UNIVERSITI PUTRA MALAYSIA

DEVELOPMENT OF A ROBOTIC WEED CONTROL SYSTEM FOR GREENHOUSES

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ITMA 2019 4

DEVELOPMENT OF A ROBOTIC WEED CONTROL SYSTEM FOR GREENHOUSES

By

AMID HERAVI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

April 2018

DEDICATION

This thesis is dedicated to my dearest Family

My late father (God bless him),

My Mother for her extraordinary love and

My Wife for her support, encouragement and prayers

And, my sister, Hengameh, for her patience

My daughter, Hannah, for her endless care.

Thank You

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

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April 2018

Chairman : Professor Desa Bin Ahmad, PhD, P.Eng
Institute : Advanced Technology

In this study, a robot prototype that moves on a monorail was designed and developed using analytical and experimental methods. It's purpose was weed elimination between cucumber plants inside the greenhouse plants since there is not much research done for a robotic weed control in a cucumber greenhouse. The plants are cultivated in one row and the distance between two plants is about 40 cm. The distance between two rows is almost 1 meter. The soil type of the cucumber greenhouse was sandy loam soil. The robot benefits from 3 arrays of ultrasonic sensors for weed detection and a PIC18 F4550-E/P microcontroller board for processing. The feedback from the sensors activates a robotic arm which moves inside the rows of the cucumber plants for cutting the weeds using rotating blades. Fifty four experiments were carried out inside a greenhouse to find the best combination of arm motor (AM) speed, blade rotation (BR) speed, and blade design. Three BR speeds of 3500, 2500 and 1500 rpm were assigned. The selection of the BR speeds was based on the previously published results on rotary movers, and two AM speed of 10 and 30 rpm to three blade designs of S-shaped, triangular-shaped, and circular-shaped. These blades were selected due to their availability, low cost, and their performance during the initial test experiments.

The results of analysis of variance indicated that different types of blades, different BR speed, and different AM speed had significant effects ($P < 0.05$) on the percentage of weeds cut (PWC). However, no significant interaction effects were observed. The comparison between the interaction effect of the factors (three blade designs, three BR speeds, and two AM speeds) showed that maximum mean PWC was equal to 89% with standard deviation of 3.9% and was achieved with the S-shaped blade when the BR speed was 3500 rpm, and the AM speed was 10 rpm. Using this setting, the maximum PWC that the robot achieved in a random experiment was 95%. The lowest mean PWC was observed with the circular-shaped blade (mean of 45.66% and

SD=1.86) which resulted from BR speed of 1500 rpm and AM speed of 30 rpm. This study can contribute to the commercialization of a reliable and affordable robot for automated weed control in greenhouse cultivation of cucumbers.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PEMBANGUNAN SISTEM KAWALAN WEB ROBOTIC UNTUK HIJAU

Oleh

AMID HERAVI

April 2018

Pengerusi: : Profesor Desa Ahmad,PhD,P.Eng.
Institut : Teknologi Maju

Dalam kajian ini, robot prototaip yang bergerak di atas monorel di sepanjang rumah hijau untuk penghapusan rumpai di antara pokok timun telah direka dan dibangunkan menggunakan kaedah analitik dan eksperimen memandangkan tiada kajian dilakukan mengenai kawalan rumpai menggunakan robot dalam rumah hijau. Tumbuhan ini ditanam dalam satu baris dan jarak antara 2 tumbuhan adalah kira-kira 40 cm. Jarak antara 2 baris hampir 1 meter. Jenis tanah rumah hijau timun adalah tanah berpasir berpasir. Robot ini mendapat manfaat daripada 3 aras sensor ultrasonik untuk pengesanan rumpai dan papan mikrokontroler PIC18 F4550-E / P untuk diproses. Maklum balas dari sensor mengaktifkan lengan robot yang bergerak di dalam barisan tumbuhan timun untuk memotong rumput menggunakan pisau berputar. Lima puluh lima percubaan telah dijalankan di dalam rumah hijau untuk mencari kombinasi terbaik kelajuan motor lengan (AM), giliran putaran bilah (BR), dan reka bentuk bilah. Tiga kelajuan BR sebanyak 3500, 2500 dan 1500 rpm, pemilihan laju BR didasarkan pada hasil yang diterbitkan sebelum ini pada penggerak putar, dan kelajuan dua AM 10 dan 30 rpm hingga tiga reka bentuk bilah bentuk S, bentuk segi tiga, dan bentuk bulat. Bilah-bilah ini telah dipilih kerana mudah diperolehi, kos rendah, dan prestasi mereka semasa eksperimen ujian awal. Keputusan analisis varians menunjukkan bahawa jenis bilah yang berlainan, kelajuan BR berbeza, dan kelajuan AM yang berlainan mempunyai kesan ketara ($P < 0.05$) pada peratusan potongan rumpai (PWC), namun tiada kesan interaksi signifikan yang diperhatikan. Perbandingan antara kesan interaksi faktor-faktor (tiga reka bentuk pisau, tiga kelajuan BR, dan dua kelajuan AM) menunjukkan bahawa maksimum PWC adalah sama dengan 89% dengan sisihan piawai 3.9% dan dicapai dengan bilah berbentuk S apabila Kelajuan BR adalah 3500 rpm, dan kelajuan AM adalah 10 rpm. Dengan menggunakan tetapan ini, maksimum PWC robot yang dicapai dalam eksperimen rawak adalah 95%. PWC min yang paling rendah diperhatikan dengan bilah berbentuk bulat (min 45.66% dan SD = 1.86) yang disebabkan oleh kelajuan BR 1500 rpm dan kelajuan AM 30 rpm. Kajian ini boleh menyumbang kepada pengkomersialan robot yang boleh dipercayai dan berpatutan untuk kawalan rumpai automatik dalam penanaman timun dalam rumah.

ACKNOWLEDGEMENTS

In the name of God, The Compassionate, the Merciful.

All praises be to Him for providing strength and inspiration to reach this stage in my life.

I wish to express my deepest gratitude to the numerous people who have walked with me along the journey of this thesis. First and foremost I would like to express my deep gratefulness to my supervisor Professor Ir. Dr. Desa Ahmad, the chairman of the supervisory committee for his kind assistance, strong support, critical advice, encouragement, suggestions and direction throughout my research and preparation of this thesis.

I would also like to express my gratitude towards Professor Datin Dr. Napsiah Ismail and Professor Dr. Ishak Aris, the members of supervisory committee for their supervision, helpful advice and fruitful discussions that made an invaluable contribution to this dissertation.

My appreciation is addressed to my sister Ms. Hengameh Heravi and her husband Mr. Mohammad Reza Shapouri., the owners of green houses in Jiroft to encourage and guide me at the onset of design procedure and his valuable advice on robot design. My special appreciations are extended to my cousin Mr. Omid Amanpour for his support and assistance.

My special appreciations are extended to Dr. Shafiei, Head of Machinery Design Laboratory, at Payame- Noor-University of Kerman (PNUK) for the guidance and cooperation in the robot tests.

My special appreciation is for all staff of the Department of Biological and Agricultural Engineering, UPM who contributed in the completion of this study. Thanks are extended to staff of Institute of Advanced Technology (ITMA).
I want to give my utmost appreciation to all my friends especially Dr. Hassan Zareei; Mr. Majid Taheri; Mr. Vahid Soltani; Dr. Morteza Almassi and to all who supported and assisted me especially friends and colleagues from Iran.

Lastly, I want to thank my family members; especially to my late father who passed away Apr 1997 who was a source of inspiration during my study. Big thanks to my mother, aunt, sisters, wife and child for their love, prayers, support, sacrifices and encouragement throughout my life.

Declaration by graduate student

I hereby confirm that:

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LIST OF ABBREVIATIONS

Alfap	Angular momentum of plant
AMS	Arm motor movement speed
BR	Blade Rotation
DS	Diagonal of stem in the cutting level (mm)
f b	Bending strength of the plant body
Fr	Cutting power
ITMA	Institute of Advanced Technology
NW	Number of weeds
PNUK	Payame Noor University of Kerman
RM	Ringgit Malaysia
SB	Shape of blade
t	Time
T	Type of blade
UPM	University Putra Malaysia
RPM	rotations per minute
Vb	Environmental speed of blade
Vbf	Total speed of blade
Vf	Moving speed
WB	Circular speed of blade
WBT	Angle between blade and movement direction
X	Stopper distance
MSA	Micro switch, NO.1
MSB	Micro switch, NO.2
UAE	Ultrasound-assisted extraction

CHAPTER 1

INTRODUCTION

1.1 Overview

The world's point of view about the usage of the resources has changed, and the extensive agriculture is replaced by compact cultivation. Indiscriminate use of chemicals has changed with its reasonable alternatives. The demand for off-season production of fruits and vegetables and other agricultural products require controlled environmental conditions. The greenhouse technology can answer almost all the items mentioned above. In addition, greenhouse technology is a career in which payback occurs very quickly. One of the main reasons to exchange greenhouse cultivation with open-field cultivation is to be able to better control environmental conditions. A greenhouse generally is a closed, roofed area. It looks like a big room from a distance.

The types of commercial greenhouses:

1. Tunnel Green house (ground to ground).
2. Combined greenhouses with a saw tooth roof.
3. Combined Greenhouse with triangular roof.
4. Greenhouse interlocking curved roof.
5. Interconnected greenhouses with a domed roof.

In greenhouse planting and growing, some objectives are normally followed:

1. Control over the water soil temperature and sunlight
2. Out-of-season crop production;
3. Dense planting;
4. Producing crops original to regions other than the location where greenhouses are established;
5. Optimal control over pests and diseases;

A greenhouse can protect crops against factors such as high temperatures, strong winds, heavy rains, devastating storms, pests, and diseases. Other benefits of the greenhouse technology include off-season production, efficient use of equipments, increasing the export capacity, annual production per unit area, and the productivity of resources, and ultimately improving profitability. Greenhouse cultivation is an agricultural technique that has many advantages compared with the open-field cultivation. Tropical conditions for vegetable production throughout the year is ideal, depending on the temperature and light in a good condition for greenhouse cultivation by reducing bottlenecks in the production of high quality fruits and vegetables.

Vegetable production in the tropics is one of the main sources of fresh food, minerals, and especially rural livelihoods. (Vilas and Ajay, 2011).

1.1.1 Overview about Cucumber

Cucumber (*cucumis sritivas*) is a grass plant that originates from India. (Robinson & Decker Walters, 1997). It is widely consumed in the Middle East and is available all year round. About 13 million tonnes of cucumbers, like tomatoes and lettuce, are grown globally where 8 million tons are produced in Asia alone.

Optimum conditions for cucumber production include : minimum temperature of 16 to 18 degrees Celsius, normal temperature of 22 to 27 degrees Celsius, maximum temperature of 30– 32 degrees Celsius, average daytime temperature of 25 degrees Celsius, and night time temperature of 20 Celsius. Cucumbers grow well at 10,000 lux with 12 – 24 hours of light and with intensive light of 18,000– 20,000 lux. Suitable moisture for cucumber growth is 70%. Excessive moisture leads to diseases and low moisture leads to 25% – 30% increase in production. An increase in Co_2 by 6 hours a day leads to a 30% increase in the output. Cucumbers need 800– 1000 liters of water per square meter and irrigation is necessary after seedlings have been planted. After two weeks, watering should decrease to allow new roots to develop. Systemic watering should then be conducted: 15 minutes of watering every two hours. Soil Ph should be at 5 – 6 or 6 – 8 and electrical direction of 2 mili mous/cm or DC Zimens/m.

Airflow of 0.5 meter/s leads to gentle movements of the leaves which in turn increase moisture in the lower levels of the greenhouse under the leaves. Co_2 levels increase leaf size-especially for cucumbers and feminine flowers (Gynoecious). (Hassandokht and Nosrati, 2003).

Average time of budding is 3 -4 days and the length of time needed for fruits to ripen is 35 – 50 days. The area needed for seeding is 1000 square meters; 1700 – 2000N with plant accumulation 1.7 to 2.2 plants. (Hassandokht and Nosrati, 2003).

1.1.2 Cultivation Distances

Many farmers think that growing more plants in a small area yields greater output. This is a fallacy because successful cultivation depends on the quality of soil. When plants are densely populated, it is hard to monitor them and diseases can occur. Good soil and summer plough with a concentration of seed per 2– 2.2 square meters is suggested. However, in winter it has to be 1.5– 1.7 square meters with a one square meter passageway separating the plants. In some corridor greenhouses, it is necessary to grow plants 40 – 45 centimeters apart, with 1700 – 2000 bushes every 1000 square meters.

1.1.3 Production of Cucumber

Typically consumers want cucumbers that measure 10 -15 cm in length with a bew crop every two or three days. Cucumbers are harvested manually and grand total produce is 5 to 10 kg for each bush (Hassandokht and Masiha, 2012).

1.1.4 Overview of Weeds in Greenhouse

The growth of weeds like Cleavers, Amaranth, Camelthorn, Grass Quack, Oat wild, in greenhouses decreases the production of cucumbers (Generally every type of plant besides cucumber is considered a “weed”). Weeds compete with cucumbers for nutrients,water and photosynthesies in greenhouses (Table 2.1).

They also attract insects and plant diseases such as aphis, triphis and other fungi which attack cucumber plants. Viruses like wild spinosa (Atriplex. Spp) often infect cucumber plants. They can be treated by using michelberomyte or sun energy (Ansari et al, 2007).

1.1.5 Control and Destruction of Weeds

The growth of the weeds can be prevented by irrigating the greenhouse with tap water, using compost instead of animal manure, and removing weeds before they produce seeds.

Weeds can be controlled by using the seedling system. Weed growth usually occurs during irrigation and transplanting seedlings. Often weeds “hide” amongst cucumber plants and shrubs and cause damage to them by using their nutrients.

Weeds can be destroyed before or after cultivation with herbicides. However, non-chemical forms of weed control are better as the use of herbicides leads to inorganic cucumbers of low quality. Weeds can also be removed manually. It must be mentioned that the soil type of the greenhouse was the sandy loam soil.

1.2 Problem Statement

The growth condition for cucumber in the greenhouse provides the leeway for the growth of other plants too. This condition is ideal for the growth of weeds because due to their physiological conditions, they grow simultaneously with the original plant. To date, many methods and ways have been proposed to prevent the growth of weeds, including controlling them before cultivating the main plant and after that. In the first method, the soil can be disinfected the soil bed before planting either naturally or chemically. The chemicals are used to prevent the growth of weeds that remain in the soil for a long time and cause poisoning (acidic). In the second method, a dark plastic cover is pulled over the greenhouse and on the ground floor in the summer. This increases the temperature under the plastic significantly which in turn results in the destruction of the weed seeds. This method is expensive, and also a high percentage of weeds maintain their potential to grow.

Another method is to remove weeds entangling with the main crop using herbicides. which are usually general type of herbicides due to a variety of weeds including (hardwood, narrow leaves, etc.). However, it must be noted that not only do herbicides pollute the soil but also a small mistake can lead to the loss of the main plant.

1.2.1 The reasons for not using typical robots in cucumber greenhouse

The typical instruments and robots used for removing weeds in open-field cannot be used in the cucumber greenhouse. Below are some of these reasons:

1. Given that the greenhouses are usually small, farmers try to use the maximum available space.
2. Each plant is fastened to the ceiling by a string, so the instruments and robots cannot move from the above or to the rows that have planted
3. There is not enough space for the machines and robots to turn back at the beginning and end of each row. Hence, a rail or monorail is needed for a robot or device to travel to the next row
4. Most of the instruments and robots that are used in the open field have engines that run on fuel. However, if such devices are used in greenhouses that are enclosed, they pollute the atmosphere and generate toxins.
5. Most robots that are used to detect weeds, depend on GPS and satellites. As greenhouses are enclosed and have roofs, robots cannot be used in such environments.
6. The terrain in greenhouses is not always level and as there are chassis in the rows, most robots and devices cannot be used.

Therefore, most of the farmers tend to use the manual way to pull out the weeds and have the workers carry them outside. These methods have two main problems. First, it is time-consuming ; for example, in a one-hectare greenhouse, four workers should work eight hours a day throughout the growing season (about 8 months, 832 man/hour) to eliminate the weeds and once the workers get to the end of the greenhouse, they must start again to remove the weeds from the beginning. Moreover, employing this is highly costly for the farmers.

Given the new approach across the world and increasing demand for organic products, old methods are obsolete because these manual methods have not only resulted in the production of non-organic products, but also they have been found to be inefficient as they are expensive and time-consuming.

This review clearly shows that new methods for removing weeds in the greenhouses such as using weeding robots are necessary. Therefore, in this study, a robot was designed that can move in cucumbers greenhouses where the products are planted in the ground floor. The robot, removes the weeds and solves the problems related to the manual methods. In this study, an attempt has been made to remove weeds through the fastest mechanical method and without the use of chemicals. In addition to being economical for the farmers, this method is very simple to understand and apply.

1.2.2 Summary of uncertainty in the proper functioning of the robot

Unfortunately, farmers ignore or change all or parts of the principles to reduce their costs and this can result in some problems. Here's a summary of some of them.

1. While designing this robot, it is assumed that the cucumbers greenhouse should be fully mechanized and should be based on the scientific planting maintenance, and harvesting.
2. Every other two rows must use one aisle, which could also be used for the weeding and harvesting as well as using two rows of monorail.
3. Manure spills are usually stacked in rows, and the seed is planted in the middle. This stack has a rough surface and is curved shaped.
4. After seeding, the irrigation pipes will be placed on it. These pipes usually have to be placed at a depth of 1 cm from the ground, and the subsurface irrigation should be done.
5. When 3 to 5 leaves of cucumber were grown since then, the bush should be connected to the ceiling by a string. Otherwise, the plant will be tilted and start to grow horizontally.
6. The distance between the seeds that should be 40cm, must be adhered to correctly.
7. The main stem will be placed in a pipe-shaped bar laid inside the frame, which is called chassis.
8. While using the chassis of the greenhouse, it should be considered that the bases of the chassis are placed completely in the soil exactly across form the stem of the plant (at a distance of 40 cm from each other).

The comprehensive of uncertainty in the proper functioning of the robot is presented in Sections 4.10.

1.3 Objectives of the Study

The main objective of this research was to develope and test a robot for weeding in between cucumber plants in a greenhouse with some specific conditions for it to be functional.

The specific objectives of this study were:

1- To determine the capability of the robot to remove weeds within the cultivation rows in a greenhouse.
2- To determine the best type of blades to cut weeds within the cultivation rows.
3- To determine the best rotational speed for the cutting blade.
4- To determine and investigate the best speed for the robot and the guiding arm of the blade within the cultivation rows (a specific machine to control weeds).

The mechanical weeder robot was tested for the time and motion study in caring weeding operation in the greenhouse.

1.4 The Scope of the Study

The scope of this project was to design and develop a moving robot to control weeds in a cucumber greenhouse. This study was limited to designing and fabricating different parts of the robot for weed control and developing a mono rail system to optimize the performance of the robot. Choosing the right blade type and rotation rate facilitates the cutting and disposal of weeds. Several experiments were conducted to evaluate the performance of each blade, types and shapes and also cutting speed of the prototype robot. The best main arm speed was investigated. Systems and units were chosen based on the best performance in cutting and removing weeds.

1.5 Outline of the Thesis

The thesis is organized as follows; Chapter One describes the overview of the greenhouse, cucumber, weed and objectives of the study. The related literature was reviewed in chapter two, including the general purposes as follows:

The purpose behind the greenhouse establishment, definition of greenhouse, advantages and disadvantages of greenhouses, the introduction of greenhouse cucumber, cultivating conditions and its necessities, definition of weed, the conventional ways of weed elimination, and introducing some types of weeds and controlling weeds methods.

Chapter Three deals with the materials and methodology used for designing, fabricating, and testing the weed control robot. A detailed explanation of the results is presented and discussed in Chapter Four. Conclusions are drawn at the end of the study and suggestions for future research are discussed in Chapter Five

REFERENCES

Abagail, Fusilero Ma., Mangubat, Jhoanavi., Eve Ragas , Baguinon, Nestor., Taya, Hanna., Rasco Jr, Eufemio., Weed management systems and other factors affecting the earthworm population in a banana plantation, European Journal of Soil Biology Volume 56, May–June (2013). Pages 89–94.

AGCO Global Technologies. (2007). Fieldstar. Available online on http://www.field star.dk/Agco/FieldStar/FieldStarUK.

Ahmad U. and Kondo, N. (1997). Weed Detection in Lawn Field. http://mama.agr. okayama-u.ac.jp/lase/weed.htm.

Amatya, Suraj, Manoj Karkee, Aleana Gongal, Qin Zhang, and Matthew D. Whiting. (2015). "Detection of Cherry Tree Branches with Full Foliage in Planar Architecture for Automated Sweet-Cherry Harvesting." Biosystems Engineering 146:3–15. Retrieved (http://dx.doi.org/10.1016/j.biosystemseng.2015.10.003).

Anonymous, (2000). Land- en tuinbouwcijfers [Statistics of Dutch Agriculture and Horticulture]. LEI/CBS, 's Gravenhage, The Netherlands.

Altemimi A, Watson DG, Choudhary R, Dasari MR, Lightfoot DA. (2016). Ultrasound Assisted Extraction of Phenolic Compounds from Peaches and Pumpkins. PLOS ONE 11(2): e0148758. doi:10.1371/journal.pone.0148758.

Arcidiacono, C., A. D'Emilio, R. Mazzarella, and C. Leonardi. (2006). "COVERING MATERIALS TO IMPROVE GREENHOUSE MICROCLIMATE DURING SUMMER IN HOT CLIMATES." Pp. 247–54 in Acta Horticulturae. International Society for Horticultural Science (ISHS), Leuven, Belgium. Retrieved (https://doi.org/10.17660/ActaHortic.2006.719.27).

Ansari, MR.., Heydari, RN., Jeyrani, J, Allaye., M, Farshi, AA., Vaziri, zh.(2007). Water use efficiency in greenhouse cultivation, Iranian National Committee on Irrigation and Drainage, NO:111, 180 Pages.

Arsalanbod, M .and Roland D .Kay.(2013).Farm Management-Planting ,Control ,And Implementation. Agricultural Department, Oromieh, Iran

Astrand, B. and Baerveldt, A. J. (2003). Mobile Robot for Mechanical Weed Control. Int. Sugar J., 105(1250): 89-95.

Azhar, M., and D Ahmad. (2009). A Small-scale Self-propelled 4-row Kenaf Harvesting Machine. Proceedings of International Conference on Kenaf and Allied Fibers (ICKAF 2009), Kuala lumpur, Malaysia.

Bac, C. W., Henten, E. J., Hemming, J. Edan, Y. (2014). "Harvesting Robots for value Crops: State-of-the-art Review and Challenges Ahead." Journal of Field Robotics 31(6):888–911.

Bac, C. W., J. Hemming, and E. J. Van Henten. (2013). “Robust Pixel-Based Classification of Obstacles for Robotic Harvesting of Sweet-Pepper.” Computers and Electronics in Agriculture 96:148–62. Retrieved (http://dx.doi.org/10.1016/j.compag.2013.05.004).

Bac, C.Wouter. (2016). “Analysis of a Motion Planning Problem for Sweet-Pepper Harvesting in a Dense Obstacle Environment.” Biosystems Engineering 146:85–97. Retrieved (http://dx.doi.org/10.1016/j.biosystemseng.2015.07.004).

Bac, Cornelis Wouter. (2015). “Improving Obstacle Awareness for Robotic Harvesting of Sweet-Pepper.” Wagenigen University.

Bao, Guanjun. (2016). “Multi-Template Matching Algorithm for Cucumber Recognition in Natural Environment.” Computers and Electronics in Agriculture 127(SupplementC):754–62.Retrieved (http://www.sciencedirect.com/science/article/pii/S0168169916305816).

Barnea, Ehud, Rotem Mairon, and Ohad Ben-Shahar. (2016). “Colour-Agnostic Shape-Based 3D Fruit Detection for Crop Harvesting Robots.” Biosystems Engineering 146:57–70. Retrieved (http://dx.doi.org/10.1016/j.biosystemseng.2016.01.013).

Baskin, Y. (1996). Curbing undesirable aliens. Bioscience, 46(10): 732–736.

Baumann, P.A., D.H. Bade, and D.L. Biediger. (1991). Forage grass response to chemical and mechanical weed control measures. Abstr., Proc. 44th South. Weed Sci. Soc. p. 193.

Badgery-Parker, J. (1999), Agnote DPI/249, Edition 1, pp. 1-2.

Bak, T. and Jakobsen, H. (2004). Agricultural Robotic Platform with Four Wheel Steering for Weed Detection. Biosystems Engineering 87(2), 125–136.

Behroozilar, M. (2000). Enginering Principles of Agricultural Machines.Tehran: Islamic Azad University Scientific Publication Center.

Belforte, G., R. Deboli, P. Gay, P. Piccarolo, and D. Ricauda. (2006). Robot design and testing for greenhouse applications. Biosystems Eng. 95(3): 309-321.

Bennis, N., J. Duplaix, G. Enéa, M. Haloua, and H. Youlal. (2008). “Greenhouse Climate Modelling and Robust Control.” Computers and Electronics in Agriculture 61(2):96–107.

Bloch, Victor, Amir Degani, and Avital Bechar. (2018). “A Methodology of Orchard Architecture Design for an Optimal Harvesting Robot.” Biosystems Engineering 166:126–37.Retrieved (https://www.sciencedirect.com/science/article/pii/S1537511017300612).

Billingsley, John, Arto Visala, Arto, Mark, Dunn. (2007). Robotics in Agriculture and Forestry, Chapter 46, p:2-14.

Borenstein, J.; Everett, H.R.; Feng, L. (1996). Navigating Mobile Robots. Systems and Techniques, 1st ed.; A.K. Peters, Ltd.: Wellesley, MA, USA.

Bocquet, Aime. (1979). Lake bottom archeology. Sci. Amer. 240(2):48–56.

Bruins, M. and Van Gurp, H. (2000). Oogstrobot heeft nog een flinke weg te gaan [The harvesting robot still has a long way to go], Groenten en Fruit, May 21, 20-21.

Bulanon, D. M., T. F. Burks, and V. Alchanatis. (2008). "Study on Temporal Variation in Citrus Canopy Using Thermal Imaging for Citrus Fruit Detection." Biosystems Engineering101(2):161–71.Retrieved (http://www.sciencedirect.com/science/article/pii/S1537511008002420).

Bulanon, D. M., T. F. Burks, and V. Alchanatis. (2009). "Image Fusion of Visible and Thermal Images for Fruit Detection." Biosystems Engineering 103(1):12–22. Retrieved (http://www.sciencedirect.com/science/article/pii/S1537511009000610).

Burks, T. F., Shearer, S. A., Heath, J. R. and Donohue, K. D. (2005). Evaluation of Neuralnetwork Classifiers for Weed Species Discrimination. Biosystgems Engineering 91(3), 293-304.

Chi, Y. T. and P. P. Ling. (2004). Fast Fruit identification for Robotic Tomato Picker. ASAE Paper No: 043083. St. Joseph Mich.: ASAE.

Chattopadhyay, P. S., and K. P Pandey. (1999). Effect of Knife and Operational Parameters on Energy Requirement in Flail Forage Harvesting. Journal of Agricultural Engineering Research, 73, 3-12.

Chemical Weed Control for Field Crops, Pastures, Rangeland, and Noncropland, (2014). Kansas State University Agricultural Experiment Station and Cooperative Extension Service.

Cho, S. I., Lee, D. S. and Jeong, J. Y. (2002). Weed-plant Discrimination by Machine Vision and Artificial Neural Network. Biosystems Eng., 83 (3): 275–280.

Claus G. Sorensen, Michael Norremark, Rasmus Nyholm Jørgensen, Kjeld Jensen, Jorgen Maagaard, Lars Aalkjaer Jensen. (2007). An ASABE Meeting Presentation Paper Number: 077019. Written for presentation at the ASABE Annual International Meeting. 17- 20.

Comba, L.; Martínez, S.F.; Gay, P.; Aimonino, D.A. (2012). Reliable low cost sensors and systems for the navigation of autonomous robots in pot crop nurseries. In Proceedings of International Conference on Robotics and Associated High-technologies and Equipment for Agriculture, RHEA', Pisa, Italy; pp. 203–208.

Dario, P., G. Sandini, B. Allotta, A. Bucci, F. Buemi, M. Massa, F. Ferrari, M. Magrassi, L. Bosio, R. Valleggi, E. Gallo, A. Bologna, F. Cantatore, G. Torrielli, and A. Mannucci. (1994). The Agrobot Project for greenhouse automation. Acta Hort. (ISHS) 361, 85-92.

De-An, Zhao, Lv Jidong, Ji Wei, Zhang Ying, and Chen Yu. (2011). "Design and Control of an Apple Harvesting Robot." Biosystems Engineering 110(2):112–22. Retrieved (http://dx.doi.org/10.1016/j.biosystemseng.2011.07.005).

Délye. Christophe, Jasieniuk. Marie, Corre. Valérie Le, (2013), Deciphering the evolution of herbicide resistance in weeds, terrnds in genetic, Volume 29, Issue 11, November 2013, Pages 649–658.

Denglin, L., Juan, L.,Yuhong, L., Guangyue, R. (2015). Drying characteristics and mathematical model of ultrasound assisted hot-air drying of carrots. Int J Agriculture & Biol Engineering, 2015; 8(4): 124－132.

Derksen, R.C.; Frantz, J.; Ranger, C.M.; Locke, J.C.; Zhu, H., Krause, C.R. (2008). Comparing greenhouse handgun delivery to poinsettias by spray volume and quality. Trans. ASABE, 51, 27–33.

De Maeyer, E. A. A., and W. Huisman. (1994). New Technology to Harvest and Store Fiber Hemp for Paper Pulp. Journal of the International Hemp Association 1:38-41.

Derksen, R.C.; Zhu, H.; Ozkan, H.E.; Hammond, R.B.; Dorrance, A.E.; Spongberg, A.L. (2008). Determining the influence of spray quality, nozzle type, spray volume, and air-assisted application strategies on deposition of pesticides in soybean canopy. Trans. ASABE, 51, 1529–1537.

Dorna, Brigitte. Stadlera, Marina. van der Heijden, Marcel. Strei, Bernhard. Regulation of cover crops and weeds using a roll-chopper for herbicide reduction in no-tillage winter wheat. Soil and Tillage Research, Volume 134, November (2013), Pages 121–132.

Donaire,G. (2013). Mechatronic Description of a Laser Auto guided Vehicle for Greenhouse Operations Sensors. 13, 769-784; doi:10.3390/s130100769.

El-Sheikh. Mohamed A. (2013), Weed vegetation ecology of arable land in Salalah, Southern Oman, Saudi Journal of Biological Sciences, Volume 20, Issue 3, July 2013, Pages 291–304.

Funasaki, G.Y., P.Y. Lai, L.M. Nakahara, J.W. Beardsley, and A.K. Ota. (1988). A review of bilological control introductions in Hawaii: 1890 to 1985. Proc. Hawaiian Entomol. Soc. 28: 105–160.

Gan-Mor S., Ronen B., Kazaz I., Josef S., Bilanki Y. (1997). Guidance for Automatic Vehicle for Greenhouse Transportation", ACTA Horticulture, Vol 443, pp. 99-104.

González. R., Rodríguez. F., Sánchez-Hermosilla. J., G. Donaire. J. (2009). Navigation techniques for mobile robots in greenhouses. Applied Engineering in Agriculture. Vol. 25(2): 153-165. American Society of Agricultural and Biological Engineers.

Gravalos, I.; Loutridis, S.; Moshou, D.; Gialamas, T.; Kateris, D.; Tsiropoulos, Z.; Xyradakis, P. (2012). Vibration effects of bumper suspension system on pipeline sensor- based platform for soil water monitoring. In Proceedings of International Conference on Robotics and Associated High-technologies and Equipment for Agriculture, RHEA, Pisa, Italy, 19–21 September 2012; pp. 209–214.

Granitto, P. M., Verdes, P. F. and Ceccatto, H. A. (2005). Large-scale investigation of weed seed identification by machine vision. Computers and Electronics in Agriculture 47, 15–24.

Gruber, J. K. (2011). "Nonlinear MPC Based on a Volterra Series Model for Greenhouse Temperature Control Using Natural Ventilation." Control Engineering Practice 19(4):354–66.

Godwin, R. J., R. Earl, J. C. Taylor, G. A. Wood, R. I. Bradley, J. P. Welsh, T. Richards, B. S. Blackmore, M. C. Carver, S. M. Knight and B. Welti. (2001). Precision Farming of cereal crops: A five-year experiment to develop management guidelines. Project report 264e, - 328pp. London, UK: Home Grown Cereals Authority.

Guarnieri, A, C. Maglioni, and G. Molari. (2007). Dynamic Analysis of Reciprocating Single-blade Cutter-bars. Transactions of the ASABE 50 (3):755-764.

Han, Kil-Su, Si-Chan Kim, Young Bum Lee, Sang Chul Kim, Dong Hyuk Im, Hong Ki Choi, and Heon Hwang. 2012. "Strawberry Harvesting Robot for Bench-Type Cultivation." Biosystems Engineering 37(1):65–74.

Hannan, W. M. and F. T. Burks. (2004). Current Developments in Automated Citrus Harvesting.ASAE Paper No. 043087. St. Joseph Mich.: ASAE.

Hassandokht, MR., Masiha, S., (2012). Greenhous management (technology of greenhouse crops production). Selsele press, PP: 32-33, 51-53, 326, In Farsi.

Hassandokht, MR,. Nosrati, VS. (2003). Earliness and yield of greenhouse cucumber under the age of transplanting and pruning of fruit, Research project in Tehran university, 30 pages.

Have, H., Nielsen, J. Blackmore, S. and Theilby, F. (2005). Development and test of an autonomous Christmas tree weeder. In: ECPA 05: Proceedings of the of 5th European Conference of Precision Agriculture, Uppsala July 9-12, edited by. J. V. Stafford, Wageningen Academic Publishers, The Netherlands, 629-635.

Hayashi, Shigehiko. (2010). “Evaluation of a Strawberry-Harvesting Robot in a Field Test.” Biosystems Engineering 105(2):160–71. Retrieved (http://dx.doi.org/10.1016/j.biosystemseng.2009.09.011).

Hellström, T. and Ringdahl, O. (2013). “A Software Framework for Agricultural and Forestry Robots, Industrial Robot.” Industrial Robot: An International Journal 40(1):20–26.

Hemming, Jochen, Wouter Bac. (2014). “A Robot for Harvesting Sweet-Pepper in Greenhouses.” Proceedings International Conference of Agricultural Engineering 6–10.Retrieved (http://www.geyseco.es/geystiona/adjs/comunicaciones/304/C01140001.pdf).

Hemming, Jochen, Jan Bontsema. (2014). “Final Report Sweet-Pepper Harvesting Robot.” (December):22.

Hemming, Jochen, Jos Ruizendaal, Jan W.illem Hofstee, and Eldert J. van Henten. (2014). “Fruit Detectability Analysis for Different Camera Positions in Sweet-Pepper.” Sensors (Basel, Switzerland) 14(4):6032–44.

Huang, Y. J., and L. Fang-Fan. (2010). An automatic machine vision guided grasping system for Phalaneopsis tissue culture plantlets. Computer and Electronic in Agriculture, 70: 42-51. http://www.agroatlas.ru/en/content/weeds/Portulaca_oleracea. http://www.planetayurveda.com/mustakpowder.

Ioslovich, Ilya, Per Olof Gutman, and Raphael Linker. (2009). “Hamilton-Jacobi-Bellman Formalism for Optimal Climate Control of Greenhouse Crop.” Automatica 45(5):1227–31.

Ismail, W. I. W., R. Shamshiri, D. Ahmad, and R. Janius. (2015). “Adaptability Factors for Open-Field Tomato Production in East and West of Malaysia.” in American Society of Agricultural and Biological Engineers Annual International Meeting 2015, vol. 3.

Julián Sánchez-Hermosilla 1, Ramón González 2, Francisco Rodríguez 2 and Julián Jacob Carbal ido, Manuel Perez-Ruiz, ChrisGliever, Juan Agüera, Design. (2012). development and lab evaluation of a weed control sprayer to be used in robotic systems. First RHEA International Conference on Robotics and associated High-technologies and Equipment for Agriculture Hosted by the University of Pisa, Italy, September 19-20-21.

Lehnert, Christopher, Andrew English, Christopher McCool, Adam W. Tow, and Tristan Perez. (2017). “Autonomous Sweet Pepper Harvesting for Protected Cropping Systems.” IEEE Robotics and Automation Letters 2(2):872–79.

Li, Peilin, Review on Fruit Harvesting Method, Sang-heon Lee, and Hung-Yao Hsu. (2011). “Review on Fruit Harvesting Method for Potential Use of Automatic Fruit Harvesting Systems.” Procedia Engineering 23:351–66. Retrieved (http://www.sciencedirect.com/science/article/pii/S1877705811053574).

Li, Zhiguo, Pingping Li, Hongling Yang, and Yuqing Wang.(2013). “Stability Tests of Two-Finger Tomato Grasping for Harvesting Robots.” Biosystems Engineering 116(2):163–70.Retrieved (http://www.sciencedirect.com/science/article/pii/S1537511013001244).

Longo, D.; Pennisi, A.; Caruso, L.; Muscato, G.; Schillaci, G. (2010). An autonomous electrical vehicle based on low- cost ultrasound sensors for safer operations inside greenhouses. In Proceedings of International Conference Ragusa, SHWA, Ragusa, Italy, 16–18 September 2010; pp. 437–443.

Kiani1, S and Jafari, A (2012). Crop Detection and Positioning in the Field Using Discriminant Analysis and Neural Networks Based on Shape Features.J. Agriculture. Science. Tech. Vol. 14: 755-765.

Kobayashi, Y., K. Otsuka, K. Taniwaki, M. Sugimoto, and K. Kobayashi. (2003). Development of Kenaf Harvesting Technology Using a Modified Sugarcane Harvester. JARQ 37 (1):65 – 69.

Kohan. (2011). Robotic harvesting of Rosa Damascena using spectroscopic machine vision. Faculty of Agricultural Machinery Engineering. Islamic Azad University, Science and Research Branch, Tehran. (In Farsi).

Koloor, Reza Tabatabae. (2007). Paddy Stems Cutting Energy and Suggested Blade Optimum Parameters. Pakistan Journal of biological Sciences 10 (24):4523-4526.

Koloor, R. T., and A. Borgheie. (2006). Measuring the Static and Dynamic Cutting Force of Stems for Iranian Rice Varieties. J. Agriculture. Science. Techol. 8 (3):193-198.

Koloor, R. T., and G. Kiani. (2007). Soybean Stems Cutting Energy and Blades Parameters. Pakistan Journal of Biological Sciences 10 (9):1532-1535.

Kondo, N., and K. C. Ting. (1998). Robotics for plant production. Artificial Intelligence Review, 12: 227-243.

Kondo, N; Monta, M.; Noguchi, N. (2011). Agricultural Robots. Mechanisms and Practice, 1st ed.; Kyoto University Press: Kyoto, Japan.

Kondo, N., K. Ninomiya, S. Hayashi, T. Ohta and K. Kubota. (2005). A new challenge of robot for harvesting strawberry Grown on Table Top Culture. ASAE Paper No: 043083. St Joseph Mich.: ASAE.

Langenakens, J., Vergauwe, G.; De Moor, A. (2002). Comparing hand-held spray guns and spray booms in lettuce crops in a greenhouse. Aspects Appl. Biol. 66, 123–128.

Majzoobi, M., Seifzadeh, N., Farahnaky, A., & Mesbahi, G. (2015). Effects of sonication on physical properties of native and cross-linked wheat starches. Journal of Texture Studies.1745-4603. doi:10.1111/jtxs.12119.

Mandow, A., Gómez de Gabriel, J.M.; Martínez, J.L.; Muñoz, V.F.; Ollero, A; García-Cerezo, A. (1996). The autonomous mobile robot Aurora for greenhouse operation. IEEE Robot. Auto. Mag., 3, 18–28.

Mandow, A., J. M. Gomez de Gabriel, J. L. Martínez, V. F. Muñoz, A. Ollero, and A. García-Cerezo.(1996).The autonomous mobile robot Aurora for greenhouse operation. IEEE Robotics & Automation 3(4): 18-28.

Martinez, J. L., A. Mandow, J. Morales, S. Pedraza, and A. Garcia-Cerezo. (2005). Approximating kinematics for tracked mobile robots. The Intl. J. of Robotics Res. 24(10): 867-878.

Martin Holm Pedersen, Jens Lund Jensen. (2007). Autonomous Agricultural Robot. Suprvisors: Roozbeh Izadi-Zamanabadi, Jesper A. Larsen.

Mashonjowa, E., F. Ronsse, J. R. Milford, and J. G. Pieters. (2013). "Modelling the Thermal Performance of a Naturally Ventilated Greenhouse in Zimbabwe Using a Dynamic Greenhouse Climate Model." Solar Energy 91:381–93. Retrieved (http://dx.doi.org/10.1016/j.solener.2012.09.010).

Mehta, S. S. and T. F. Burks. (2014). "Vision-Based Control of Robotic Manipulator for Citrus Harvesting." Computers and Electronics in Agriculture 102:146–58. Retrieved (http://dx.doi.org/10.1016/j.compag.2014.01.003).

Murphy, Robin. 2000. Introduction to AI Robotics. MIT press.

Millar, J.D. (1992). Editorial. FarmSafe (2000). Spring. United States Dept. Health Human Svc., Nat. Inst. Occup. Saf. And Health. pp. 1–2.

Miranda, F.R. Yoder, R.E, Wilkerson, J.B., Odhiambo, L.O. (2005). An autonomous controller for site-specific management of fixed irrigation systems. Computers and Electronics in Agriculture 48: 183–197.

Moharram Habbibnejad Kurayem, Taki AmirMasud, (2008). The final factor for harvesting tomato robot, National Conference on Manufacturing Engineering (in Farsi).

Monta, M. (2000). Robot for bioproduction systems. 2nd IFAC/CIGR International workshop on Bio-Robotics, Information Technology and Intelligent Control for Bioproduction Systems. Osaka, Japan.

Murphy, Robin. (2000). Introduction to AI Robotics. MIT press.

Narvdez-Floresa, M., Sanchez-Madrigala, M.A., Quintero-Ramoso, A., Paredes-Lizarragab, M.A., Gonzdlez-Laredoc, R.F., Ruiz-Gutierreza, M.G., Pinon-Castillod, H.A., & Melendez-Pizarroa, C.O. (2015). Ultrasound assisted extraction modeling of fructans from agave (Agave tequilana Weber var. Azul) at different temperatures and ultrasound powers. Food and Bioproducts Processing. 96 (2015) 232-239.

Neal, Joseph C. (1997). Greenhouse weed control, Horticulture Information Information Leaflet 570, Official Publication of the North Carolina Commercial Flower Growers' Association, North Carolina Flower Growers' Bulletin Volume 42, Number 1.

Nemat Shahi, M.M., Sabetghadam, M., Nemat shahi, N., & Athari, M. (2016). The effect of osmotic and ultrasound pre-treatment on some physicochemical features of avocado. International Journal of Pharmaceutical Research & Allied Sciences, 2016, 5(4):121-131.

Nolte B.H. and Fausey N. R. (2001). Soil compaction and drainage.Available online on http://ohioline.osu.edu/b301/index.html.

Nuyttens, D.; Braekman, P.; Windey, S.; Sonck, B. (2009). Potential dermal pesticide exposure affected by greenhouse spray application technique. Pest Management. Science., 65, 781–790.

Nuyttens, D., S. Windey, and B. Sonck. (2004). Comparison of operator exposure for five different greenhouse spraying applications. J. Agriculture. Safety and Health 10(3): 187-195.

Nuyttens, D.; Windey, S.; Sonck, B. (2004). Optimisation of a vertical spray boom for greenhouse spray applications. Biosystem. Eng, 89: 417–423.

Okamoto, Hiroshi and Won Suk Lee. (2009). "Green Citrus Detection Using Hyperspectral Imaging." Computers and Electronics in Agriculture 66(2):201–8. Retrieved (http://www.sciencedirect.com/science/article/pii/S0168169909000258).

Ollero, A., A. Mandow, V. F. Muñoz, and J. Gómez de Gabriel. (1994). Control architecture for mobile robot operation and navigation, Robotics. & Computer-Integrated- Mfg. 11(4): 259-269.

Omid Ghahraei, Design and development of kenaf harvesting machine.(2011). Unpublished PhD,Thesis. Universiti Putra Malaysia.

Pan, J., Min, H. and Yong, H. (2007). Crop and Weed Image Recognition by Morphological Operations and ANN Model. Instrumentation and Measurement, Technology Conference – IMTC. Warsaw, Poland, May 1-3, 2007.

Pedersen, S. M., S. Fountas, H. Have and B.S. Blackmore. (2006). Agricultural robots –system analysis and economic feasibility. Precision Agriculture 7(4): 295-308., Springer.

Pedersen S.M, Fountas S and Blackmore B.S .(2007). Economic potential of robots for high value crops and landscape treatment, Precision Agriculture 08457-465, Wageningen Academic Publishers.

Pe´rez, A. J., Lopez, F., Benlloch, J. V. and Christensen, S. (2000). Colour and Shape Analysis Techniques for Weed Detection in Cereal Felds. Comput. Electron. Agric. 25: 197–212.

Persson, S. (1987). Mechanics of Cutting Plant Material. Vol. Monograph No. 7. St Joseph, MIch., USA: ASAE.

Philip Motooka, Lincoln Ching , Guy Nagai. (2002). Herbicidal Weed Control Methods for Pastures and Natural Areas of Hawaii. Cooperative Extevsion Service. College of Hawai at Havai at Manos.

Pilarski, T., Happold, M., Pangels, H., Ollis, M., Fitzpatrick, K., Stentz A. (2002). The Dementer System for Automated Harvesting, Autonomous Robots, Vol 13: pp. 9-20.

Polder, G., Van Evert, F. K., Lamber, A. (2007). Weed Detection Using Textural Image Analysis. Efita. http://www.efita.net/apps/accesbase/dbsommaire.asp?d = 6257.

Prasad, J., and C. P. Gupta. (1975). Mechanical Properties of Maize Stalk as Related to Harvesting. Journal of Agricultural Engineering Research, 20:79-87.

Radicetti, Emanuele. Mancinelli Roberto , Campiglia Enio. (2013), Impact of managing cover crop residues on the floristic composition and species diversity of the weed community of pepper crop (Capsicum annuum L.), Crop Protection, Volume 44: February 2013, Pages 109–119.

Rains, G. C., J. S. Cundiff, and D. H. Vaughan. (1990). Developement of a whole-stalk sweet sorghum harvester Transctions in Agriculture, 33 (1): 56-62.

Riley B., Siemsen-Newman L. (2003). Health hazards Posed to Pesticide Applicators, Northwest Coalition For Alternatives to Pesticides, pp. 17- 24.

Robinson, R.W., Decker Walters, D.S. (1997). Cucurbits. Cabi Publishers, PP: 226.

Sánchez-Hermosilla, J.; Rincón, V.J.; Páez, F.; Agüera, F.; Carvajal, F. (2011). Field evaluation of a self-propelled sprayer and effects of the application rate on spray deposition and losses to the ground in greenhouse tomato crops. Pest Management. Science. 2011, 67: 942–947.

Sánchez-Hermosilla, J.; Rincón, V.J.; Páez, F.; Fernández, M. (2012). Comparative spray deposits by manually pulled trolley sprayer and a spray gun in greenhouse tomato crops. Crop Prot., 31: 119–124.

Sánchez-Hermosilla, J.; Rodríguez, F.; González, R.; Guzmán, J.L.; Berenguel, M. (2010). A Mechatronic Description of an Autonomous Mobile Robot for Agricultural Tasks in Greenhouses. In Mobile Robots Navigation; Barrera, A., Ed.; InTech.: Rijeka, Croatia,; pp. 583–608.

Sandini, G., F. Buemi, M. Massa, and M. Zucchini. (1990). Visually guided operations in greenhouses. IEEE Intl. Workshop on Intelligent Robots and Systems. Piscataway, N.J.: IEEE.

Sani Behzad. (2013), The Use of Weed Control Robot (WCR) for Achieve to the Sustainable Agriculture, Research Journal of Applied Sciences, Engineering and Technology 6(18): 3332-3334.

Senthilnath, J. (2016). "Detection of Tomatoes Using Spectral-Spatial Methods in Remotely Sensed RGB Images Captured by UAV." Biosystems Engineering 146:16–32. Retrieved (http://dx.doi.org/10.1016/j.biosystemseng.2015.12.003).

Shamshiri, R. (2017). "Measuring Optimality Degrees of Microclimate Parameters in Protected Cultivation of Tomato under Tropical Climate Condition." Measurement: Journal of the International Measurement Confederation 106.

Shamshiri, R. and W. I. W. Ismail. (2014). "Data Acquisition for Monitoring Vapor Pressure Deficit in a Tropical Lowland Shelter-House Plant Production." Research Journal of Applied Sciences, Engineering and Technology 7(20).

Shamshiri, R. R. (2018). "Advances in Greenhouse Automation and Controlled Environment Agriculture: A Transition to Plant Factories and Urban Agriculture." International Journal of Agricultural and Biological Engineering 11(1).

Shamshiri, Ramin. (2016). "Comparative Evaluation of Naturally Ventilated Screenhouse and Evaporative Cooled Greenhouse Based on Optimal Vapor Pressure Deficit." (2016) ASABE Annual International Meeting 1. Retrieved (http://elibrary.asabe.org/abstract.asp?aid=46786&t=5).

Shamshiri, Ramin, Wan Ishak, and Wan Ismail. (2012a). "Nonlinear Tracking Control of a Two Link Oil Palm Harvesting Robot Manipulator." 5(2):1–11.

Shamshiri, Ramin, Wan Ishak, and Wan Ismail. (2012b). "PERFORMANCE EVALUATION OF VENTILATION AND PAD-AND-FAN SYSTEMS FOR GREENHOUSE PRODUCTION OF TOMATO IN LOWLAND MALAYSIA." World Research Journal of Agricultural & Biosystems Engineering 1(1):1–5. Retrieved (http://www.bioinfo.in/contents.php?id=250).

Shamshiri, Ramin, Wan Ishak Wan Ismail, and Desa Ahmad. (2015). "Determining Adaptability Factor in Modern Controlled Plant Production Systems." P. 1 in ASABE 1st Climate Change Symposium: Adaptation and Mitigation Conference Proceedings. St. Joseph, MI: ASABE. Retrieved (http://elibrary.asabe.org/abstract.asp?aid=45495&t=1).

Shamshiri, Ramin, Wan Ishak Wan Ismail, Hasfalina Che Man, and Desa Ahmad. 2015. "Light Condition Based Analysis of Microclimate Parameters for Improvement of Closed-Field Tomato Production in Tropical Lowlands." (2015) ASABE Annual International Meeting 1. Retrieved (http://elibrary.asabe.org/abstract.asp?aid=45732&t=5).

Shamshiri, Ramin and Wan Ishak Wan Ismail. (2013). "A Review of Greenhouse Climate Control and Automation Systems in Tropical Regions." J. Agric. Sci. Appl 2(3):176–83.

Shamshiri, Ramin, Wan Ishak Wan Ismail, and Desa bin Ahmad. (2014). "Experimental Evaluation of Air Temperature, Relative Humidity and Vapor Pressure Deficit in Tropical Lowland Plant Production Environments." Advances in Environmental Biology 5–14.

Shamshiri, Redmond R. (2017). "Adaptive Management Framework for Evaluating and Adjusting Microclimate Parameters in Tropical Greenhouse Crop Production Systems." in Plant Engineering, edited by S. Jurić. Rijeka: InTech. Retrieved (http://dx.doi.org/10.5772/intechopen.69972).

Shamshiri, Redmond R., Ibrahim A. Hameed, Manoj Karkee, and Cornelia Weltzien. (2018). "Robotic Harvesting of Fruiting Vegetables: A Simulation Approach in V-REP, ROS and MATLAB." in Automation in Agriculture-Securing Food Supplies for Future Generations. InTech.

Shamshiri R., Ahmad, D.B., Wan Ismail, W.I., Hasfalina, C. M., Zakaria A.J., and Yamin M. (2016). "Evaluation of the Reduced State-Variable TOMGRO Model Using Boundary Data." 2016 ASABE International Meeting (2454205):2–12. Retrieved (http://elibrary.asabe.org/azdez.asp?JID=5&aid=46785&abstract=162454205.htm&cid=orl2016&t=3).

Singh, S., T. F. Burks, and W. S. Lee. (2004). Autonomous robotic vehicle for greenhouse spraying. ASAE Paper No. 043091. St. Joseph, Mich.: ASAE.

Slaughter, D. C., Giles, D. K., & Downey, D. (2008). Autonomous robotic weed control systems: A review. Computers and electronics in agriculture, 61(1), 63-78.

Solhi,MA., Mollahasani, HA. (2009). Scaffold Cucumber, Nosuh press. Pp: 7-9, In Farsi.

Song, Y. 2014. "Automatic Fruit Recognition and Counting from Multiple Images." Biosystems Engineering 118(Supplement C):203–15. Retrieved (http://www.sciencedirect.com/science/article/pii/S1537511013002109).

Sridhar, H .S. (2013). Development of Single wheel multi use manually operated weed remover. International Journal of Modern Engineering Research (IJMER), Volume. 3, Issue. 6, Nov - Dec. 2013 pp-3836-3840.

Subramanian, V.; Burks, T.F.; Singh, S. (2005). Autonomous greenhouse sprayer vehicle using machine visión and ladar for steering control. Appl. Engineering. Agriculture., 21: 935–943.

Subramanian, V., T. F. Burks, and S. Singh. (2005). Autonomous greenhouse sprayer vehicle using machine vision and ladar for steering control. Applied Eng. in Agric. 21(5): 935-943.

Suryanto, H., D. Ahmad, A. Yahya, F. B. Akande, and K. Syahrita. (2009). Cutting Tests of Oil Palm Empty Fruit Bunches. Transactions of the ASABE 52 (3):723-726.

Suryanto, H., M. Zohadie Bardaie, D. Ahmad, and A. Yahya. (1993). Force and Energy Requirement for Cutting Oil Palm Fresh Fruit Bunch. The Planter 69:399-407.

Tang, X., Zhang, T., Liu, L., Xiao, D., & Chen, Y. (2009). "A New Robot System for Harvesting Cucumber." Pp. 3873–85 in American Society of Agricultural and Biological Engineers Annual International Meeting.

Tanigaki, Kanae, Tateshi Fujiura, Akira Akase, and Junichi Imagawa. (2008). "Cherry-Harvesting Robot." Computers and Electronics in Agriculture 63(1):65–72.

Tao, Yongting and Jun Zhou. (2017). "Automatic Apple Recognition Based on the Fusion of Color and 3D Feature for Robotic Fruit Picking." Computers and Electronics in Agriculture 142(Part A):388–96. Retrieved (http://www.sciencedirect.com/science/article/pii/S0168169917302764).

Thanh Nguyen, T., Vandevoorde, K., Wouters, N., Kayacan, E., De Baerdemaeker, J. G., & Saeys, W. (2016). "Detection of Red and Bicoloured Apples on Tree with an RGB-D Camera." Biosystems Engineering 146:33–44.

Ting, K. C., Tao Lin, and Paul C. Davidson. (2016). "Integrated Urban Controlled Environment Agriculture Systems." Pp. 19–36 in LED Lighting for Urban Agriculture, edited by T. Kozai, K. Fujiwara, and E. S. Runkle. Singapore: Springer Singapore. Retrieved (https://doi.org/10.1007/978-981-10-1848-0_2).

Ting, K. C., G. A. Giacomeli, and S. J. Shen. (1990). Robot workcell for transplanting of seedlings.Transactions of the ASAE 33.

Torres, Carolina. , Mimosa, Mariana., Florencia, Ferreira María., Galetto, Leonardo., (2013), Reproductive strategies of Datura ferox, an abundant invasive weed in agro-ecosystems from central Argentina, Flora - Morphology, Distribution, Functional Ecology of Plants, Volume 208, Issue 4, April 2013, Pages 253–258.

Tosaki K., Miyahara S., Ichikawa T, Taniai S., Mizukura Y, Moriki H., and Miyashita S. (1998), Development of Microcomputer-Controlled Un-manned Air Blast Sprayer" JARQ Japan Agricultural Research Quarterly, Volume 32, No. 3, pp. 83-90.

Van Henten, E. J., Van Tuijl, B. A. J., Hemming, J., Kornet, J. G., Bontsema, J., & Van Os, E. A. (2003). "Field Test of an Autonomous Cucumber Picking Robot." Biosystems Engineering 86(3):305–13.

Van Henten, E. J., Van Tuijl, B. A. J., Hoogakker, G. J., Van Der Weerd, M. J., Hemming, J., Kornet, J. G., & Bontsema, J. (2006). "An Autonomous Robot for de-Leafing Cucumber Plants Grown in a High-Wire Cultivation System." Biosystems Engineering 94(3):317–23.

Van Henten, E.J., J. Hemming, B.A.J. van Tuijl, J.G. Kornet, J. Meuleman, J.Bontsema and E. A.van Os. (2002). "An Autonomous Robot for Harvesting Cucumbers in Greenhouses." Journal on Autonomous Robots 13:241–58.

Van Henten, E.J., Hemming J., Van Tuijl, B.A.J., Kornet, J.G., Meuleman, J., Bontsema J. (2003). Collision-free Motion Planning for a Cucumber Picking Robot, Biosystems Engineering, Vol 86, No. 2 pp. 135-144.

Van Henten, E.J. Van Tuijl, B.A.J. Hoogakker, G-J. Van Der Weerd, M.J . Hemming, J.J. Kornet, J.G and Bontsema, J (2005). An Autonomous Robot for De-leafing Cucumber Plants Grown in a High-wire Cultivation System, Greenhouse Technology Group, Agrotechnology & Food Innovations Ltd. P.O. Box 17, NL6700 AA Wageningen The Netherlands.

Vitzrabin, Efi and Yael Edan. (2016). "Adaptive Thresholding with Fusion Using a RGBD Sensor for Red Sweet-Pepper Detection." Biosystems Engineering 146:45–56. Retrieved (http://dx.doi.org/10.1016/j.biosystemseng.2015.12.002).

Vrindts, E., De Baerdemaeker, J., Ramon, H. (2002). Weed Detection Using Canopy Reflection. Precision Agriculture, 3: 63–80.

Weeden, Brett. (2006). Evaluation of Hemp and Kenaf Varieties in Tropical and Sub-tropical Environments. BARTON ACT 2600, Australia: Rural Industries Research and Development Corporation.

Weiner J and Olsen J .(2007). Konkurrencevenen kan udnyttes, Momentum nr. 12.07.p 28-30.

Yanyun, J., Wanlin, G., Han, Z., Dong, A., Sihan, G., Iftikhar Ahmed, S.,& Yunling, L. (2016). Identification of damaged corn seeds using air-coupled ultrasound. Int J Agriculture & Biol Engineering, 2016; 9(1): 63－70.

Yıldırım, A.,& Öner, M.D. (2015). Electrical conductivity, water absorption, leaching, and color change of chickpea (Cicer arietinum L.) during soaking with ultrasound treatment. International Journal of Food Properties, 18:1359–1372, 2015.

Zhu, B., Jiang, L., Luo, Y. and Tao, Y. (2007). Gabor Feature-based Apple Quality Inspection Using Kernel Principal Component Analysis. J. Food Engineering. 8(4): 741-749.

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Amid Heravi was born in May 1969 in the city of Kerman, Iran. He is married and has a daughter. He finished his high school in Shahid Ayatollah Saeedi high school in Kerman in 1987. He studied agriculture at the University of Jiroft. After completing the two-year period (high Diploma) in 1989, he was admitted to a bachelor's degree program in Mechanics of Agricultural Machinery (4 year period) in Kerman University. He graduated in 1997 and engaged in agriculture in Jiroft. He was admitted to the Agricultural Mechanization MA program in Tehran Science and Research University in 2002. In his thesis, he examined the cost of wood and metal cucumber greenhouses and the effect of heater on the production of cucumber in Jiroft and graduated with a top grade in 2005. The study was presented at the international research seminar of greenhouse in Iran in 2002. He then continued doing agriculture activities in Jiroft and at the same time he was teaching in the university of Bam. After the earthquake in Bam, the University of Bam was transferred to Kerman. He continued teaching in the University of Bam and Payame Noor University of Kerman. He has taught various courses of Mechanization and Agricultural Machinery Mechanics in the University of Applied Science. Since 2008, he has been conducting a research study in the field of precision farming at the Institute of Advance Technology (ITMA), Universiti Putra Malaysia

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