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FARMER'S AWARENESS, ACCEPTANCE, AND CHALLENGES FOR ADOPTING SOILLESS CULTURE (HYDROPONICS TECHNOLOGY) FOR VEGETABLE PRODUCTION IN JORDAN

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Abstract

Soilless cultivation and hydroponic technology in Jordan recently gained attention as future techniques for growing crops in greenhouses. Soils pose serious challenges to plant growth, for that soilless cultivation systems offer the opportunity to produce without soil and avoid unfavorable soil conditions. This study investigated Jordanian farmers' awareness and attitudes regarding accepting the adoption of soilless cultivation technologies. An online or onsite survey was distributed to vegetables' farmers in Jordan Valley. Data was collected via google forms and compiled manually. The results showed no differences in any of these domains with age, educational levels, and years of experience. Comparison of means of total scores of awareness and acceptance between farmers with previous knowledge or receiving any previous training on hydroponics technologies and farmers without prior knowledge was statistically significant with a p-value (<0.05). Results indicated that 69.4% of the farmers have prior knowledge about soilless culture – hydroponic technology, the results showed a good acceptance score, and lower challenges score. Areas of improvement in delivering the knowledge can help increasing the acceptance rate to adopt the new technologies and to overcome the current challenges.

Keywords: Sustainable Agriculture; Hydroponics; Soil-Less Culture, Vegetable Production, Jordan.

1. INTRODUCTION

With the increasing population around the world, more crops need to be produced. A recent official report showed that more than fifty-one million people are suffering from hunger in Arab nations. The Middle East is facing a significant challenge to secure continuous food production, because of the limited production land available, and the scarcity of water that is associated with the climatic changes (FAO, 2021). Additionally, decreasing water quality, increasing salinization, increasing soil erosion, and expanding the desertification area, all

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increase the threat to our food production chain. (Rockström and Karlberg, 2010). Therefore, not only governmental policymakers but also farmers and producers need to accept and adapt new cultivation methods with lower water requirements higher rates production, more modern and sustainable agriculture technologies that can keep up with the growing demand for food.

Traditional cultivation is becoming a challenge in areas with poor soil conditions and small available areas for cultivation, therefore soil-less culture under controlled environments can be successfully used (Butler and Oebker, 2006).

Countries with water scarcity and low fertile soils (such as the desert) need to produce their crops hydroponically. Hydroponic is a modern cultivation technology used in greenhouses to reduce the waste of water and valuable green space (Gonnella and Renna, 2021). Under unfavorable soil conditions such as soil disease, compaction, poor drainage, and degradation of plant growth, therefore, soil-less culture is needed and can be successfully used. (Sardare *et al*., 2019). Desertification and salinization are threatening greenhouse-produced crops; therefore, vegetable producers are heading towards promoting urban agriculture, and adopting hydroponics technologies to optimize crop yields within greenhouse systems, and achieve food security and environmentally sustainable products for future generations (Fussy and Papenbrock, 2022).

It was reported that urban agriculture plays a significant role in urban food security in Uganda and Kenya (Lee-Smith, 2010). Using soil-less techniques, producing different crops can be possible anywhere no matter what the season is. Busy cities can produce crops and significantly contribute to increasing food security (Wheeler and Von Braun, 2013).

Farmers in Africa stated that food security can be increased using hydroponics technology if production systems sensitization is attained, and if the high cost is reduced (Gumisiriza *et al*., 2022 moreover Brazilian grain farmers, indicated that advanced and more time in education and awareness is needed for new technologies to be adopted (Pivoto *et al*., 2019).

Hydroponic systems produced crops with high nutritional value (Jones, 2012). Hydroponic farming allows the use of automated production systems including the use of (solar panels to solve energy input problems, cooling fans to control temperature, and oxygen pump for aeration problem) (Nalwade and Tushar, 2017). In the last decade more projects were targeting Jordanian farmers and the use of new technologies, for example in 2020, The Food and Agriculture Organization of the United Nations (FAO) and the Ministry of Agriculture (MoA) in Jordan started a pioneering project to provide capacity building and technical support for hydroponics farming systems in Jordan. But much more is needed in evaluating the awareness and challenges that farmers in Jordan are facing to maintain high-quality education.

With the increasing interest in adopting new technologies in crop production, more questions are facing the researchers and agricultural technologies developers about how much the farmer knows about hydroponics, will the farmer accept and adopt soilless culture (hydroponic technology), and what are the challenges that hinder the switch from traditional cultivation to the new modernized cultivation technology?

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Therefore, this study aims to evaluate vegetables farmers' experience with soilless culture (hydroponics technology) in Jordan. The focus of this study was to evaluate Jordanian farmers' awareness, acceptance, and perceived challenges toward adopting hydroponics systems as a sustainable agriculture method. The results from this study will provide intrinsic points that can be used to overcome farmers' fears and challenges to adopting hydroponic cultivation technologies.

2. MATERIALS AND METHODS

A survey was conducted in the period from March to August 2022. The study sample included farmers from Jordan Valley- Deir-Alla region; who produce vegetable under protected greenhouse. A valid survey questionnaire was used, and the survey questions were reviewed by experts for content validity. The questionnaire consisted of three domains: farmers' awareness, acceptance, and challenges to adopting hydroponics-soilless culture for vegetable production. The questionnaire followed a 5-Likert scale where strongly agree = (5), agree = (4), neutral = (3), disagree = (2), and strongly disagree = (1). The composite scores for awareness, acceptance, and challenges were the average of ten, twelve, and ten questions, respectively. The test of validity confirmed an acceptable level of reliability with a Cronbach's score of (0.830). The survey questionnaire was sent to farmers through electronic application messages, and through site visits when electronic communication was not possible. The sample size was calculated, n=196 farmers. A total of 157 farmers responded to the survey within the period of the study so the response rate was 80%.

2.1 Statistical Analysis

The categorical variables were presented as frequency and proportions and continuous variables were presented as mean and standard deviation. Pearson's correlation coefficient was used to find the correlation between age, years of experience, and farm size, knowledge or training on hydroponics, and total scores of awareness, acceptance, and challenges. Spearman's correlation coefficient was used to find the correlation between educational levels, farm ownership, cultivation method, type of work on the farm, soil problems, previous awareness or training on hydroponics, and total scores of awareness, acceptance, and challenges. One-way analysis of variance (ANOVA) was performed to address farmers' awareness, acceptance, and challenges toward hydroponics at different levels of sociodemographic characteristics. Kolmogorov-Smirnov test of normality was performed. All data were compiled using Microsoft Excel 2010 [Microsoft Ltd., USA] and data were analyzed using SPSS 20.0 version [IBS Ltd., USA]. The statistical significance was fixed at a p-value < 0.05.

3. RESULTS

3.1. Socio-demographic characteristics

In this study, 157 responses from the farmers we evaluated, the participant age average was 38.2 ±10.2 (range from 22-60) years, and most of participants were in the age group 31-40 years old. About 57.3 % of the respondents hold a university degree bachelor's). Among 157

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participants 29.9 % have more than 15 years of experience in the agriculture field. Of the total farmers who responded to the survey, about 79% reported that their farm is from 1-100 dunum. Farmers reported different problems in their soils that impacted their vegetable production, about 36.9 % reported soil salinity, and 29.9% reported soil disease in their soils. Most of the participants (69.4%) reported that they didn't receive previous awareness or training about hydroponics and only 30.6 % did. The means of the total score for awareness, acceptance and challenges are shown in **Table -1.**

Table 1: Distribution of socio-demographic and mean total scores of Awareness, acceptance, and challenges among the participants

Socio-demographic Variables	No. of Participants (n)	Percentage (%)
Age – Groups (years)		
21 – 30	46	29.3
31 – 40	49	31.2
41 – 50	46	29.3
> 50	16	10.2
Age (in years) Mean ± SD	38.2 ±10.2 (22-60)	
Educational Level		
High school/ or less	38	24.2
Diploma degree	11	7.0
Bachelor's degree	90	57.3
Graduate degree	18	11.5
Years of Experience (years)		
1-5	42	26.8
6-10	40	25.5
11-15	28	17.8
> 15	47	29.9
Soil Issues		
Soil pH	6	3.8
Soil Pest	47	29.9
Soil EC	58	36.9
others	46	29.3
Farm Size Groups (Dunum)		
1-100	124	79.0
101-200	10	6.4
201-400	11	7.0
> 400	12	7.6
Previous awareness/training about hydroponic		
Yes	48	30.6
No	109	69.4
Survey Domains		
Awareness Total Score (10 Questions)	39.4±5.8	
Acceptance Total Score (12 Questions)	48.7±5.8	
Challenges Total Score (10 Questions)	39.1±4.7	

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3.2. Age effect on awareness, acceptance, and challenges total score

In this section the scores from the survey for all domains were calculated and compared among different age groups (by years). The participant's age was classified into four groups in years as shown in table -1. The average scores for awareness, acceptance, and challenges in all age groups and the comparison of means are shown in **Table-2**.

Table 2: Comparison of means between total scores of awareness, acceptance, and challenges with age groups:

	Age – Groups (Years)	N	Mean	Std. Deviation	95% Confidence Interval for Mean		p-value
					Lower Bound	Upper Bound	
Awareness Total Score	21-30	46	41.2	5.0	39.7	42.7	0.08
	31 - 40	49	39.0	5.4	37.5	40.6	
	41 - 50	46	38.4	6.4	36.5	40.3	
	>50	16	37.9	6.7	34.4	41.5	
Acceptance total score	21 - 30	46	49.0	5.3	47.4	50.6	0.941
	31 - 40	49	48.7	5.3	47.2	50.3	
	41 - 50	46	48.7	7.0	46.5	50.6	
	>50	16	47.9	5.6	44.9	50.9	
Challenges total score	21 - 30	46	39.9	4.8	38.4	41.3	0.314
	31 - 40	49	39.4	5.1	38.0	40.9	
	41 - 50	46	38.3	4.5	37.0	39.6	
	>50	16	38.1	3.0	36.5	39.7	

Mean comparison between total scores of awareness, acceptance and challenges with age groups was not statistically significant with p-value >0.05. In awareness domain, the highest score was for farmers with 21 – 30 years old (41.2±5) and the lowest score was for farmers >50 years old (37 ± 6.7).

For the correlation between age and the mean scores of all three domains. Awareness mean score showed negative correlation (r)= -0.169 with statistical significance at p value = 0.03 (<0.05), while acceptance mean score showed negative correlation (r)= -0.025 with no statistical significance at p value = 0.75 (>0.05), and challenges mean score showed negative correlation (r)= -0.151 with border line statistical significance at p value = 0.052 (≥ 0.05).

3.3. Effect of educational level on awareness, acceptance, and challenges total score

Scores for all domains were calculated and compared among participants educational levels. The participants were classified into four groups as shown in Table 1. Educational levels were high school or less, diploma degree, bachelor degree, and graduate degree. The mean comparison between educational levels and total scores of awareness, acceptance and challenges showed no statistically significance with p-value >0.05 as shown in **Table-3.**

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Table 3: Comparison of means between total scores of awareness, acceptance, and challenges with educational Levels:

	Educational Level	N	Mean	Std. Deviation	95% Confidence Interval for Mean		p - value
					Lower Bound	Upper Bound	
Awareness Total Score	High school/ or less	38	38.4	6.1	36.4	40.4	0.643
	Diploma degree	11	40.5	7.02	35.7	45.2	
	Bachelor's degree	90	39.5	5.7	38.3	40.7	
	Post-Graduate degree	18	40.1	5.3	37.4	42.7	
Acceptance total score	High school/ or less	38	48.7	5.6	46.9	50.5	0.594
	Diploma degree	11	47.6	7.2	42.8	52.5	
	Bachelor's degree	90	49.1	5.9	47.9	50.3	
	Post-Graduate degree	18	47.2	5.4	44.6	49.9	
Challenges total score	High school/ or less	38	40.0	4.7	38.4	41.5	0.508
	Diploma degree	11	38.5	5.2	35.0	41.9	
	Bachelor's degree	90	39.0	4.4	38.0	39.9	
	Post-Graduate degree	18	38.2	5.3	35.5	40.8	

Mean comparison between total scores of awareness, acceptance and challenges with educational levels was not statistically significant with p-value >0.05. In awareness domain, the highest score was for farmers with diploma degree (40.5±7.02) and the lowest score was for farmers with high school or less (38.4±6.1). In the acceptance domain, the highest score was for farmers with bachelor's degree (49.1±5.9) while in the challenges domain, the highest score was for farmers high school or less (40±4.7) and the lowest score was for farmers with post graduate degree (38.2±5.3).

For the correlation between educational levels and the mean of the three domains total scores; awareness mean score showed positive correlation (r)= 0.048 with no statistical significance at p value = 0.55 (>0.05), while acceptance mean score showed a negative correlation (r)= -0.013 with no statistical significance at p-value = 0.87 (>0.05), and challenges mean score showed negative correlation (r)= - 0.074 with no statistical significance at p-value = 0.36 (>0.05).

3.4. Years of experience effect on awareness, acceptance, and challenges total score

In this section the scores from the survey for all domains were calculated and compared among different farming experience levels (by years). The participant's experience was classified into four groups in years as shown in table -1. The average scores for awareness, acceptance, and challenges are shown in **Table-4**.

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Table 4: Comparison of means between total scores of awareness, acceptance, and challenges with years of experience

	Farming Experience Level (Year)	N	Mean	Std. Deviation	95% Confidence Interval for Mean		p - value
					Lower Bound	Upper Bound	
Awareness Total Score	1-5	42	39.2	5.3	37.6	40.9	0.819
	6-10	40	39.3	6.1	37.4	41.3	
	11-15	28	38.7	5.4	36.6	40.8	
	> 15	47	40.0	6.3	38.1	41.8	
Acceptance total score	1-5	42	49.4	5.1	47.8	50.9	0.257
	6-10	40	47.2	5.6	45.4	49.0	
	11-15	28	48.4	5.7	46.2	50.6	
	> 15	47	49.5	6.7	47.5	51.4	
Challenges total score	1-5	42	39.6	3.8	38.4	40.7	0.710
	6-10	40	38.7	5.1	37.1	40.4	
	11-15	28	38.4	5.0	36.5	40.4	
	> 15	47	39.3	4.8	37.9	40.8	

Mean comparison between total scores of awareness, acceptance and challenges with years of experience was not statistically significant with p-value >0.05. In awareness domain, the highest score was for farmers with more than fifteen years of experience (40.0±6.3) and the lowest score was for farmers with 11-15 years of experience (38.7±5.4). In the acceptance domain, the highest score was for farmers with more than 15 years of experience (49.1±5) while in the challenges domain, the highest score was for farmers 1-5 years of experience (39.6±3.6) and the lowest score was for farmers with 11-15 years of experience (38.4±5.0).

Correlation between experience levels and the mean scores of the three domains; awareness mean score showed positive correlation (r)= 0.054, 0.31, and 0.015 respectively with no statistical significance at p value = 0.55, 0.69, and 0.85 respectively (>0.05).

3.5. Farm size effect on awareness, acceptance, and challenges total score

In this section the scores from the survey for all domains were calculated and compared among farm size. For farm size participant's response was divided into 4 groups as shown in Table - 1.

The mean comparison between total scores of awareness, acceptance and challenges with farm size was not statistically significant with p-value >0.05. For farm size: in awareness domain, the highest score was for farmers working in farm size 101-200 dunum (40.8± 3.9) and the lowest score was for farmers working in farm more than 400 dunum (38.7± 7). In the acceptance domain, the highest score was for farmers working in farm with more than 400 dunum (49.8±5.4), while in the challenges domain, the highest score was for farmers working in farm more than 400 dunum (40±3.4) and the lowest score was for farmers working in farm with 1-100 dunum (38.9± 4.7).

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3.6. Effect of farmers' previous knowledge or training about hydroponic on awareness, acceptance and challenges total score

In this section the scores from the survey for all domains were calculated and compared among farmers for awareness and training on hydroponics. The participant's response was classified into two groups as shown in table -1. The average scores for awareness, acceptance, and challenges are shown in **Table-5**.

Table 5: Comparison of means between total scores of awareness, acceptance, and challenges with knowledge or training about hydroponic:

	Previous knowledge/ training about hydroponic	N	Mean	Std. Deviation	95% Confidence Interval for Mean		p - value
					Lower Bound	Upper Bound	
Awareness Total Score	No	109	38.0	5.6	36.9	39.0	**2.32E-06**
	Yes	48	42.6	5.0	41.1	44.0	
Acceptance total score	No	109	47.7	5.2	46.7	48.7	**0.002**
	Yes	48	50.8	6.7	48.9	52.8	
Challenges total score	No	109	39.3	4.4	38.5	40.1	0.394
	Yes	48	38.6	5.2	37.1	40.1	

Means comparison between total scores of awareness and acceptance with farmers previous knowledge or receiving any previous training on hydroponics technologies was statistically significant with p-value (<0.05).

In the awareness domain, the highest score was for farmers who have previous training on hydroponic or previously knew about the hydroponics technology (42.6±5) and the lowest score was for farmers who didn't have previous knowledge on hydroponic or received training this technology (38±5.6). In the acceptance domain, the highest score was for farmers who have previous knowledge and training on hydroponic technology (50.8±6.7), while the lowest score was for farmers who didn't have any previous knowledge and training on hydroponic technology (47.7±5.2). Mean comparison between total scores of challenges with knowledge or previous training on hydroponic was not statistically significant with p-value >0.05.

For the correlation between knowledge or previous training on hydroponic mean and the three domains; awareness total score mean showed positive correlation (r)= 0.363 with high statistical significance at p value = 0.00 (<0.05), also acceptance total score mean showed positive correlation (r)= 0.218 with high statistical significance at p value = 0.006 (<0.05), however, challenges total score mean showed negative correlation (r)= - 0.093 with no statistical significance at p value = 0.25 (>0.05).

4. DISCUSSION

Maintaining food security and achieving sustainable agricultural are receiving great interest around the world and thus require the adoption of new and effective techniques in vegetable and crop production. In this study about 68.8 % of the respondent have a minimum bachelor's degree or higher, and that can positively reflect the role that academic programs to increase

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awareness toward the importance in adopting and accepting soilless culture techniques in the near future.

Farmers were somehow concerned about the challenges if they switch their business from traditional greenhouse farming to high technology greenhouse. High initial cost for construction of hydroponic systems in greenhouse (Tyson et al., 2004), installation of climate control monitor system (Hochmuth and Hochmuth, 2001b), and high-level management for maintaining hydroponic systems inside greenhouse (Shaw et al. 2001) are among the cited concerns. These factors may hinder the farmers acceptance to transfer from low- cost greenhouse production to fully controlled greenhouse cultivation.

Our current study indicated that 69.4% of the farmers have prior knowledge about soilless culture – hydroponic technology, results also showed significant positive correlation between previous knowledge or training. These indicators showed good acceptance scores, and lower challenges score and that can be explained by the good knowledge and the hard work that start with basic educational concepts and practical workshop that is wildly utilized around the country starting from universities, in addition to non-governmental organization specialized in agricultural activities, and the private sectors (supplier and field experts). Highlighting farmer's awareness of soilless culture and changing the way of delivering the knowledge can easily increase the acceptance and adoption rates of new techniques (Cahapay,2020).

In this study 70.6% of the farmers reported factors affecting their soil productivity, 36.9% reported soil salinity as a challenge and 29.9% reported that soil pests were a serious issue in their production system. Because of these main challenges regarding soil health and continuous production growing different crops in soilless culture nowadays is receiving strong attention to be a foundation for future plant production depending on research and practical applications. (Fussy and Papenbrock., 2022). In soilless culture, plants grow in controlled environment, where soil pest can be easily reduced and therefore production losses is also reduced (Texier, 2015).

Limitations of the Study

This is a survey questionnaire study that is not free of limitation. It is an observational, opinion-based study that can alter the quality of the results. In this study participation was voluntarily, majority of the respondents were, middle aged (21-50 years old), with higher educational levels. Universities and non-formal educational institutions should participate and have an important role in delivering the right knowledge for farmers who were not aware of hydroponic technologies and somehow convince them to adapt to the new era of modern agriculture technology needed around the country.

5. CONCLUSION

This study reported the awareness, acceptance and challenges expressed by the farmer in Jordan Valley- Der- Alla. The goal of this study was ultimately towards increasing awareness and improving the acceptance rate of farmer toward adopting newly modernized agriculture technologies. The results indicated a satisfactory awareness, positive acceptance of adopting

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the technology, and acceptable perception of challenges associated with the transfer from traditional cultivation methods to the controlled high technology. Academic and educational institutions may utilize this information for further planning of their curriculum for their study plan in the future which will increase the quality of graduated students who work hand by hand in the field with farmers.

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References

1) Abdel-Aziz, N.G., Mazher, A.A., Farahat, M.M., 2010. Response of vegetative growth and chemical constituents of Thuja orientals L.to foliar application of different amino acid at Nubaria. J.Am.Sci. 6(3), 295-303.

2) Butler, J.D., Oebker, N.F., 2006. Hydroponics as a Hobby Growing Plants Without Soil. Circular 844. Information Office, College of Agriculture, University of Illinois, Urbana, IL61801.

3) Cahapay, M. B., 2020. Rethinking education in the new normal post-covid-19 era: A curriculum studies perspective. Aquademia, 4(2), ep20018. https://doi.org/10.29333/aquademia/8315.

4) Caputo, S., Rumble, H., Shaefer, M., 2020. "I like to get my hands stuck in the soil": A pilot study in the acceptance of soil-less methods of cultivation in community gardens. J Clean Prod. 258. p. 120585. ISSN: 0959-6526.

5) FAO. 2022. World Food and Agriculture – Statistical Yearbook 2022. Rome.

6) Belhaj, F., Soliman, A., 2021. MENA Has a Food Security Problem, But There Are Ways to Address It. https://www.worldbank.org/en/news/opinion/2021/09/24/mena-has-a-food-security-problem-but-there-are-ways-to-address-it.

7) Fussy, A., Papenbrock, J., 2022. An Overview of Soil and Soilless Cultivation Techniques—Chances, Challenges and the Neglected Question of Sustainability. Plants 11, 1153. https://doi.org/10.3390/plants11091153.

8) Gonnella, M., Renna, M., 2021. The Evolution of Soilless Systems towards Ecological Sustainability in the Perspective of a Circular Economy. Is It Really the Opposite of Organic Agriculture? Agronomy. 11, 950.

9) Hochmuth, R., Hochmuth, G. J. 2001b. A decade of change in Florida's greenhouse vegetable industry: 1991-2001. In Proc. Fla. State Hort. Soc., 114, pp. 280-283.

10) Jones Jr, J.B. 2012. Hydroponics: Apractical guide for the soilless grower. New York: CRC press.

11) Lee-Smith, D. 2010. Cities feeding people: An update on urban agriculture in equatorial 684 Africa. Environ Urban. 22(2), 483-499.

12) Gumisiriza, M. S., Kabirizi, J. M.L., Mugerwa, Micheal., Ndakidemi, P. A., Mbega, E. R., 2022. Can soilless farming feed urban East Africa? An assessment of the benefits and challenges of hydroponics in Uganda and Tanzania, Environ Chall. (6). doi.org/10.1016/j.envc.2021.100413.

13) Nalwade, R., and Mote, Tushar., 2017. "Hydroponics Farming", International Conference on Trends in Electronics and Informatics ICEI 2017.

The Seybold Report
ISSN 1533-9211
DOI: 10.5281/zenodo.10817306

14) Rockström, J., Karlberg, L. 2017. The Quadruple Squeeze: Defining the safe operating space for freshwater use to achieve a triply green revolution in the Anthropocene. AMBIO J. Environ. Soc. 39, 257–265.

15) Pivoto, D., Barham, B., Waquil, P.D., Foguesatto, C.R., Corte, V.F.D., Zhang, D., Talaminic, E. 2019. Factors influencing the adoption of smart farming by Brazilian grain farmers. Int. Food Agribus. Manag. Rev. 22, 571–588.

16) Sardare, M. 2013. A review on plant without soil-hydroponics.2013. Int J Adv Res Sci Eng Technol. 2: 299-304.

17) Shaw, N. L., Cantliffe, D. J., Taylor, B. S. 2001. Hydroponically produced 'Galia' muskmelon What's the secret. In Proc. Fla. State Hort. Soc, 114: 288-293.

18) Texier, W. 2015. Hydroponics for Everybody - All about Home Horticulture. Mama Publishing, English Edition, Paris, pp. 235

19) Tyson, R., Hochmuth, R., Lamb, E., McAvoy, E., Olczyk, T. Lamberts, M. 2004. Greenhouse vegetables in Florida's mild winter climate-2004 update. Acta Horticulture, 659, 37-40.

20) Wheeler, T., Von Braun, J. 2013. Climate change impacts on global food security. Science 756 341(6145), 508-513.