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Table Olives: Toward Mechanical Harvesting

Iris Biton, Dvora Namdar, Yair Mani and Giora Ben Ari

Abstract

The major reasons for developing mechanical technologies for olive harvesting are the chronic shortage of workers for manual harvesting and increasing labor costs. To enable these technologies to operate, new table olive cultivars suitable for mechanical harvesting are necessary. The two major factors required for the shift from manual to mechanical harvesting of table olives are improved harvesting efficiency and prevention of fruit injury. Improved harvesting efficiency requires suitable pretreatment to enable fruit abscission with minimal defoliation, even when the harvesting is performed by a trunk shaker. The second requirement is prevention of external fruit color change or browning as a result of fruit injury, by development of olive cultivars with firm skin and higher resistance to the bruising caused by mechanical harvesting. This genetic adaptation to mechanical harvesting must be accompanied by efficient post-harvest processing of the olives. In this chapter, we will review the published studies regarding mechanical harvest of table olives, and attempt to identify the main issues, which still need to be studied in order to facilitate the transition from hand to mechanical harvest of table olives.

Keywords: table olive, mechanical harvest, olive cultivars, fruit injury, trunk shaker, harvester

1. Introduction

Table olives (*Olea europaea* L.) have been consumed by populations surrounding the Mediterranean basin, as long as 7000 years ago [1]. Their consumption has expanded to many other countries due to the increasing popularity of the Mediterranean diet [2]. The World Catalog of Olive Cultivars reports about 2500 olive varieties, and their selected use—for oil, table or both, is determined by given parameters [3]. Of these, table olives account for an annual worldwide production of close to 3 million tons.

In general, varieties of table olives are mostly low in oil content, medium to large in size, with flesh-to-pit ratios higher than 4:1 and appropriate texture as set by the International Olive Oil Council (IOC) [4]. The olive trees produce drupes consisting of an epidermis and a soft mesocarp surrounding a stone containing the seed [5]. The epidermis (1.5–3% of the total weight), is constituted mainly of cellulose and cutin, its main function being to protect against external infestations or injury [6]. The olive mesocarp constitutes 70–90% of the fruit weight, the stone accounts for another 5–30%, and the seed is about 1–3% of the fruit, by weight [7].

The five major producers of table olives today are (listed in alphabetic order) Algeria, Egypt, Greece, Spain and Turkey [4]. According to the IOC 2019 report, world table olive production exceeded 2.9 million tons for the season of 2017/2018 [8]. Production is increasing in other regions, such as South America, Australia, and the Middle East with Italy and Portugal also being major producers [9]. Israel has also developed several varieties of table olives, such as 'Kadeshon' and 'Lavee' [10]. However, these varieties play a minor role in the world market.

Classification of table olives is based on standards set by the International Olive Council in 2008 and reaffirmed in 2011 (COI/OT/MO/Doc. No 1. Method for the sensory analysis of table olives and Decision No DEC-18/99-V/2011 COI/OT/MO No 1/Rev. 2). Classification of table olives is based on the median Defect Predominantly Perceived (DPP). Four categories were designated: (1) Extra or Fancy: $DPP \leq 3$; (2) First Choice or Select: $3 < DPP \leq 4.5$; (3) Second or Standard: $4.5 < DPP \leq 7.0$; (4) Olives that may not be sold as table olives: $DPP > 7.0$. Hardness, crunchiness and fibrousness have also been characterized in table olives [11]. Thus, it is important to be aware of the external characteristics of table olives, such as texture and appearance, their importance in the demand for table olives and their role in determining the price to be obtained in the marketplace.

For these reasons, table olives are traditionally harvested manually. It is interesting to note that despite being one of the oldest domesticated fruit crops in the world [1], table olives have benefitted from few technological innovations, especially in regard to harvesting [12]. Because their external appearance and texture are so important in their marketing appeal, special caution must be practiced at harvest. However, a chronic shortage of workers and high labor costs have prompted the need for other, more efficient and economic solutions. Mechanical harvesting methods practiced today are (1) trunk shaking, which can be applied simultaneously with rod beating; and (2) use of an overhead harvester. To promote harvest efficiency, application of an abscission agent should also be considered. Different cultivars may react differently to these mechanical and agronomical methods. In their research, Zipori et al. [13] compared the harvesting efficiency and final product quality of four cultivars of green table olive, 'Manzanillo', 'Hojiblanca', 'Souri', and 'Nabali Mouhassan', in response to manual versus trunk shaker harvesting.

When mechanical harvesting was supplemented by rod beating, harvesting efficiency reached 80–95%, similar to the efficiency of manual picking. However, harvesting efficiency of the trunk shaker without rod beating was significantly lower [13]. Interestingly, application of an abscission agent to accelerate fruit detachment and facilitate mechanical harvest, did not improve harvesting efficiency. Cultivar dependence was also observed: 'Hojiblanca', 'Souri' and 'Nabali Mouhassan' varieties showed similar final product quality using either method, while the quality of 'Manzanillo' olives harvested mechanically was inferior to those harvested manually.

The high sensitivity of table olives to damage caused by mechanical harvesting limits the suitability of this rather efficient method. An objective determination and quantification of the damage caused to table olives by mechanical harvesting may be obtained by digital image analysis. Investigation of fruit damage conducted on 'Manzanillo' table olives in Seville, Spain showed that mechanical harvesting with a trunk shaker led to a rate of bruising 12 times greater than that obtained by manual harvesting. About 60% of the damage to fruit was attributed to fruit-fruit abrasion, fruit-branch contact, and friction from the vibration of the fruit in the tree canopy during harvesting [14]. Most external bruising appeared within the first hour after harvesting.

Another recently developed harvesting technology is the New Pneumatic Harvester (NPH). Two oil cultivars ('Mari' and 'Yellow') were selected to evaluate the NPH system. Harvesting capacity and efficiency, leaf loss and fruit damage were measured. Results showed that the NPH harvested 92% of olive fruits. The percent of leaf loss during the harvesting process was 2.55%. The collector system reduced the level of damaged fruit from 61–25% in both tested cultivars [15].

The mean value of harvesting efficiency with trunk shakers is 72–74%, when applied without the addition of rod beating or abscission agents [16, 17]. In order to achieve harvesting efficiency greater than 85%, tree trunk vibration parameters were set above an acceleration value of 183.4 m/s^2 , and at a frequency of 28.1 Hz. Although increasing the trunk acceleration improved harvesting efficiency, it led to an increase in damage to the harvested fruit 3.5 times greater than the damage caused by manual harvesting [16]. This technique also caused damage to the tree trunk [17].

Olive orchards should be specially prepared for this technology before its application. Ferguson and Garcia [12] studied the effects of pruning on fruit yield that was mechanically harvested. They compared the yield achieved by mechanical harvesting after two different pruning methods - mechanical pruning during six consequential years to that of manual pruning. They reported that use of mechanical pruning resulted in a harvest of 92% of the total yield on the trees where only 81% was harvested from trees that had been hand-pruned. There were no significant differences in the percentage of fruit yield and fruit size as a result of the different pruning treatments. They concluded that the use of mechanical pruning does not decrease average annual yields. These results suggest that in addition to the use of mechanical harvesting, pruning can also be done mechanically without lowering the yield of the tree, thus reducing the management costs of the trees "trained" and adapted for.

Mechanical harvesting can also be carried out by use of an overhead grape harvester. To use this device, the olive grove must be planted with suitable varieties with rows aligned specially for the harvester. New grove designs and management practices such as super-high-density groves which are used in oil olive production should be developed as an option for mechanical harvesting of table olives. In 2012, two table olive cultivars, 'Manzanillo de Sevilla' and 'Manzanillo Cacereña', were harvested in a 5-year-old super-high-density grove (1975 trees/ha) after being planted in continuous hedgerows ($\approx 10,000$ and $18,000 \text{ kg}\cdot\text{ha}^{-1}$, respectively). The differences between manual and mechanical harvesting (using a grape straddle harvester), in time, efficiency, and fruit quality were assessed [18]. The average harvest time per hectare with a grape straddle harvester was less than 1.7 hours compared with minimum of 576 man-hours/hectare for manual harvest. Fruit removal efficiency was high in both cases (98%). The mechanically harvested olives had a very high rate of bruised fruits (>90%). The severity of the damage was greater in 'Manzanillo de Sevilla' than in 'Manzanillo Cacereña.' After Spanish-style green processing, however, the proportion of bruised fruits was below 3% for each cultivar. Mechanically harvested fruits showed a significantly higher proportion of cutting (18%), a type of damage that may take place during harvesting, and reduced firmness than those harvested manually [18].

2. The challenge

It is clear that growers, technologists and scientists must join in a partnership developing and screening cultivars suitable for mechanical harvesting, either by overhead harvester or trunk shaker. Developing varieties with harder or thicker pills may

help in achieving this goal. Another approach would be to investigate the mechanism of fruit detachment in olives, and develop a selective treatment which is commercially practical, and does not cause leaf abscission. A possible reason for the long survival of traditional harvest methods for table olives may be the low efficiency of the detachment mechanism in olive fruits. Multiple analyses carried out by the authors show that mature olive fruits do not produce or release ethylene to any detectable level. It seems therefore, that the fruit detachment mechanism in olives is not regulated by ethylene release, but by a different mechanism.

The desired characteristics of olives fit for table use include larger fruit size, firmness of the flesh of the fruit, resistance to disease, high flesh-to-seed ratio; skin thickness desirable for eating, resistance of epicarp to cracks and bruising and the ability to maintain intact appearance.

One of the main challenges facing growers of table olives interested in converting to mechanical harvesting, is reducing damage to the fruit caused by the harvesting process. This may be achieved by combining the two parameters: (1) enhancing pill durability by increasing thickness of the pill [19]. As the pill thickens, the fruit is more resistant to damage. However, this must be balanced against sensory sensitivity to the feel of the olive in the mouth (2) Reduction of the attachment force of the fruit to the branch, without increasing leaf abscission.

In developing strategies to reduce bruising of the olives at harvest, it is important to understand major factors influencing bruise susceptibility of fresh fruits. Excessive compression forces and a series of impacts during harvesting can cause severe bruise damage. In addition to mechanical forces applied to the fruit and the tree, the stage of fruit maturity also affects bruising. (The susceptibility to bruising depends partly on physiological and biochemical variables. Environmental factors such as temperature, humidity and post-harvest treatments may play a role in susceptibility to fruit damage [20]. Thus, mechanical harvesting must be performed properly in order to reduce both frequency and severity of bruising and increase the resistance of fresh fruit to bruise damage.

As olive varieties differ in many qualities such as heat and disease resistance, fruit size, yield and many more traits [10, 21–23], they differ also in their resistance to shock and bruising. Jiménez et al. [24] observed significant differences among 14 selected genotypes in sensitivity to bruising. Histological sections of bruised and unaffected fruit tissues revealed a subsurface zone of tissue discoloration but a much greater area in which cell structure was disrupted. To further assess the susceptibility of different table olives varieties to bruising, Jiménez et al. [25] studied damages incurred by two different cultivars—‘Manzanillo de Sevilla’ and ‘Hojiblanca’, at 4 and 24 h after impact induced bruising. The predominant post bruising changes they noted in the mesocarp included ruptured cells, cell wall thinning, and discoloration. These changes appeared greater in ‘Manzanillo de Sevilla’ than ‘Hojiblanca’ and were more evident 24 h after the impact. This verifies the assumption that different table olive cultivars may demonstrate differential resistance to bruising. Furthermore, the authors noted several factors that may serve as parameters defining the level of damage: total damaged area, the number of tissue ruptures in the mesocarp, and the distance from the fruit exterior to the nearest tissue rupture were different in the two cultivars. These factors were recommended by the authors as useful parameters characterizing susceptibility to bruising among table olives.

Another criterion useful in assessing bruised fruit is the proportional area of brown coloring after injury, compared to the total fruit surface area. Using the knowledge that mesocarp cells are damaged when pressure is applied, Goldental-Cohen

et al. [19] screened 106 olive cultivars of the Israeli germplasm collection managed at the Volcani Institute for sensitivity to browning in response to injury. Using the above criterion, they showed that post-bruise browning may vary from 0 to 83.61%. Fourteen genetically different cultivars did not brown 3 h after application of pressure. Among them, some cultivars may be selected as suitable table olives. Cultivars resistant to browning were found to have thicker cuticles than those of susceptible varieties, thus cuticle thickness may very well be an important parameter in selecting table olive cultivars suitable for mechanical harvest. A shift to browning-resistant cultivars in place of the popular cultivars currently in use will encourage mechanical harvest of table olive without affecting fruit quality.

Overcoming the bruising caused by mechanical harvest may be aided by adopting the proper irrigation regime. Casanova et al. [26] showed that fruits under regulated deficit irrigation were less susceptible to bruising than fruits fully irrigated. Fruits of 'Manzanillo de Sevilla' that were subjected to regulated deficit irrigation and full irrigation were bruise-induced by a standardized mechanical blow to evaluate bruising susceptibility. Damage was evaluated 3 h after treatment. Fruits under restricted water regimes in the weeks before harvest were much less susceptible to bruising [27]. Thus, controlling irrigation may overcome bruising effects in existing orchards, even for more susceptible varieties.

The low efficiency of hand harvesting of table olives and the rise in the costs of labor prioritizes the need for mechanical harvesting. To achieve mechanical harvesting, the attachment force of fruit to the branch should be lower than 200 gr. Today, most farmers use a pre-harvest abscission compound in order to decrease the fruit detachment force to a level less than 200 gr before mechanically harvesting their oil producing groves. However, table olives are harvested before ripening. At this early stage, the detachment force of the fruits is still very high and does not differ significantly from the detachment force of the leaves. A selective abscission compound is crucial for adapting table olive groves to mechanical harvesting. Goldental-Cohen et al. [28] studied the anatomical and molecular differences between the fruit and leaf abscission zones in olive. Typically, the abscission zone is characterized by small cells with less pectin compared to neighboring cells. This type of cell is found in the leaf but not in the fruit abscission zone. The fruit abscission zone 3 (FAZ3), located between the fruit and the pedicel, was found to be the active AZ in mature fruits. In an attempt to differentiate between fruit and leaf AZs, olive-bearing trees were treated with ethephon, an ethylene-releasing compound, and the effect of this treatment on the detachment force of fruits and leaves 5 days after its application was determined. Transcriptomic analysis of the various abscission zones revealed induction of genes involved in oxidation stress specifically in the leaf abscission zone. They found that adding antioxidants such as ascorbic acid or butyric acid to the ethephon inhibited leaf abscission but enhanced fruit abscission. Treating olive-bearing trees with a combination of ethephon and antioxidants reduces the detachment force of fruit without weakening that of the leaves. Hence, this selective abscission treatment may be used to promote mechanized harvest of olives [28].

Another way to reduce the consequences of bruising by mechanical harvesting is by application of post-harvest treatments. Zipori et al. [29] studied postharvest field treatments on 'Manzanillo' olives, the main table olive cultivar in Israel. This variety is highly sensitive to bruising and other damage caused by mechanical harvesting. Immersing the fruit in a 1% NaOH solution immediately after harvest seems to be the most effective treatment among those studied. This treatment reduced the percentage of severely bruised fruit to reasonable values. We suggest that this treatment, together with other

advances in the field, such as improved shakers and/or use of abscission agents, will enable cost-effective mechanical harvesting of ‘Manzanillo’ table olives [29].

3. Conclusions and further perspectives

The increasing demand for healthy foods has stimulated the industry to study more intensively the existing varieties of table olives found in Mediterranean countries. Olives are considered by many in the food industry to be the “food of the future” [30]. Their balanced fatty acid content and the presence of significant concentrations of polyphenols and fibers increases their attractiveness to the modern consumer. The variety of methods and styles of preparation further increases their demand. For these reasons, most research during the last two decades has focused on the effects of pre-harvesting care and processing technologies, on the nutritional and sensory properties of the different varieties of table olives. Technical aspects of harvesting and post-harvesting processes seem to have been neglected, and to a large extent, traditional methods of handling the produce were retained.

The transition to mechanical harvesting of table olives is essential for the economic survival of this branch of agriculture just as it was for oil olives. The costs of manual labor are increasing, thus lowering profitability to a dangerous level. The changes suggested in this chapter, and the availability of the technologies enabling these changes, are necessary for adapting local, family-sized olive orchards to the scale needed to meet the demands of the world market of the future.

Figure 1. In order to switch from hand to mechanical harvest of table olives several studies must be completed. The two main methods of mechanical harvesting of olives are use of a harvester or use of a trunk shaker. In order to use a harvester, we need to screen and identify (or develop) olive cultivars resistant to bruising, which can be harvested mechanically, without damage to the fruit. For use of a trunk shaker, we also need to identify or develop table olive cultivars resistant to bruising. This must be accompanied by a pre-harvest treatment to decrease fruit detachment force, while avoiding leaf abscission. In both mechanical harvesting methods, fast post-harvest treatment is crucial to avoiding defects and producing quality table olives.

The transition from traditional to fully mechanical systems is challenging not only for the individual farmer; investments in research and infrastructure are also required. New olive varieties adapted for intensive cultivation and super high density harvesting must be developed, suitable equipment must be purchased, and manpower trained. However, profits should cover these investments within a relatively short time (**Figure 1**).

The second area in which technical innovations are required is post-harvest treatments designed to decrease bruising of the fruit during harvest. These treatments should keep in mind the need to reduce the concentration of the polyphenols which cause the bitterness in untreated olives to desired levels. Natural fermentation has been confirmed as the best method for maintaining the high content of polyphenols and triacylglycerols necessary for preserving the nutritional and sensory qualities characteristic of table olives. Reducing processing time is another important goal of research, which must be integrated into the efforts to reduce bitterness and bruising of the fruit [4, 8].

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Conflicts of interest

The authors declare no conflict of interest.

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References

- [1] Galili E, Langgut D, Terral JF, Barazani O, Dag A, Kolska Horwitz L, et al. Early production of table olives at a mid-7th millennium BP submerged site off the Carmel coast (Israel). *Scientific Reports*. 2021;**11**:2218. DOI: 10.1038/s41598-020-80772-6
- [2] Lanza B, Di Serio MG, Iannucci E, Russi F, Marfisi P. Nutritional, textural and sensorial characterisation of Italian table olives (*Olea europaea* L. cv. 'Intosso d'Abruzzo'). *International Journal of Food Science & Technology*. 2010;**45**:67-74. DOI: 10.1111/j.1365-2621.2009.02104.x
- [3] IOC. World Catalogue of Olive Varieties. Príncipe de vergara, Madrid, Spain: International Olive Oil Council; 2013
- [4] Conte P, Fadda C, Del Caro A, Urgeghe PP, Piga A. Table olives: An overview on effects of processing on nutritional and sensory quality. *Food*. 2020;**9**:514
- [5] Garrido Fernández A, Fernández Díez MJ, Adams MR. Control methods. In: *Table Olives Production and Processing*. London: Chapman & Hall; 1997. pp. 461-480
- [6] Bianchi G, Murelli C, Vlahov G. Surface waxes from olive fruits. *Phytochemistry*. 1992;**31**:3503-3506. DOI: 10.1016/0031-9422(92)83716-C
- [7] Rodríguez G, Lama A, Rodríguez R, Jiménez A, Guillén R, Fernández-Bolaños J. Olive stone an attractive source of bioactive and valuable compounds. *Bioresource Technology*. 2008;**99**:5261-5269. DOI: 10.1016/j.biortech.2007.11.027
- [8] Perpetuini G, Prete R, Garcia-Gonzalez N, Khairul Alam M, Corsetti A. Table olives more than a fermented food. *Food*. 2020;**9**:178
- [9] Sánchez A-H, Ruiz-Barba JL, López-López A, Montañó A. Chapter 1- table olives: Types and trade preparations. In: Preedy VR, Watson RR, editors. *Olives and Olive Oil in Health and Disease Prevention (Second Edition)*. San Diego: Academic Press; 2021. pp. 5-14. DOI: 10.1016/B978-0-12-819528-4.00019-5
- [10] Lavee S, Avidan B, Ben-Ari G. Trends in breeding new olive varieties in Israel for quality and economic management. *Agricultural Sciences*. 2014;**05**(08):9. DOI: 10.4236/as.2014.58073
- [11] Lanza B. Abnormal fermentations in table-olive processing: Microbial origin and sensory evaluation. *Frontiers in Microbiology*. 2013;**4**. Article 91. DOI: 10.3389/fmicb.2013.00091
- [12] Ferguson L, Garcia SC. Transformation of an ancient crop: Preparing California 'Manzanillo' table olives for mechanical harvesting. *HortTechnology*. 2014;**24**:274-280. DOI: 10.21273/horttech.24.3.274
- [13] Zipori I, Dag A, Tugendhaft Y, Birger R. Mechanical harvesting of table olives: Harvest efficiency and fruit quality. *Horticultural Science*. 2014;**49**:55-58. DOI: 10.21273/hortsci.49.1.55
- [14] Jimenez-Jimenez F, Castro-Garcia S, Blanco-Roldan GL, González-Sánchez EJ, Gil-Ribes JA. Isolation of table olive damage causes and bruise time evolution during fruit detachment with trunk shaker. *Spanish Journal of Agricultural Research*. 2013;**11**:65-71. DOI: 10.5424/sjar/2013111-3399

- [15] Zare F, Najafi G, Hashjin TT, Kermani AM, Ghiasi P. A new pneumatic harvester for improvement and facilitation the harvesting of the olive fruits. *Advances in Horticultural Science*. 2021;**35**:43-51. DOI: 10.36253/ahsc-9609
- [16] Castro-Garcia S, Castillo F, Jiménez-Jiménez F, Gil-Ribes J, Blanco-Roldan G. Suitability of Spanish 'Manzanilla' table olive orchards for trunk shaker harvesting. *Biosystems Engineering*. 2014;**129**:388-395. DOI: 10.1016/j.biosystemseng.2014.11.012
- [17] Jiménez-Jiménez F, Blanco-Roldan GL, Castillo F, Castro-Garcia S, Sola-Guirado R, Gil-Ribes JA. Table olives mechanical harvesting with trunk shakers: Orchard adaption and machine improvements. *Chemical Engineering Transactions*. 2015;**44**:271-276. DOI: 10.3303/CET1544046
- [18] Morales-Sillero A, Rallo P, Jiménez MR, Casanova L, Suárez MP. Suitability of two table olive cultivars ('Manzanilla de Sevilla' and 'Manzanilla Cacereña') for mechanical harvesting in super high-density hedgerows. *HortScience*. 2014;**49**:1028-1033. DOI: 10.21273/hortsci.49.8.1028
- [19] Goldental-Cohen S, Biton I, Many Y, Ben-Sason S, Zemach H, Avidan B, et al. Green olive Browning differ between cultivars. *Frontiers in Plant Science*. 2019;**10**:1260. DOI: 10.3389/fpls.2019.01260
- [20] Hussein Z, Fawole OA, Opara UL. Harvest and postharvest factors affecting bruise damage of fresh fruits. *Horticultural Plant Journal*. 2020;**6**:1-13. DOI: 10.1016/j.hpj.2019.07.006
- [21] Biton I, Doron-Faigenboim A, Jamwal M, Mani Y, Eshed R, Rosen A, et al. Development of a large set of SNP markers for assessing phylogenetic relationships between the olive cultivars composing the Israeli olive germplasm collection. *Molecular Breeding*. 2015;**35**:107. DOI: 10.1007/s11032-015-0304-7
- [22] Nissim Y, Shloberg M, Biton I, Many Y, Doron-Faigenboim A, Zemach H, et al. High temperature environment reduces olive oil yield and quality. *PLoS One*. 2020;**15**:e0231956. DOI: 10.1371/journal.pone.0231956
- [23] Nissim Y, Shlosberg M, Biton I, Many Y, Doron-Faigenboim A, Hovav R, et al. A high temperature environment regulates the olive oil biosynthesis network. *Plants*. 2020;**9**:1135
- [24] Jiménez R, Rallo P, Suárez MP, Morales-Sillero AM, Casanova L, Rapoport HF. Cultivar susceptibility and anatomical evaluation of table olive fruit bruising. *Acta Horticulturae*. **924**:419-424. DOI: 10.17660/ActaHortic.2011.924.53
- [25] Jiménez MR, Rallo P, Rapoport HF, Suárez MP. Distribution and timing of cell damage associated with olive fruit bruising and its use in analyzing susceptibility. *Postharvest Biology and Technology*. 2016;**111**:117-125. DOI: 10.1016/j.postharvbio.2015.07.029
- [26] Casanova L, Corell M, Suárez MP, Rallo P, Martín-Palomo MJ, Jiménez MR. Bruising susceptibility of Manzanilla de Sevilla table olive cultivar under regulated deficit irrigation. *Agricultural Water Management*. 2017;**189**:1-4
- [27] Casanova L, Corell M, Suárez MP, Rallo P, Martín-Palomo MJ, Morales-Sillero A, et al. Bruising response in 'Manzanilla de Sevilla' olives to RDI strategies based on water potential. *Agricultural Water Management*. 2019;**222**:265-273. DOI: 10.1016/j.agwat.2019.06.007

[28] Goldental-Cohen S, Burstein C, Biton I, Ben Sasson S, Sadeh A, Many Y, et al. Ethephon induced oxidative stress in the olive leaf abscission zone enables development of a selective abscission compound. *BMC Plant Biology*. 2017;**17**:87-87. DOI: 10.1186/s12870-017-1035-1

[29] Zipori I, Fishman A, Zelas ZB-B, Subbotin Y, Dag A. Effect of postharvest treatments of mechanically harvested 'Manzanilla' table olives on product quality. *Postharvest Biology and Technology*. 2021;**174**:111462. DOI: 10.1016/j.postharvbio.2021.111462

[30] Bonatsou S, Tassou CC, Panagou EZ, Nychas G-JE. Table olive fermentation using starter cultures with multifunctional potential. *Microorganism*. 2017;**5**:30. DOI: 10.3390/microorganisms5020030