International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X

www.agronomyjournals.com
2024; SP-7(9): 940-945
Received: 11-07-2024
Accepted: 17-08-2024

P Srinivas
Scientist, Department of Horticulture, Turmeric Research Station, SKLTGHU, Kammarpally, Telangana, India

G Vijay Krishna
Scientist, Department of Horticulture, Horticulture Research Station, SKLTGHU, Aswaraopet, Khammam, Telangana.

K Nagaraju
Scientist, Department of Horticulture, JV Horticulture Research Station, SKLTGHU, Malyal, Mahanubabad, Telangana, India

S Mallesh
Assistant Professor, Post-Graduation Institute of Horticultural Sciences, SKLTGHU, Mulugu, Siddipet, Telangana, India

J Srinivas
Assistant Professor, College of Horticulture, Mojerla, SKLTGHU, Telangana, India

M Srinivas
Assistant Professor, College of Horticulture, Rajendranagar, SKLTGHU, Telangana, India

Corresponding Author:
P Srinivas
Scientist, Department of Horticulture, Turmeric Research Station, SKLTGHU, Kammarpally, Telangana, India

Mechanized harvesting techniques in horticultural crops: A step towards reduction of cost of cultivation

P Srinivas, G Vijay Krishna, K Nagaraju, S Mallesh, J Srinivas and M Srinivas

DOI: https://doi.org/10.33545/2618060X.2024.v7.i9Sm.1636

Abstract
Indian agriculture is diverse and capable of producing most of the food and horticultural crops of the world. Several studies suggest a direct correlation between farm mechanization and crop productivity. It saves inputs like seeds and fertilizers by 15-20 percent, labour requirement and operational time by 20-30 percent, increases cropping intensity by 5-20 percent and crop productivity by 10-15 percent. At present, Indian farmers are adopting farm mechanization at a faster rate in comparison to recent past. The conversion of agricultural land to non-agricultural uses, non-expansion of cultivable area, non-availability of labour due to shifting in urban avenues becomes crucial in sustaining horticultural production. The only option to cope up with this situation is sustainable mechanization and service according to the future demands. Mechanized harvesting technologies in horticultural crops have been widely investigated and significantly developed over the past several decades. The modern-day horticultural mechanization includes various growing techniques and production processes, working operations, technical procedures, appropriate techniques and machineries for soil management to the intercultural operations and finally the harvesting and processing of the produce. In this article explains the various mechanized harvesting techniques related different horticultural crops that can be utilized to lower the production cost of the farmers. This paper reviews the research and development progress of mechanized harvesting of horticultural crops systematically with a focus on the theoretical study, crop type and their actual applications which can be utilized to lower the production cost of the farmers.

Keywords: Mechanization, harvester, shaker, automation, picking, implements

Introduction
Around the world, increasing population is heightening the food and feed demand. Given the low mechanization in horticultural crops production is by far based on physical labour source (human power). However, the rising cost and decreasing availability of farm labour has heightened interest in mechanization. There is no doubt that farm mechanization has substantial role in boosting the scale of farm operations, lessening the production cost, tumbling drudgery, enlightening the timeliness of operations, augmenting crop productivity and contributing to improve food security and rural livelihoods.

According to the World Bank estimates, half of the total Indian population would be in urban areas by 2050. It is further estimated that the percentage of farm workers of total work force would reduce to 49.9 percent in 2033 and 25.70 percent in 2050 from 54.60 percent in 2011. The share of agricultural workers in total power availability in 1960-61 was about 16.3 percent which is going to reduce to 2.3 percent in 2032-33. The overall level of farm mechanization in the country is only 40-45 percent and 90 percent of the total farm power is contributed by mechanical and electrical power sources. To assure timeliness and quality in various field operations, the average farm power availability needs to be increased to a minimum of 2.5 kW/ha by 2020.

Increasing agricultural operating income is not only an important step in improving agricultural work for farmers in the new era, but is also a powerful way to promote rural revitalization. Based on field survey data on farmers, this study analysed the influence of agricultural mechanization level on agricultural production and income by utilizing a sample-modified endogenous merging model and a threshold effect model. The level of mechanization has a significant positive impact on the cost, output value, income and return rate of all types of crops. For every 1 percent increase in the level of mechanization, the yields of all crops, grain crops and cash crops increase by 1.2151, 1.5941 and 0.4351 percent, respectively. Heterogeneity analysis shows that the level of mechanization has a certain threshold effect on income, with a greater effect occurring after the threshold. A test of action mechanism shows that the mechanization level can increase income via a factor intensification path and quality improvement path, with the partial mediation effects of the two paths being 28.8 and 27.4 percent, respectively. It is recommended to increase subsidies to purchase agricultural machinery, research and promote machinery suitable for cash crops, increase the level of socialized agricultural services, and improve the ability of farmers to apply novel agricultural machinery and tools so as to increase their operating profits.

Although the country has some positive moves in fruit mechanization area (especially in tillage), the level of fruit mechanization is very poor with respect to mechanical power (especially in hills), effective tools and implements, irrigation, pest, and orchard management, harvesting and post-harvest technology areas. The physical constraints of rugged terrain and steep topography, small and fragmented turfs, lack of skilled manpower, poor facilities of spare parts, repair and maintenance, low investing capacity of the farmers, lack of awareness among farmers and non-availability of farm implements and machine based on gender and agroecology are some of the main bottleneck for low level of mechanization in the country. Despite various constraints, there is an enormous opportunity to integrate appropriate machines into most cultivation tasks in a way that optimizes productivity of land and farmer’s life and economy. Making the best use of these machines requires a holistic approach that considers the ecological belt, topographical characteristics, fruit cultivar and equipment available. Therefore, a widespread participatory research method is required to test, validate and disseminate the fruit machinery and tools performance compared with traditional farming method. In fact, operation wise mechanization of orchard crops including nursery house, transplanting of saplings, pit making, spraying and weeding in tall crops and harvesting of fruits and post-harvest operations are prime intervention areas of current situation. Furthermore, immediate attention of the government and other bodies is required to strengthen and rejuvenate unproductive old orchards farm with proper tools and mechanism. Overall, this study highlights the need to prioritize and strengthen fruit mechanization research based on agro ecology and farmers need, improve credit access and spare parts, invest in technical human resources and agricultural machinery workshop, targeted subsidy for poor, women and youth friendly enterprises or real farmers following proper monitoring, incentivize local fabrication and, effective extension and custom hiring services to address the mechanization gaps and harness the potentiality of fruit development.

The undulating topography, small and irregular sized fields, lack of skilled manpower, poor facilities of repair and maintenance, poor purchasing power of farmers and non-availability of improved farm implements and machine are some of the main reason for low level of mechanization in the hilly region of the state. Despite various constraints, there is a vast scope for increasing productivity of land and farmer’s economy through creation of small water resources for irrigation, land development, use of efficient gender friendly farm power and implements, rain water harvest, disseminating renewable energy gadgets and introducing small scale agro based industries employing post-harvest engineering principles.

Harvesting is considered as one of the crucial and critical tasks in fruit production, handling and storage and market cycle due to possible damage to the fruits and musculo skeletal stress on the worker. Traditional picking (hand plucking, tree shaking) and post-harvest practice are responsible for deteriorating the fruit quality and shortening the postharvest shelf-life. Generally, fruit harvesting is done by hand pulling using ladder and collecting bag. Moreover, conventional methods such as tree climbing, tree shaking and hitting by sticks are also commonly applied by farmers (Khatri *et al*., 2022) [3]. These methods are risky, labour and time intensive practices as well as affects market quality and nutritive value of the fruits. Mechanized harvesting is recognized as the most promising area of intervention to tackle increasing phenomena of labour scarcity and costs and to fuel farm prosperity and entrepreneurial opportunity in the rural part of the country (Khatri *et al.*, 2021) [14]. Around the world, mechanical harvesters like limb shaker, air blasting, canopy shaker and trunk shaker, particularly for citrus fruits have been investigated and practiced improving profitability and efficiency of citrus farming. However, there are major issues such as the flexibility, the fruit selection ability, the damage to the fruit and trees, the layout of the grove design for mechanical harvester and topographical constraints which still limits the investment capability and application of the mechanical harvesters in developing countries. Recent studies by Khatri *et al.* (2021) [14] and Khatri *et al.* (2022) [3] evaluated performance of different models of manual fruit harvester along with storage trials on fruit physiochemical attributes on sweet orange and mandarin in Nepal and reported higher harvesting output and improved storability and extended shelf-life of fruits in stored condition than traditional farmers practice. Thus, these kinds of appropriate and effective small scale harvesting tools suitable for smallholder farmers to replace the manual picking of fruits need to be promoted in Nepal that has an immense potentiality to raise the quality fruit production and productivity.

Mechanization in horticultural crops

Horticulture is one of the important sector in determining the economy of many countries but for most of the farmers the cost of different horticultural operation are probably considered as one of the major factors in determining whether there will be economically successful season or not. Different horticultural operations like soil and seed bed preparation digging, fertilization and irrigation, manure spreading, pruning and training, spraying and harvesting, accounts more than half of production cost. In many countries farmers mostly faces these problems which are likely to take more time and also increases the total production cost. So in order to minimize production cost and to saves time we have to take a step towards mechanization. Current mechanized horticulture includes use of trucks, tractors, harvesters. Modern orchards even sometimes use computers in conjuction with satellite imagery and GPS guidelines to increase yield. In fruit cultivation several machinery are available to increase production, mould board plough, disc plough and rotavator are being used in ploughing and seed bed preparation. Operations such as harvesting, spraying, weeding and irrigation use of trunk shaker, air blast sprayer, bush cutter, drip irrigation, respectively can be used to overcome production cost and to saves time compare to conventional method.

Mechanized harvesting technologies in horticultural crops have been widely investigated and significantly developed over the past several decades which were presented by a large amount of literature. This paper reviews the research and development progress of mechanized harvesting of horticultural crops systematically with a focus on the theoretical study, crop type, abscission chemical agents, and their actual applications. Based on the comprehensive review, mechanized harvesting systems for different horticultural crops appear multifarious modes with various vibratory mechanisms and structural dimensions. Major advantages in the development of horticultural mechanical harvesting with effective vibratory patterns and catching frames provide a series of economic and agronomic benefits, such as reducing labor costs, promoting standardized planting, and increasing productivity. In addition, employing sorting technologies to classify the postharvest of horticultural crops provide a new direction for the further development of mechanized harvesting in high-value horticultural crops, as well as bring more benefits to growers and increase their interest in equipment investment on the mechanical harvesting techniques for the horticultural industry.

Harvesting machinery related different fruit crops

Harvesting is considered as one of the crucial and critical tasks in fruit production, handling and storage and market cycle due to possible damage to the fruits and musculo skeletal stress on the worker. Traditional picking (hand plucking, tree shaking) and post-harvest practice are responsible for deteriorating the fruit quality and shortening the postharvest shelf-life. Generally, fruit harvesting is done by hand pulling using ladder and collecting bag. Moreover, conventional methods such as tree climbing, tree shaking and hitting by sticks are also commonly applied by farmers (Khatri *et al.*, 2022) [14]. These methods are risky, labour and time intensive practices as well as affects market quality and nutritive value of the fruits. Mechanized harvesting is recognized as the most promising area of intervention to tackle increasing phenomena of labour scarcity and costs and to fuel farm prosperity and entrepreneurial opportunity in the rural part of the country.

Mango harvester

This tool is useful to plucking mango fruits from the trees without fruit damage. It is a simple and maintenance free gadget comprising of a metal ring with a fixed knife edge at one end for cutting the petiole of the fruit. Nylon net is fixed to the metal ring to hold the plucked fruits. The unit needs to be fixed to a long pole of suitable length to reach the fruits on the tree. It has especially handmade cotton net design to hold a greater number of mangoes. About 80-100 kg or 750 fruit of fruits can be harvested in one hour.

Sapota harvester

The sapota harvester has been developed and it is also suitable for harvesting guava. The fruits of required size only get harvested while the immature fruits are left on the tree. About 100 kg of fruits can be harvested in one hour.

Lime harvester

Lime harvester has been developed for harvesting limes. It is easy to push the lime harvester in dense canopy of the plant. The fruit is held in the hook, harvested and collected in the box while pulling the harvester. The developed lime harvester contains fruit catching unit, fruit collection mouth, conveyance pipe and collection chamber. About 15-20 kg of lime fruits can be harvested in one hour.

Branch shaker

Branch shakers that are used to harvest the fruits. By using branch shaker citrus fruits, apricots, peaches and cherries can be harvested (Ajay *et al*., 2021) [16].

Canopy shaker

Fruits are harvested in this method by using a vibrating mechanism that causes the tines to impact fruit directly or fruit bearing branches. Shaker depth at canopy and force on fruit for detachment

Trunk shaker

Fruits mainly deciduous fruits, olives, nuts, and citrus are used to remove by trunk shaker. Mostly a tractor-mounted trunk shaker is used on cultivars of different fruits in comparison to a hand-held shaker. Defoliation was high at high shaking frequency and the bark was damaged

Air blast harvester

Fruit was detached from the tree by using a force generated air blast. Oscillating air blast devices are employed in this system, and the fruit detachment rate is maximized by the oscillation rate.

Long reach telescopic fruit harvester

The Telescopic adjustment lock helps adjust the length of the Fruit Grabber and finally locking it to a desired length for easy grabbing and plucking.

Apple harvester

This is a new model 2015 Centipede Harvester that can cover over one and a half acres per hour. No need for extra passes down orchard row and no need to blow fruit from between the tree trunks. Its range of machines includes harvesters that can pick up to 150 tonnes of fruit per day.

Grapes harvesting

Mechanical harvesting of grapes has been one of the major changes in many vineyards in the last third of a century. A mechanical grape harvester works by beating the vine with rubber sticks to get the vine to drop its fruit onto a conveyor belt that brings the fruit to a holding bin.

Banana picking assist

Guangxi University, China, have manufactured a simple banana mechanical picking device. The brackets support the banana bunches when picking bananas, and a worm gear mechanism and a vertical rod are installed on the frame. When picking bananas, the bunches can be protected without damaging the banana plants, which can effectively reduce mechanical damages and decrease the labour intensity of workers.

Crawler banana picker

The Western Australian Department of agriculture designs and manufactures a banana picking machine and this machine is specially designed for picking bananas. The entire machine is mounted on a trailer towed by a miniature agricultural tractor. When picking bananas, the manipulator moves the bucket container and cutter to an appropriate position and then cuts the banana bunch stalk. This banana picker greatly reduces the labour intensity of worker.

Bunch stalk cutters

South China Agricultural University, China, developed a banana picking machine, based on banana planting patterns and the clamping mechanism of the end-effector is driven by a motor to rotate the screw, driving the clamping gripper on the manipulator opening and closing to clamp the banana bunch stalk and then the cutters to cut the bunch stalk.

Banana conveying cableway

The invention provides a banana conveying cableway which specifically consists of a conveying belt, a bracket, a conveying device and a connecting rod. The banana conveying cableway is assembled on a banana processing place.

Automatic fruit picking robot (apple)

Automation and labour saving in Horticultural have been required recently. However, mechanization and robots for growing fruits have not been advanced. This study proposes a method of detecting fruits and automated harvesting using a robot arm.

Harvesting machinery related different plantation and spice crops

Oil palm

Harvesting machinery

Harvest in the FFB lifting process (harvest), the tractor trailer system shows the highest level of adoption, despite having lower productivity rates (22-38%) than the tractor grabber system. The productivity rates reported in this study are similar to those reported in the literature, ranging from 20.30 t FFB (31.00 ha/day) in low bunch density seasons to 30.50 t FFB (12.70 ha/day) in high bunch density seasons (Munévar *et al.*, 2020) [17]. The grabber system reduces the unit cost in lifting by 44 percent compared to the tractor trailer system. Global harvesting (including bunches cutter) costs decrease by 21-25 percent when coupling the grabber to the tractor trailer system (Mosquera-Montoya *et al.*, 2023) [18]. In the same way, the grabber system eliminates the need for manual loading and unloading of the logs, which saves time and labor, the grabber system, can also save 1 or 2 wages compared to the traditional method. This paragraph highlights a significant benefit of using the grabber system for harvesting crops that need to be collected every two weeks. This means that 8 fewer wages are needed per hectare per year compared to the manual system. This is a substantial saving for the farmers and a more efficient way of harvesting.

Ultra-light weight coconut harvester

The harvester developed by CPCRI, which can be used harvest up to a height 12 m from the ground. The pipe height can be locked at any desired height on the top end of pipe especially design knife is fitted used to cut coconut. Joseph model has got mainly two Assemblies of similar construction. The steel rope wires of both top and bottom assembly need to be looped with the tree and locked. Joseph model of climbing machine, the only limitation felt by the climbers is the safety of climbers in case of machines failure or from accidental falling. Recently CPCRI has developed a safety attachment to this model of climbing machines the safety attachment is independent of the climbing machine and gives fool proof safety to the climber from falling.

Turmeric harvester

Generally turmeric is harvested manually with crow bar or unique tool "konki" in Telangana. Manual digging of turmeric may cause the rhizome to damage or break down in the field. These broken rhizomes fetch lower price in the market. This can be overcome by the harvesting or digging of turmeric with mechanical digger (turmeric harvester). There is a mesh like structure made with iron material behind the implement which allows the turmeric rhizomes to separate the mound attached to them while harvesting process with mechanical vibration. Farmer can harvest one acre of turmeric rhizomes in 3 hours and in one day total 3 to 4 acres of turmeric rhizomes can be harvested. It is mandatory to cultivate turmeric in bed method to harvest the turmeric with this mechanical.

Harvesting machinery related different flower crops

Automation Systems

Automation makes a work process, process or equipment automatic rather than human action or control. Automation does not simply transfer human functions to machines, but involves a profound reorganization of the work process, in which both human and machine functions are redefined. Early automation was based on mechanical and electromechanical controls but over the past 40 years, the computer has gradually become the primary automation tool. Modern automation is usually associated with computerization (Gerovitch, 2003) [19]. Technological advances make it possible to automate almost every part of agriculture, from planting to harvesting. Most agricultural technologies fall into three categories expected to support the smart farm: autonomous robots, drones or UAVs, sensors and the Internet of Things (IOT). IOT focuses on three aspects Communication, automation, and cost savings in the system. IOT enables people to perform routine activities using the Internet, thus saving time and cost and making them more productive. IOT enables the detection and/or remote control of objects through an existing network model. IOT in environmental monitoring helps to know the quality of air and water, temperature and soil conditions. IOT can also play an important role in precision agriculture to improve farm productivity (Sreekantha and Kavya, 2017) [20]. Mobile robots originally built as automated guided vehicles (AGVs). This work deals with a mobile robot as a device that had to perform tasks in a partially known external environment to deal with unpleasant or dangerous tasks that humans actually perform. Automation of control and speed is a challenge that can increase productivity in many agricultural operations (Garcia *et al.*, 2001) [22].

Harvesting robots

Harvesting robot consider as automation application in agriculture production. Not only reduce current labor costs, which account for 29 percent of total production costs but also harvesting robot enable new functionality by utilizing sensing abilities that humans either lack or cannot achieve with comparable accuracy, consistency, and cost. In recent years, research and development in harvesting robots have focused on economically viable crops harvesting robots like harvesting robots that working in greenhouses. Robots, that working in open field are one of the areas that require years of development due to the many variable factors that affect the working environment which making the need for smarter robots that can deal with an unstable work environment more urgent for robots application in open fields.

Automatic harvesting theories

Automatic robotic harvesters that require little or no human intervention are considered a category of harvest theory classification (Li *et al.*, 2011) [15]. It became necessary to update the classification of automatic harvesting methods to include these latest technologies (Navas *et al.*, 2021) [21]. The updated classification of harvesting methods made by Navas *et al.* (2021)

[21], divide it into three main groups;

Indirect harvesting: application of mechanical force or movement indirectly on the whole plant or part of it. To make the fruits fall without any contact points. air blasting, limb shaking, trunk shaking and canopy shaking are examples methods of indirect harvesting;

Direct harvesting: harvesting method used in case of Difficulty applying direct harvesting due to the characteristics of the plant structure but require the direct application of a mechanical force on the fruit or its peduncle; these picking techniques also known as picking patterns (e.g., twisting, pulling or bending (Dimeas *et al.*, 2015) [23].

The last group is direct harvest with a driving force applied to plant stem: a method applied to fruits that require a direct mechanical movement or another type of cutting method applied directly to the stem because they are morphologically related to a plant with a hard stem that must be cut, such as eggplants, melons, oranges, cucumbers and harvested peppers. According to this classification, the theories of flowers harvesting automated systems can be considered as falling under the direct harvesting and direct harvest with driving force methods. Brabandt and Ehlert (2011) [24] classified the picking principle of flowers to two basic principles; picking comb and picking rotor. The picking combs can move linearly or rotate. As addition feature, the linearly moved picking combs can be designed with additional cutting of stalks. The rotating picking combs are characterized by central and outside discharge of the flower heads and it could be presented in two forms; the form of pin drums and brush pairs

Status of the flowers harvesting automated system

The key technical problems are mainly the lack of picking automated equipment. At present, the mechanization of flowers production is minimal-only a few time consuming work. However, laboratory studies into some of these technologies are underway. At present, flowers picking relies mainly on manual labor and is flowers harvesting began in recent decades. Rath and Kawollek (2009) [25] invented an autonomous cutting flowers picking robot at Leibniz University Hannover in Germany. The robot possessed a machine vision control system and standing robot with 6 DOF, mounted onto an additional vertical linear axis for the expansion of its work space. Consequently, the robot could carry out additional upward and downward motions that could pick *Gerbera jamesonii* which was used as model plant to testing the system. A pneumatic harvest knife was equipped with the robot which was able to cut the Gerbera pedicels and to hold them with a holding fixture. A pneumatic end effect or harvester was created that harvests the crop by cutting.

Flowers harvesting success rate

The success rate of the robot during the harvest was measured (Rath and Kawollek 2009) [25] as the results varied according to the number of flowering stems. The results showed that the robot achieved 97 percent success in the presence of one or two flower stems. Due to the presence of 3 or 4 flower stalks, that percentage dropped to 89 percent, with 5 flower stalks, this percentage is 50 percent. Guo *et al.* (2022) [26] designed picking robot for safflower, and evaluated its performance. 15 pots of plants were equally divided into groups of 3 pots for a total of 5 groups of test samples. The picking test was carried out under laboratory conditions. The test results showed that the average picking cycle of safflower filaments was 16 s/flower ball. The net picking rate of filaments was ranged 85.88 percent and 89.16 percent with average value of 87.91 percent, which satisfied the filament picking requirements and verified the feasibility of the safflower picking robot.

Conclusion

Mechanical harvesting technologies pertaining to horticultural crops play the key role in reducing the production cost on the other hand, mechanized harvesting improves productivity and velocity, allowing for the quick gathering of substantial amounts of crops and decreasing reliance on seasonal workforce. To summarize, the analysis of human and automated harvesting demonstrates an intricate interaction of variables that impact horticultural cultivation methods. Manual harvesting, known for its labor intensive nature, provides meticulousness and attentiveness, which are crucial for fragile horticultural crops, but is impeded by exorbitant labor expenses and the possibility of labor scarcities. Nevertheless, this approach requires substantial upfront investment in equipment and continuous upkeep, which may not be viable for smaller horticultural operations. In addition, mechanical harvesting may result in crop and soil damage and lacks the flexibility to handle various crop kinds and terrains, which is a characteristic of manual approaches. Notwithstanding these obstacles, the future of horticulture is expected to see a growing incorporation of automation, propelled by technological breakthroughs and the need for environmentally-friendly and expandable agricultural methods.

References

1. Maksudan DP, Aditya G. Role of mechanization in fruit production. Agriculture & Food E-newsletter. Article ID: 37577. E-ISSN: 2581-8317.
2. Tiwari PS, Singh KK, Sahni RK, Kumar V. Farm mechanization - trends and policy for its promotion in India. Indian J Agric Sci. 2019;89(10):1555-1562.
3. Khatri S, Shrestha S. Mechanization in fruit cultivation: present status, issues, constraints and future aspects of Nepal. Acta Mechanica Malaysia. 2022;5(2):35-43. ISSN: 2616-4302.
4. Singh S, Singh K. Status and potential of farm mechanization in northwestern Himalayan state Uttarakhand of India. Indian J Hill Farming. 2018;31(1):98-105.
5. Yingjun P, Shuming W, Fuzeng Y, Reza E, Lijun Z, Chengsong L, *et al*. Recent progress and future prospects for mechanized harvesting of fruit crops with shaking systems. Int J Agric & Biol Eng., 2023, 16(1).
6. Food and Agri Strategic Advisory and Research (FASAR). Farm mechanization in India: the custom hiring perspective. YES BANK; July c2016.
7. Chinanshuk G, Priyanka B, Anupam M. Horticulture mechanization - stepping towards increased farm income. SATSA Mukhapatra. 2021;25:1-6.
8. Jiquan P, Zihao Z, Dingning. Impact of agricultural mechanization on agricultural production, income, and mechanism: evidence from Hubei Province, China. Front Environ Sci. 2022;10:838686.
9. Houshang O, Iraj R, Mohammad G, Parashkoohi MG. Economic analysis of horticultural crop production at various levels of mechanization: case study in Ghazvin Province. Int J Adv Biol Biom. Res. 2015;3(1):115-118.
10. Bhawna T. Advancement in harvesting, precooling, and

grading of fruits. Innovare J Agri Sci. 2016;4(2):13-23. ISSN - 2321-6832.
11. Manmohan L, Neeraj Singh P, Ankit. Mechanization in fruit culture. Just Agriculture. 2021;1(8):1-6. e-ISSN: 2582-8223.
12. Dina S, Salama M, Tayel MM, Ibrahim G, Nasr EM. Automated systems as a factor affecting flowers plant harvesting. J Pharm Negative Results. 2022;13(3):1-7.
13. Arley ZH, Alexandre C, Elizabeth R, Nolver A, Mosquera-Montoya M. Adoption of mechanization alternatives in oil palm crops in the Colombian Orinoquía natural region. EDP Sciences; c2024.
14. Khatri S, Shrestha S, Pokharel KP. Evaluation of manual fruit harvesters and storability characteristics of harvested sweet orange under ordinary room storage conditions. Sustainability in Food and Agriculture. 2021;2(2):1-7.
15. Li P, Lee SH, Hsu HY. Review on fruit harvesting method for potential use of automatic fruit harvesting systems. Procedia Eng. 2011;23:351-356.
16. Ajay A, Mohan SS. Mechanization for harvesting of fruit crops. Krishi Science - eMagazine for Agricultural Sciences. 2021;2(12):1-7.
17. Munévar DE, Ruiz E, Díaz-R W, Báez CD, Hernández HJ, Samalanca Ó, *et al*. Cosecha en cultivos de palma de aceite mediante el uso del grabber: Caso de estudio en una plantación de Colombia. Palmas. 2020;41:13-26.
18. Mosquera MM, Munévar DE, Ruíz E, Fontanilla DCA, Salamanca ÓH, Obregón JM, *et al*. Labor productivity assessment of three different mechanized harvest systems in Colombian oil palm crops. OCL. 2023;30:1-8.
19. Gerovitch S. Automation. In: Encyclopedia of Computer Science. c2003. p. 122-126.
20. Sreekantha DK, Kavya AM. Agricultural crop monitoring using IoT - a study. In: 11th International Conference on Intelligent Systems and Control (ISCO); c2017. p. 134-9. IEEE.
21. Navas E, Fernández R, Sepúlveda D, Armada M, Gonzalez SP. Soft grippers for automatic crop harvesting: A review. Sensors. 2021;21(8):2689.
22. Garcia AM, Ribeiro A, García PL, Martínez R. Future sustainability. In: Green urea. Green Energy and Technology. Springer, Singapore. https://doi.org/10.1007/978-981-10-7578-0_5.
23. Dimeas F, Sako DV, Moulianitis VC, Aspragathos NA. Design and fuzzy control of a robotic gripper for efficient strawberry harvesting. Robotica. 2015;33:1085-1098.
24. Brabandt H, Ehlert D. Chamomile harvesters: a review. Ind Crops Prod. 2011;34(1):818-824.
25. Rath T, Kawollek M. Robotic harvesting of Gerbera jamesonii based on detection and three-dimensional modeling of cut flower pedicels. Comput Electron Agric. 2009;66(1):85-92.
26. Guo H, Luo D, Gao G, Wu T, Diao H. Design and experiment of a safflower picking robot based on a parallel manipulator. Eng Agric., 2022, 42.