seedless cultivars, there are some problems with growing them in different countries. Companies spend a lot of money to develop these new cultivars and as a result, these cultivars are allowed to be produced in a limited area with high breeder's right. It also demands high quality production, in which case these cultivars can usually be grown by big growers or companies. It is not possible for small growers to reach these cultivars (Ibáñez et al., 2015).

In table grape breeding studies, high-budget programs are needed to develop new grape cultivars that meet the conditions required by the market. Because, taking advantage of the latest technology, eliminating the genotypes that do not carry the relevant genes, establishing trial plots and making extra efforts for the commercialization of cultivars can only be done with high-budget projects. In recent years, we have seen that some large companies or growers have come together and formed consortiums for this purpose, and they have financed some state institutions to develop new cultivars they want. Murcian Table Grape Research and Technology Society (ITUM) and Murcian Institute Agricultural and Food Development (IMIDA) are can be shown an example this cooperation. Another example is the Table Grape Genetic Improvement Program (PMG) of the Asoex Fruit Technology Consortium in Chile.

Polyploidization is an important technique used in grape breeding to create new genetic

resources and can be induced using some antimitotic agents, including colchicine. Plants with increased ploidy can gain better quality than their original diploids in some characteristics. Polyploidy methods are used to develop new cultivars with high adaptability, to shorten the time in traditional breeding studies, and to obtain agronomic characters that cannot be achieved by classic crossbreeding technique. Polyploid grape cultivars are used commercially, and the 'Kyoho' (4*x*) cultivar is one of the top grown grapes in the world and is widely grown in the Far East, especially in Japan and China. Therefore, it is used in polyploidy table grape breeding studies in different countries especially in the Far East (Kara and Yazar, 2022; Shivran et al., 2022).

TABLE GRAPE BREEDING PROGRAMS IN TURKEY

Table grape breeding studies started about 50 years ago in Turkey and many grape cultivars have been registered until today. While some of these registered grapes were grown by the growers, unfortunately some of them were not grown.

These studies, which initially started with the aim of developing early and late cultivars, later continued with breeding studies for the development of large berry, seedless and disease-resistant/resistant cultivars (Atak and Şen, 2021). In addition, clone selection studies of 'Sultani' grape, one of the most grown grape cultivars in the world, were carried out by the Manisa Viticulture Research Institute. In this clone selection study, the most suitable clones for table and raisin cultivation were selected and registered. Within the scope of another breeding program carried out in Turkey, 5 grape cultivars belonging to the *Vitis labrusca* species were selected by selection breeding program and registered. Also many table grape cultivars were registered by the Tekirdağ Viticulture Research Institute, the Manisa Viticulture Research Institute and the Yalova Atatürk Horticultural Central Research Institutes and started to be grown by growers (Anonymous, 2023).

FUTURE PERSPECTIVE OF TABLE GRABE BREEDING PROGRAMS

When we look at the total fruit production in the world, grapes and citrus are the most produced species after banana, watermelon and apple. It constitutes approximately 9% of the total fruit production (Figure 7). Table grapes constitute an important part of this production. Table grape production has to cope with many negative problems such as the negative effects of climate change, increasing production costs, competitive market conditions, heavy breeder rights and rapidly changing prices. In order to reduce these negativities, changes are seen in the ongoing breeding studies in different countries in the world, and differences are encountered in both breeding methods and breeding criteria. Studies that continued with selection breeding and then hybridization breeding continue with embryo rescue, interspecies hybridization, polyploidy breeding, tissue culture treatments, GM and biotechnology studies. In addition, CRISPR/Cas9 genome editing approaches have started to find a place for itself in these breeding studies. In parallel with the developments in biotechnology in the following years, it is expected that many breeding studies will be carried out more targeted and cisgenic vines will be more accepted (Malnoy et al., 2016; Najafi et al., 2022).

The demand for cultivars that are more resistant to biotic and abiotic stress conditions is increasing, and for this purpose, there has been a significant increase in breeding studies to develop rootstocks with cultivars that are more resistant to different stress conditions. In the coming years, it is predicted that interspecific hybrid cultivars will have a greater share in the market with their more resistant to different stress conditions and more friendly features in terms of human and environmental health. As a result of the intensive studies carried out by many scientists with the grapevine genome, it is expected that transgenic vine plants, which are more accepted by many parts of the society, will take their place in the markets in a short time. Considering existing breeding programs, new genetically modified cultivars with desired characteristics and interspecific hybrid cultivars have recently become the main subjects of grapevine breeding programs. With the integration of biotechnology into breeding programs in a way that will eliminate the ethical concerns of consumers, breeding studies will accelerate and it will be possible to make more sustainable viticulture to feed the increasing

world population (Atak, 2022).

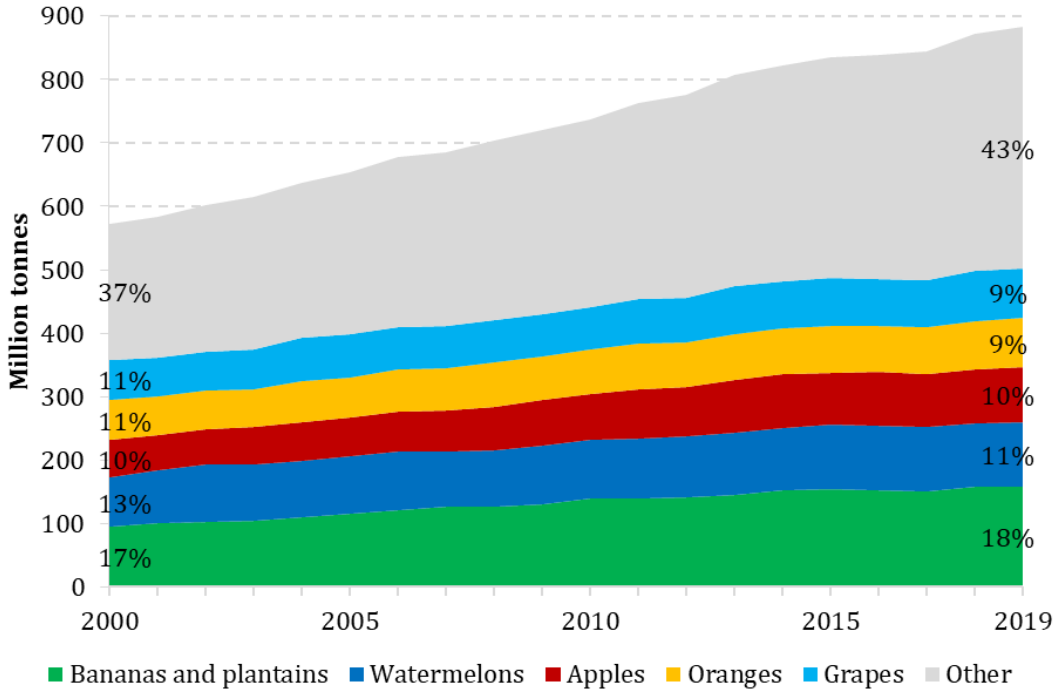


Figure 7. Percentages of total fruit production from 2000 to 2019 (percentages on the figure indicate the shares in the total; they may not tally due to rounding). Source: FAOSTAT.

CONCLUSIONS

As with agricultural products all over the world, new cultivars are developed in accordance with the expectations of consumers in table grapes and they find buyers at high prices. However, in order to develop these cultivars, it is necessary to meet both consumer and grower expectations at the same time. In other words, it is necessary to develop new cultivars that are more tolerant or resistant to increased stress conditions as a result of the effects of climate change. Moreover, there is a need for cultivars that can be grown with less production inputs (chemicals, pesticides, plant growth regulators, irrigation, labor, etc.) against increasing production costs. Moreover, these cultivars are more suitable for the environment and human health, and more suitable for sustainable agriculture model. In order to respond to these needs, research institutions, private sector companies or some consortia in different countries of the world have established some cooperation models. With these cooperation models, a large number of combinations are created with a much higher budget, and a more result-oriented selection can be made among the individuals in this combination by taking advantage of the latest developments in biotechnology. Although everything is good so far, breeder organizations/companies that have the royalty of these new cultivars make some demands for these new table grape cultivars developed. Among these are the demand for wages as breeder's right, the demands for certain breeding conditions for quality production, and the conditions such as selling the grown cultivars only to certain buyers. These breeder rights are often grown by large growers or companies, as these conditions are severe for small growers. In the coming years, the unions that small growers will come together to form against this situation can be a solution to this situation, otherwise it may be very difficult for small growers to reach these new cultivars.

Literature cited

Amato, A., Cardone, M.F., Ocarez, N., Alagna, F., Ruperti, B., Fattorini, C., Velasco, R., Mejía, N., Zenoni, S., and Bergamini, C. (2022). VviAGL11 self-regulates and targets hormone- and secondary metabolism-related genes during seed development. Hortic Res *9*, uhac133 https://doi.org/10.1093/hr/uhac133. PubMed

Anonymous. (2023). Registered Fruit and Vine Cultivars List in Turkey. https://www.tarimorman.gov.tr/BUGEM/TTSM/Sayfalar/Detay.aspx?SayfaId=87 (accessed June 23, 2023).

Atak, A. (2022). New Perspectives in Grapevine (*Vitis* spp.) (Breeding, Intechopen Book Series). https://doi.org/10.5772/intechopen.105194.

Atak, A., and Şen, A. (2021). A grape breeding programme using different *Vitis* species. Plant Breed. *140* (*6*), 1136–1149 https://doi.org/10.1111/pbr.12970.

Bavaresco, L., Gardiman, M., Brancadoro, L., Espen, L., Failla, O., Scienza, A., Vezzulli, S., Zulini, L., Velasco, R., Stefanini, M., et al (2015). Grapevine breeding programs in Italy. In Grapevine Breeding Programs for the Wine Industry, Woodhead Publishing Series in Food Science, Technology and Nutrition, A. Reynolds, ed. (Woodhead Publishing), p.135–157 https://doi.org/10.1016/b978-1-78242-075-0.00007-7.

Dry, I.B., Davies, C., Dunlevy, J.D., Smith, H.M., Thomas, M.R., Walker, A.R., Walker, R.R., and Clingeleffer, P.R. (2022). Development of new wine-, dried- and table grape scions and rootstocks for Australian viticulture: past, present and future. Aust. J. Grape Wine Res. *28* (*2*), 177–195 https://doi.org/10.1111/ajgw.12552.

Emershad, R.L., and Ramming, D.W. (1982). In-ovulo embryo culture of *Vitis vinifera* L. cv. 'Thompson Seedless'. HortScience *17*, 576.

FAOSTAT. (2023). https://www.fao.org/faostat/en/#data/QCL(accessed June 20, 2023).

Fennell, A. (2004). Freezing tolerance and injury in grapevines. J. Crop Improv. *10* (*1-2*), 201–235 https://doi.org/10.1300/J411v10n01_09.

Foria, S., Monte, C., Testolin, R., Di Gaspero, G., and Cipriani, G. (2019). Pyramidizing resistance genes in grape: a breeding program for the selection of elite cultivars. Acta Hortic. *1248*, 549–554 https://doi.org/10.17660/ActaHortic.2019.1248.73.

Foria, S., Magris, G., Jurman, I., Schwope, R., De Candido, M., De Luca, E., Ivanišević, D., Morgante, M., and Di Gaspero, G. (2022). Extent of wild-to-crop interspecific introgression in grapevine (*Vitis vinifera*) as a consequence of resistance breeding and implications for the crop species definition. Hortic Res *9*, uhab010 https://doi.org/10.1093/hr/uhab010. PubMed

Hatterman-Valenti, H.M., Auwarter, C.P., and Stenger, J.E. (2016). Evaluation of cold-hardy grape cultivars for North Dakota and the North Dakota State University germplasm enhancement project. Acta Hortic. *1115*, 13–22 https://doi.org/10.17660/ActaHortic.2016.1115.3.

Ibáñez, J., Carreño, J., Yuste, J., and Martínez-Zapater, J.M. (2015). Grapevine breeding and clonal selection programmes in Spain. In Woodhead Publishing Series in Food Science, Technology and Nutrition, Grapevine Breeding Programs for the Wine Industry, A. Reynolds, ed. (Woodhead Publishing), p.183–209 https://doi.org/10.1016/B978-1-78242-075-0.00009-0.

Izcara, S., Morante-Zarcero, S., de Andrés, M.T., Arroyo, T., and Sierra, I. (2021). A comparative study of phenolic composition and antioxidant activity in commercial and experimental seedless table grapes cultivated in a Mediterranean climate. Food Measure *15* (*2*), 1916–1930 https://doi.org/10.1007/s11694-020-00760-2.

Kara, Z., and Yazar, K. (2022). Induction of polyploidy in grapevine (*Vitis vinifera* L.) seedlings by in vivo colchicineapplications. Turk. J. Agric. For. *46* (*2*), 152–159 https://doi.org/10.55730/1300-011X.2967.

Lund, K. (2015). Western United States grapevine breeding. In In Grapevine Breeding Programs for the Wine Industry, Woodhead Publishing Series in Food Science, Technology and Nutrition, A. Reynolds, ed. (Woodhead Publishing), p.359–378 https://doi.org/10.1016/B978-1-78242-075-0.00015-6.

Malnoy, M., Viola, R., Jung, M.H., Koo, O.J., Kim, S., Kim, J.S., Velasco, R., and Nagamangala Kanchiswamy, C. (2016). DNA-Free Genetically Edited Grapevine and Apple Protoplast Using CRISPR/Cas9 Ribonucleoproteins. Front. Plant Sci. *7*, 1904.

Najafi, S., Bertini, E., D'Incà, E., Fasoli, M., and Zenoni, S. (2022). DNA-free genome editing in grapevine using CRISPR/Cas9 ribonucleoprotein complexes followed by protoplast regeneration. Hortic Res *10* (*1*), uhac240 https://doi.org/10.1093/hr/uhac240. PubMed

OIV. (2021). Annual Assessment of the World Vine and Wine Sector in 2021. https://www.oiv.int/sites/default/files/documents/OIV_Annual_Assessment_of_the_World_Vine_and_Wine_Sector_in_2021.pdf (accessed June 21, 2023).

Puglisi, D., Las Casas, G., Ferlito, F., Nicolosi, E., Di Guardo, M., Scollo, F., Saitta, G., La Malfa, S., Gentile, A., and

Distefano, G. (2022). Parents' selection affects embryo rescue, seed regeneration and the heredity of seedless trait in table grape breeding programs. Agriculture *12* (*8*), 1096 https://doi.org/10.3390/agriculture12081096.

Ramming, D.W. (1990). The use of embryo culture in fruit breeding. HortScience *25* (*4*), 393–398 https://doi.org/10.21273/HORTSCI.25.4.393.

Reisch, B.I., Owens, C.L., and Cousins, P.S. (2012). Grape. Fruit Breeding *8*, 225–262 https://doi.org/10.1007/978-1-4419-0763-9_7.

Shivran, M., Shivran, U., and Singh, N. (2022). Breeding approaches in fruit crops improvement. The Pharma Innovation Journal *11* (*4*), 2034–2038.

Wang, Z.L., Xue, T.T., Gao, F.F., Zhang, L., Han, X., Wang, Y., Hui, M., Wu, D., Li, H., and Wang, H. (2021). Intraspecific recurrent selection in *V. vinifera*: an effective method for breeding of high quality, disease-, cold-, and drought - resistant grapes. Euphytica *217* (*6*), 111 https://doi.org/10.1007/s10681-021-02851-7.

Yamada, M., and Sato, A. (2016). Advances in table grape breeding in Japan. Breed Sci *66* (*1*), 34–45 https://doi.org/10.1270/jsbbs.66.34. PubMed

Zhu, P., Gu, B., Li, P., Shu, X., Zhang, X., and Zhang, J. (2020). New cold-resistant, seedless grapes developed using embryo rescue and marker-assisted selection. Plant Cell Tissue Organ Cult. *140* (*3*), 551–562 https://doi.org/10.1007/s11240-019-01751-y.