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# Mechanized pre & post-harvest practices of berry crops cultivation

***Abstract***
*The quality of fruits is depending on the pre & postharvest management of any fruit crop including berries which are most sensitive and delicate type of fruit crops. The management of the orchards or any agricultural filed is labor intensive and slow process with high production cost. With the recent advancement in agricultural technology several mechanical and robotic machines have been introduced which have not only reduced the production cost by reducing labor but they make it easier and less time-consuming than traditional pre & harvesting management system. This study summarizes the current and state of knowledge regarding the mechanized pre & postharvest practices used for different berry crops with emphasis on the short description of the recent mechanical and robotic harvesters available in the market.*
***Keywords:*** *Berries, mechanical harvesters, mechanization, postharvest*

## Introduction

### Automation and Mechanization in Fruit Cultivation

The application of agricultural machinery to mechanize and automize the agricultural work in the field is part of nowadays mechanized agriculture which revolutionized the farm production with ease and replacing manual labor or by working animals such as oxen, horses and mules. Existing mechanical agriculture system comprises of the usage of tractors, trucks, combine harvesters, airplanes (crop dusters), helicopters etc. In addition, the usage of computer with satellite images and GPS guidance in modern agricultural farm lands is often used.

The motivation toward rapid implementation of modern mechanical technologies for fruit (including berries) and vineyard cultivation started somewhere 50 years back and has been related mainly with labor cost and output plus availability. In addition, cultivar/varietal improvements, fruit quality and protection, disease and pest pressures, environmental apprehensions and protocols, and global market pressure are some other major factors involved (Zhang and Pierce, 2013). The concept of proper automation becomes crucial in case of fruit and vineyard producers due to worldwide market pressure which limit the cost of automation to competitive levels and must be remain economically modest with worldwide traders. Thus, it is very important to take in account all range of hurdles and their solutions while talking about a production issues including manual assistants, conventional mechanization, mechanically heightened equipment, semi-autonomous robots with human's guidance and oversight, or in due course fully independent systems. The shortage and high price of manual work and the amplified competition from marketplaces with low-cost labor have instigated commercial farmers to rely on automation or modernization in vineyard and other fruit crops to insure market competition. However, mechanization may entail great capital investments and comprehensive mechanization often needs a very exhaustive managing determination (Morris, 2000).

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In the past few decades' focuses on promoting the progress of mechanized or automated solutions for harvesting the fruit specially berry crops has been seen. However, successful mechanical harvesting is problematic due to fruit damage during harvesting and limit sometimes its wide usage. Major issues to be resolved with a robotic system for picking consist of spotting and detecting the location of fruit and detaching it in accordance with the prescribed norms, without damaging either fruit or tree (Sarig, 1993). The recent advancement in computer assisted mechanization has marked with minimally damage or no damage and ease in harvesting the berry crops. In order to design a successful mechanization system just designing a machine alone is not enough and the components like variety and cultural practices must be taken into consideration (Sims, 1969). The cultural practices like field conditions, plant populations and spacing, and plant shape and size in addition of tree genetics for optimal harvesting (Davis, 1969; Lapushner et al., 1983), physical properties and fruit removal are some of the major aspects that can affect the fruit mechanical harvesting (Wolf and Alper, 1984). Mechanical pruning is most common technology to maintain both size and shape of plants/trees. Whereas, the varieties developed by plant breeders should have resistance against bruising, cracking with long shelf-life for imperious in the fresh market. Fruits should be relatively easily removed from plants and must remain attached to the stalk (Davis, 1969; Lapushner et al., 1983). As the technique of removing the fruit is usually applied principally due to cause of injury fruit, especially in the case of berries. A properly designed end effector will try to minimize fruit damage during harvest.

The use of automation and mechanization is need of the day in every crop including berries in establishing and maintaining the orchards to reduce the production cost. The application of mechanization in both pre & postharvest conditions for berry crop cultivation is exclusively discussed in this review study.

## Berry crops

The berries are the most perishable fruit crops having very short postharvest life in comparison to the other fruit crops. They are very delicate in nature that can be easily damaged during harvesting or picking and needs very gentle or careful handling in harvesting, packaging and transporting stages to ensure the highest postharvest fruit quality and for wide consumer acceptability (Mitcham, 2007). In general, berries are small, pulpy or juicy, colorful fruits with sweet or sour taste and unlike other fruits containing stone or pits, several tiny seeds or pips may present (Wikipedia, 2017a). However, the term berry in a scientific sense is a fruit developed from the ovary of a single flower, by which the outer layer of the ovary wall develops into an edible fleshy portion (botanically the pericarp) and a plant producing berries is known as *bacciferous* or *baccate* (Wikipedia, 2017a). In a such strict botanically sense, many fruits which are considered worldwide as berries are not true berries e.g. blackberries, blue berries, raspberries etc (Mitcham, 2007).

The blackberries, black raspberries, blueberries, cranberries, red raspberries, mulberries and strawberries are some of the common and widely cultivated berry species which are consumed on large scale. Whereas, the Less popular for consumption are acai, black currant, chokeberry and goji berry or Chinese wolfberry (Mitcham, 2007; Hummer et al., 2012).

The berries are enriched with several nutritional and bioactive compounds associated with several health benefits and hence are consumed on large scale (Basu et al., 2010). The

brightly colored nature, external appearance and the healthy and non-damaged skin are some of the factors attracts the consumers besides its nutritive properties. Hence, such factors should be considered during harvesting process of berry fruits. The traditional harvesting with manual labor strictly follows such rules and usually comes with less damaging issues. But, the traditional harvesting requires manual labor which is a slow or lengthy process with high cost. However, the mechanical harvesting trend is popular nowadays for harvesting many berry fruits in developed countries which not only is very rapid process of harvesting but also cost-effective in nature.

This reviews deals with the recent mechanized pre & post-harvesting practices of berry crops with emphasis on the advantages and the limitations of this modern technology for reducing postharvest losses of berry crops.

## Mechanization in pre-harvest conditions of berry fruits

The use of mechanization or mechanical instruments for some important pre-harvest factors like soil preparation, seeding or vegetative propagation, irrigation & fertilization, and pruning has of wide importance in determining the harvesting features and postharvest losses of berry crops. Adequate crop growth is key to maintaining a healthy and productive orchard. Furthermore, pruning resulted in improving the access/reach of a plant to the sunlight that helps in the process of photosynthesis (Burks et al., 2013).

### Mechanical Pruning

The pruning or thinning of fruit trees (including berry crops) to reduce the crop load is of prime importance in order to maximize the fruit quality of produce. Because, by practicing pruning to fruit trees not only help to adjust their shape but also allows an adequate light penetration by thinning the canopy and brings uniformity in fruits (Tucker et al., 1994). The earliest mechanical pruning operations started in early 1960s to prune lemon trees in California, USA with mechanical toppers involved of a modified adjustable sickle-bar mover mounted on the top of machine (Jutras and Kretchman, 1962). Later, these topper machines were improved and equipped with circular saws mounted on a horizontal arm for pruning (Sansavini, 1978). The mechanical pruning is based on a predetermined cutting plant i.e. horizontal top cutting (topping) and vertical walls or oblique hedging/surface pruning (house top) (Burks et al., 2013).

The mechanical pruning of many berry crops is of common modern practice in a developed world for commercial cultivation. A mechanical pruner, developed at the University of Arkansas not only help to properly shapes the hedgerow for maximum harvesting efficiency of erect cane of blackberries but also reduces the labor necessary for pruning (Morris et al., 1978). Nowadays, the southern blueberry plants are commonly mechanical topped pruned using a mechanical hedging equipment soon after harvesting time in order to promote new shoot growth and to manage the height (Fonsah et al., 2004). The ground losses of blueberries by traditional mechanical harvesters has often exceeded 20% (Rohrbach and Mainland, 1989) and even with very well pruned bushes, it's up to 18% (Peterson et al., 1997; van Dalfsen and Gaye, 1999). Takeda et al. (2008) tested V45 Blueberry harvester machine for pruning the rabbiteye blueberries and southern highbush blueberries (developed by USDA in 1994) and found that the ground losses were reduced to less than 1% when it harvested specially with pruned rabbiteye blueberry plants.

## Mechanization in post-harvest conditions of berry fruits

The major developments in mechanical fruit harvesting started somewhere in early and mid-1960s (Morris 2000) particularly in the field of vineyards or grapes cultivation where trellising system were introduced by scientists of University of California, Davis to mechanize grapes harvesting using reciprocating cutter bars installed on a tractor and dropping the fruit clusters onto a conveyor belt parallel with the row (Winkler et al., 1957; Lamouria et al., 1958; Winkler and Lamouria, 1960). Winkler et al., (1957) reported a mechanical harvesting technique for grapes which was though not very successfully but was the start point of mechanical harvesting. They used a cutter-bar machine in which they modified the trellises to the position of grapes to hang them under the wire to facilitate the harvesting process. In 1966, the mechanical harvesting of grapes started in the vineyards of the Arkansas Agricultural Experimental Station (USA) (Morris, 2000). At present, there are several mechanical harvesters available in the market for management of vineyards where the modern types of trellises allow the maximum accessibility of the fruit during harvesting and effective mechanical pruning stages (Burks et al., 2013). The present robotic mechanical harvesting systems are equipped with machine vision that can detect the fruit location either two-dimensional (2D) or three-dimensional (3D) position in the canopy (Fujiura, 1997; Burks et al., 2005).

According to O'Brien et al. (1983) the harvesting is the most labor-intensive agricultural operation of any fruit crop and usually comprised of 30-60% of the total production cost. The countries (mainly developed countries) where there is lack of farm labor the harvesting of crops is very expensive and the harvesting is done usually by the labor force coming from outside the country that aids an additional cost and other immigration issues. Therefore, the mechanical harvesting has been largely adopted by the developed world which has reduced the dependency of foreign labor and other production cost and as well as maximizes the quality of many fruit crops. Burks et al., (2013) has addressed two major limitations which should be considered prior to adopt any mechanical harvesting of fruits including berry crops. These limitations are the (a) horticultural characteristics of the plant (2) and the crop to be harvested *i.e.* size and shape of plant, planting density, fruiting pattern and density, and annual vs perennial crops.

The diversity of fruit and vegetable crops make it difficult to give a general classification of the mechanical harvesters. Therefore, Srivastava et al. (2006) have suggested a classification method of the mechanical harvesters based on the physical location of the desired harvesting portion of the crop. They called these portions as the production zones of interest of any crop and comprised of four zones *i.e.* root crop zone, surface crop zone, bush crop zone and tree crop zone.

As for as the berry fruit crops are concerned, they are mainly lying under bush crop zone and surface crop zone as discussed in detail by Burks et al., (2013).

### Bush Crop Harvesting

The fruit of a bush crop is randomly located in the plant and is generally taller than surface crops where the fruits is usually located near the ground. Many berry crops such as blueberries, grapes and blackberries are some of the examples of bush crops. There are different mechanical harvesting approaches have been performed for bush crops such as combing devices, rollers, air-blasting, electrical current application, mechanical fingers to duplicate the human hand, high-speed shaking, vibrating rods, and cutting devices (Burks et al., 2013).

**Surface Crop Harvesting**

In this type of harvesting, the location of the desired portion of the harvest is just above the soil surface e.g. strawberries (Burks et al., 2013) where a pulling or combing approach is used to detach the berries (O'Brien et al., 1983).

## Modern Mechanize harvesting of some important berry crops

There are some specific considerations that should be considered prior to start mechanical harvesting for any fruit crop to ensures all the constraints mentioned above. The economics of any harvester depends on the prices of fuel and labour, machine, and the fruit specie.

**Blueberries: Mechanical and Robotic harvesting**

The blueberry plant is an erect, prostrate perennial shrub of family *Ericaceae* ranging from 10 cm (3.9 inches) to 4 m (13 feet) in height. Two commonly grown species of blueberries are the lowbush blueberries (*Vaccinium angustifolium*) which are relatively wild and smaller and the highbush blueberries (*Vacciniud corymbosum*) which are tall and abundantly found and divided into northern and southern highbush blueberries (Wikipedia, 2017b). They are mainly cultivated in USA and Canada, and as well as Mediterranean regions of Europe, China etc (FAO, 2014). Blueberries are the second most popular berry among Americans after strawberries. The harvesting period of blueberries varying from region to region e.g. early May to late summers in North America, while the southern hemispheric countries like Australia, New Zealand and Argentina may have longer period of harvesting blueberries (Wikipedia, 2017b).

The blueberries were traditionally harvested by hand or with berry-picking rakes that cost much due to labor intensive. To cope with this issue different harvesters have developed and tested since late 1950s for highbush blueberries while for lowbush berries the new mechanical harvesters are under developing phase (Hedden et al., 1959; Peterson and Brown, 1996; van Dalfsen and Gaye, 1999; Takeda et al., 2008, 2013; Yu et al., 2014; Casamali et al., 2016). There are several top loading harvester tools available for mechanical harvesting of blueberries in the market nowadays. For example, AGH Model 3000 (Fig. 1) is a top loading harvester is a powerful mechanical harvester having rotary or sway and drop deck or non-drop deck options as per order. The model has a low profile conveyor system with a solid body catcher pans that offer very effective and gentle fruit catching system (AG Harvesters, 2015).


**Fig. 1.** AGH 3000 top loading mechanical harvester being used on blueberry fields

**Photo sources:** Extension Fruit Educator, Michigan State University (Gao, 2016) & AG Harvesters

Another mechanical harvester, JOANNA PREMIUM (Fig. 2) is a very efficient and cost-effective model that comes with the capability to pick up high branches for harvesting high bushes like high-bush berries up to 3 m with minimal damage to plants and berries. It has a wider transverse conveyor by 50cm with capacity to harvest the berries in big (about 500 kg) and small (10-20 kg) (WEREMCZUK FMR Ltd).

**Fig. 2.** Joanna Premium harvester of WEREMCZUK FMR Ltd

Despite of being a billion-dollar market of the blueberries production in USA, more than 70% of them is harvested by hand that aids an additional production cost due to huge labor requirement (Herrick, 2015). The use of modern mechanical harvesters often damages the fruit skin by bruising and reduces the marketing quality and such mechanical damages cannot be asses during harvesting process. But, recently some of the devices fitted with highly sensitive sensors can detect such bruising damages. Such as a device "Berry Impact Recording Device (BIRD)" (Fig. 3) developed by USDA-ARS Appalachian Fruit Research Station in Kearneysville as part of a USDA National Institute of Food and Agriculture (NIFA) Specialty Crop Research Initiative (SCRI) project is an affordable sensor technology for improving the harvesting efficiently of blueberries. This sensor rides along with blueberries through the handling process from mechanical harvesting, packing, and transportation to measure the impact. Eventually the BIRD technology can be used to predict the degree of quality loss from the impact values it gathers (Herrick, 2015).


**Fig. 3.**
The BIRD device

**Photo source:**
USDA National Institute of Food and Agriculture (NIFA) Specialty Crop Research
Initiative (SCRI) project (Herrick, 2015)

**Cranberries: Mechanical and Robotic harvesting**

Cranberries (*Vaccinium macrocarpon* Ait.) are low creepy, non-thick woody shrubs of approximately 5 - 20 cm in height and 2 meters long, with wiry stems and small evergreen leaves (Wikipedia, 2017c). They are mainly cultivated in USA accounting about 74% of the total world production while it is also found and cultivated in other countries like Canada, Argentina, Chile and Netherlands (Mitcham, 2007). The cranberries are usually white during most of its growth period and turns deep red upon ripening and harvested usually from late September to October. Cranberries are harvested by two methods; dry and wet (on-the-flood) in which the most common method is the wet harvesting. Dry harvesting is the traditional method practicing since 1900 using some hand-held scoop and later with some earliest mechanical walk-behind harvesters (Fig. 4) and now with some modern automatic dry harvesters available in the market (Caruso et al., 2000). Whereas, the wet harvesting is a modern mechanical method of harvesting cranberries in which water is flooding to the cranberries field which looks like a swamp with several inches of water. The berries in this process float on the water surface and gathered or enclosed in a corner of field using water reel type harvesters where they can be lift or pumped on a conveyor belt into containers and ready to be transported to processing units to be process or frozen (Fig. 5). While, the dry harvesting fruits can be used as fresh fruit due to less bruising effect than wet harvesting but requires high labor cost with lower production (Wikipedia, 2017c).

**Fig. 4.** Dry-Harvesting of Cranberries: harvesting with a hand-held scoop (left) and with earliest mechanical harvesters (right) (1982) in Massachusetts, USA
**Photo source:** Caruso et al., 2000)

**Fig. 5.** Wet-Harvesting of Cranberries
**Photo source:** Raney, 2015

**Raspberries: Mechanical and Robotic harvesting**

The raspberries are perennial woody bushy plants of family *Rosaceae* and are mainly cultivated in Russia, Poland, Serbia and Mexico etc. There are three types of raspberries; red raspberries (*Rubus idaeus* L.), black raspberries (*Rubus occidentalis* L.) and blue raspberries *Rubus leucodermis*) (Mitcham, 2007; Wikipedia, 2017d). Raspberries grown as a perennial crop and is best harvested when bright-red and can be stored at 0 °C only for a few days (Nunes, 2008). Majority of raspberries are planted on raised beds with10 foot row spacing with a side wire trellising system. In USA and Canada, 99% of raspberries is harvested by mechanical methods. At present, several mechanical harvesters are available for raspberries harvesting. Such as, OXBO 9000 (Fig. 6) built by Oxbo International Corporation fitted with wide 55 inch picking tunnel to accommodate more vigorous raspberry varieties. Curved belts minimize fruit drops to deliver the highest quality fruit (Oxbo International Corporation, 2017).

**Fig. 6.** OXBO 9000 being used in Raspberries field
**Photo source:** Oxbo International Corporation, 2017

**Strawberries: Mechanical and Robotic harvesting**

The strawberry (*Fragaria* × *ananassa*) is herbaceous perennial plant of rose family and one of the top cultivated berry plant. The harvesting process has not changed substantially over time. The delicate strawberries are still harvested by hand but application of some mechanical or robotic harvesters is also widely used in developed countries and particularly in tunnel or glasshouses to save labour like Agrobot company built model of a smart robotic strawberries harvester SW 6010 (Fig. 7). This robotic harvester is run by an excellent navigation and guidance system of automatic operation system (AGM) and AGvision® (artificial vision system) that enables the maximum accuracy in harvesting of only ripened berries (AGROBOT, 2012).

**Fig. 7.** AGROBOT SW 6010 harvester or robotic strawberry picker
**Photo source:** AGROBOT (2012)

**Blackcurrants: Mechanical and Robotic harvesting**

The blackcurrant (*Ribes nigrum*) is a medium-size (1 to 2 m in height) woody shrub of family *Grossulariaceae* and exlusively originally belongs to central and northern Europe and northern Asia and mostly used as culinary, juices, jellies and purees (Invenire Market Intelligence Report, 2008; Wikipedia, 2017e). They can be harvested or picked manually on small scale but the commercial harvesting is done usually by mechanical straddle harvesters. These straddle harvesters can move continually down the rows, straddling a row of bushes, shaking the branches and stripping off the fruit while some machines have cross conveyor belts allowing direct collection into large bins ready to send for processing. Pluta and Żurawicz (2008) conducted experiments on picking of blackcurrant fruits by the harvester (KPS-4b) and found smallest amount of damage of shoots and bushes during machine harvesting of cvs. 'Ojebyn', 'Ben Lomond', 'Ben Connan' and 'Ores' while the highest damages wre noted in cvs. ' Titania', 'Tiben' and 'Tisel'.

**Blackberries: Mechanical and Robotic harvesting**

The blackberry is a fruit that is popular around the world. It's known for its high nutritional content. The main blackberries producing countries are USA, China, Mexico, Serbia, Hungary, Chile, New Zealand etc. (FAO, 2014). Blackberries are self-fertile and grow easily in shallow soil. They require 3 to 8 feet of space between bushes, depending on breed and should be planted in early spring. Blackberries grow best in full sun in fertile soil that has good drainage. Healthy blackberry plants will produce harvestable fruit for about 15 to 20 years (Wikipedia, 2017f). Several mechanical harvesters are available in the market for harvesting blackberries. Such as, the OXBO 7420 & OXBO 7440 multi-crop harvesters are commonly used for harvesting blackberries mechanically that saves huge labor expenses (Oxbo International Corporation, 2017).

## Conclusion

The traditional pre & harvesting practices for any fruit crop including berries requires huge labor and other production cost and is a lengthy process. Whereas, the use of modern mechanical tools reduces such production cost and dependency on labor and as well as is very rapid process. The study has briefly discussed several available mechanical and robotic machines being used in berry crop cultivation nowadays which might be of interest for the growers cultivating different berry crops.

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**Conflict of interests**

The authors declare that they have no conflicts of interest.

## References

AG Harvesters (2015). AGH Model 3000. http://www.agharvesters.com/agh-model-3000/. Accessed on 12 June, 2017.

AGROBOT(2012). AGROBOT SW 6010 harvester.http://www.agrobot.com/products.html. Accessed on 12 June, 2017.

Basu, A., Rhone, M., Lyons, T. J. (2010). Berries: emerging impact on cardiovascular health. Nutrition reviews, 68(3), 168-77.

Burks, T., Bulanon, D., Suk-You, K., Ni, Z., Sundararajan, A. (2013). Orchard and vineyard production automation. In: Zhang, Q., Pierce, F.J. (Eds) Agricultural Automation: Fundamentals and Practices. CRC press, New York, USA, pp 150-199.

Burks, T., Villegas, F., Hannan, M., Flood, S., Sivaraman, B., Subramanian, V., Sikes, J. (2005). Engineering and horticultural aspects of robotic fruit harvesting: opportunities and constraints. HortTechnology, 15(1), 79-87.

Caruso, F. L., Bristow, P. R., Oudemans, P.V. (2000). Cranberries: The most intriguing native North American fruit. APSnet Features. doi: 10.1094/APSnetFeature-2000-1100.Accessed on 12 June, 2017.

Casamali, B., Williamson, J.G., Kovaleski, A.P., Sargent, S.A., Darnell, R. L.(2016). Mechanical harvesting and postharvest storage of two southern highbush blueberry cultivars grafted onto *Vaccinium arboreum*rootstocks. HortScience, 51, 1503-1510.

Davis, V. (1969). Mechanization of fruit and pod vegetables introduction. Rural Manpower Center, Michigan State University, Report no. 16: 205-213.

FAO (2014). Food and Agricultural Organization. Food and Agricultural statistics.

Fonsah, E.G., Krewer,G.,Harrison,K., Bruorton, M.(2004).Economic analysis of producing southern highbush blueberries in soil in Georgia. The University of Georgia, USA, AGECON 04 93. http://www.smallfruits.org/Blueberries/production/EconomicAnalysisofProducingSHBlueberryExt%20Public.pdf. Accessed on 12 June, 2017.

Fujiura, T. (1997). Agricultural robots using 3D vision sensor. Robot, 117, 32-38.

Gao, G. (2016). Mechanization in the berry patch can make your job easier. Growing produce magazineMarch 29, 2016. http://www.growingproduce.com/fruits/berries/mechanization-in-the-berry-patch-can-make-your-job-easier/. Accessed on 12 June, 2017.

Hedden, S., Gaston,H.P.,Levin,J.H. (1959). Harvesting blueberries mechanically. Michigan Agricultural Experimental Station Quarterly Bulletin, 42, 24-34.

Herrick, C. (2015). New technology helps to solve the berry mechanization challenge. Growing produce magazineSeptember 29, 2015. http://www.growingproduce.com/fruits/berries/new-technology-helps-to-solve-the-berry-mechanization-challenge/. Accessed on 12 June, 2017.

Hummer, K.E., Pomper, K.W., Postman, J., Graham, C.J., Stover, E., Mercure, E.W., Aradhya, M., Crisosto, C.H., Ferguson, L., Thompson, M. M., Byers, P., Zee, F.(2012). Emerging Fruit Crops. in: Badenes, M., Byrne, D. (Eds.), Fruit Breeding, Handbook of Plant Breeding. Springer Netherlands, pp. 97–147.

Invenire Market Intelligence Report. (2008). Berries in the World:Introduction to the international markets of berries. A report prepared for SITRA. https://media.sitra.fi/2017/02/28141842/Berries20in20the20world-2.pdf. Accessed on 12 June, 2017.

Jutras, P. J., Kretchman, D. W. (1962). A topping machine for Florida citrus groves. Florida State Horticultural Society, USA, pp 32-35.

Lamouria, L. H., Winkler, A. J., Ernathy, G. H., Kampke, C.R. (1958).Designing a grape harvester. Agric. Engng., St. Joseph, Michigan, USA, 39, 218.

Lapushner, D., Frankel, R., Edelman, E. (1983). Genetical and cultural aspects for mechanical harvested fresh market tomatoes. In: Proceedings of the International Symposium on Fruit, Nut and Vegetable Harvesting Mechanization. ASAE 5(12), 404-407.

Mitcham, E. (2007). Quality of berries associated with preharvest and postharvest conditions, in: Zhao, Y. (Ed.), Berry Fruit: Value-Added Products for Health Promotion. CRC Press/Taylor & Francis, p. 207.

Morris, J.R. (2000). The Past, Present, and Future of Vineyard Mechanization. In: Proceedings of the ASEV 50th Anniversary Annual Meeting, Seattle, USA,51 (5), 55-164.

Morris, J.R., Nelson G.S., Kattan A.A., Cawthon, D.L. (1978). Developing a mechanized harvesting and production system for erect blackberries. HortScience, 13(3), 228-235.

Nunes, C.M. N.(2008). Color atlas of postharvest quality of fruits and vegetables. Blackwell publishing.

O'Brien, M., Cargill B. F., Fridley, R. B. (1983). Principles and Practices for Harvesting and Handling Fruits and Nuts. AVI Publishing, Westport, USA.

Oxbo International Corporation, 2017. OXBO 9000 Harvester model. http://www.oxbodev.com/Products/Berries/BlackberryHarvesters/9000.aspx. Accessed on 12 June, 2017.

Peterson, D.L.,Brown,G. K. (1996). Mechanical harvester for fresh market quality blueberries. Transactions of the

ASAE, 39(3), 823-827.
Peterson, D.L., Wolford,S.D.,Timm,E.J.,Takeda,F. (1997). Fresh market quality blueberry harvester. Transactions of the ASAE,40, 535-540.
Pluta, S., Żurawicz, E. (2008). Suitability of the new Polish Blackcurrant cultivars for Mechanical Fruit Harvesting. In: Proceedings of international scientific conference "Sustainable Fruit Growing: From Plant to Product", Dobele, Latvia, pp 213-221.
Raney, J. 2015. Debunking myths and misconceptions about Wisconsin's oldest fruit. Star Journal October 16, 2015. http://www.starjournalnow.com/2015/10/16/cranberry-harvest-comes-to-an-end/#_. Accessed on 12 June, 2017.
Rohrbach, R.P., Mainland, C.M. (1989). Crown restriction in blueberries reduce harvesting ground losses. Acta Horticulturae, 241, 366-372.
Sansavini, S. (1978). Mechanical pruning of fruit tree. Acta Horticulturae,65, 183-197.
Sarig, Y. (1993). Robotics of fruit harvesting: a state-of-the-art review. Journal of Agricultural Engineering Research, 54(4), 265-280.
Sims, W. L. (1969). Cultural practices for fruit vegetables. Rural Manpower Center, Michigan State University, Report no. 16, 225–237.
Srivastava, A. K., Goering, C. E., Rohrbach, R. P., Buckmaster, D. R. (2006). Engineering Principles of Agricultural Machines. ASABE, St. Joseph, USA.
Takeda, F., Krewer, G.,Li,C.,MacLean,D.,Olmstead,J.W. (2013). Techniques for increasing machine harvest efficiency in highbush blueberry. HortTechnology, 23, 430-436.
Takeda, F., Krewer, G., Andrews, E.L., Mullinix, B., Peterson, D.L. (2008). Assessment of the V45 blueberry harvester on rabbiteye blueberry and southern highbush blueberry pruned to V-shaped canopy. Horttechnology, 18, 130-138.
Tucker, D. P. H., Wheaton, T. A., Muraro, R. P. (1994). Citrus tree pruning principles and practices. Horticultural Sciences Department, Florida Cooperative Extension Service. IFAS, Florida, USA.
Van Dalfsen, K.B.,Gaye, M.M. (1999). Yield of hand and mechanical harvesting of highbush blueberries in British Columbia. Applied engineering in agriculture,15, 393-398.
WEREMCZUK FMR Ltd. Joanna Premium harvester. http://www.haskapharvest.com/joanna-premium. Accessed on 12 June, 2017.
Wikipedia(2017a). Berry. https://en.wikipedia.org/wiki/Berry. Accessed on 12 June, 2017.
Wikipedia(2017b). Blueberries. https://en.wikipedia.org/wiki/Blueberry. Accessed on 12 June, 2017.
Wikipedia (2017c). Cranberry. https://en.wikipedia.org/wiki/Cranberry. Accessed on 12 June, 2017.
Wikipedia(2017d). Raspberry. https://en.wikipedia.org/wiki/Raspberry. Accessed on 12 June, 2017.
Wikipedia(2017e). Blackcurrant. https://en.wikipedia.org/wiki/Blackcurrant. Accessed on 12 June, 2017.
Wikipedia (2017f). Blackberry. https://en.wikipedia.org/wiki/Blackberry. Accessed on 12 June, 2017.
Winkler, A. J., Lamouria, L. H. (1960). Mechanical grape harvest. California Agriculture, 14(11), 14.
Winkler, A. J., Lamouria, L. H., Abernathy, G. H. (1957). Mechanical grape harvest problems and progress. American journal of Enology and Viticulture, 8 (4), 182-187.
Wolf, I., Alper, Y. (1984). Mechanization of Paprika Harvest. In: Proceedings of the International Symposium on Fruit, Nut and Vegetable Harvesting Mechanization Bet Dagan, Israel, October 1983. ASAE publication no. 5-84, 265-275.
Yu, P., Li, C., Takeda, F., Krewer, G., Rains, G., Hamrita, T. (2014). Measurement of mechanical impacts created by rotary, slapper, and sway blueberry mechanical harvesters. Computers and Electronics in Agriculture, 101, 84-92.
Zhang, Q., Pierce, F.J. (2013). Agricultural Automation: Fundamentals and Practices. CRC press, New York, USA.

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## Mehanizacija u uzgoju i postupcima poslije berbe za bobičasto voće

***Sažetak***

*Kakvoća voća ovisi o postupcima prije i poslije berbe, što je naročito izraženo kod bobičastog voća koje se ubraja u skupinu najosjetljivijih voćnih vrsta na mehanička oštećenja. Uzgoj voća je radno intenzivan i spor proces s visokim troškovima proizvodnje. Uz nedavni napredak u poljoprivrednoj tehnologiji uvedeni su mehanički i robotski strojevi koji ne samo da smanjuju troškove proizvodnje smanjenjem rada već i ostvaruju značajnu uštedu vremena. Ovaj rad sažima trenutno stanje znanja o mehanizaciji u uzgoju bobičastog voća s naglaskom na kratki opis nedavnih mehaničkih i robotskih kombajna dostupnih na tržištu.*

***Ključne riječi:*** *bobičasto voće, kombajni, mehanizacija, postupci poslije berbe*