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Pest Risk Analysis and Management Practices for Increasing Profitability of Lemon Production

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Authors' contributions

This work was carried out in collaboration among all authors. Author SH and MEH designed the study. Author SH performed the statistical analysis, literature searches, wrote the protocol, and first draft of the manuscript. Authors MEH, MSIA, MZA, MZH and MRI edited and improved the draft manuscript. All authors read and approved the final manuscript.

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ABSTRACT

The study aimed at assessing the pest risk and management practices of lemon production and its profitability in Tangail district of Bangladesh. Household survey was conducted by an interview schedule from 120 lemon growers who were selected as sample respondents following a proportionate random sampling technique. Lemon butterfly and dieback disease were identified as important problems in lemon cultivation. Lemon butterfly was found with the highest infestation in Elachi lemon (70.0%) and Kagozi lemon (57.0%). Dieback disease was found with the highest infestation rate of 49.3% in Elachi lemon, 38.0% in Kagozi lemon, and 33.3% in Sakara-2 variety. Almost 82.5 percent of the respondents had medium to high adoption of pest management practices. The adoption of pest management practices was positively related to the profitability of lemon cultivation. However, there is further scope to make pest management practices sustainable by enhancing the adoption of biological, cultural, and mechanical approaches.

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1. INTRODUCTION

Citrus plants are encompassed in the family Rutaceae. This is well known for its regenerative fragrance, thirst-mitigating ability, and dietary allowance, providing the recommended adequate vitamin C [1]. *Citrus* lemon is an evergreen, small, medium-size plant that are cultivated in the tropical and subtropical regions [2]. It is also distributed widely throughout the Arab World and Mediterranean region [3]. Lemon is eaten alone as fresh fruit and also processed into juice, or added to dishes and beverages [4]. Lemon trees are grown in truly subtropical climates of the world. Lemon fruits grow well between temperature ranges of 13°C to 37°C. Temperatures below – 4°C is injurious for the juvenile plants. The best season of planting is June to August. As a group of several species, *Citrus* fruit is the most widely produced fruit and is grown in over 80 countries [1].

Citrus fruits include oranges, lemons, limes, tangerines, grapefruits, satsumas and pomelos. The *Citrus* fruits comprise compounds called flavonoids, which may have anticancer properties. Studies show that *Citrus* flavonoids may raise blood flow through coronary arteries, reduce the ability of arteries to form blood clots, and obstruct the oxidation of low-density lipoprotein (LDL) ("bad") cholesterol, which is a primary step in the formation of artery plaques [5]. Lemon is very important in respect of its nutritional values especially in Vitamin C [6]. The daily requirement of vitamin C is 30 mg per person. It was reported that 90.0% of the people of Bangladesh are suffering from vitamin C deficiency [7]. Lemon can solve this Vitamin C deficiency partially. It also contains some organic compounds, which work against asthma, antidepressant, stress relief, aids digestion, colds, flu, fever, nosebleeds, mouth ulcers, throat infection and boils [6]. In Bangladesh, about 69132 M. tons of lime and lemon are grown annually [8]. In 2019, *Citrus* fruit production for Bangladesh was 165,327 tons [9]. In recent years, there is a steady increase in *Citrus* production in Bangladesh. From 1992 to 2002, yearly *Citrus* production of the world grew at a rate of 2.3% and yearly all types of *Citrus* production are over 110 million tons covering an area of nearly 18.7 million acres among those around 13.7 million tons are lemon and limes [10]. *Citrus* fruit production of Bangladesh increased from 23,513 tonnes in 1970 to 165,327 tonnes in 2019 growing at an average annual rate of 5.06% [9].

Pest risk analysis (PRA) provides the fundamental principle for phytosanitary measures for a specified area. It assesses scientific standards to determine whether an organism is a pest [11]. If so, the analysis assesses the chance of spreading and introduction of the pest and the magnificence of potential economic consequences in a specific area, using biological or other scientific and economic standards. The PRA process consists of three stages: Stage 1- Initiation, The identity of the pest or pathways being analysed and the area in relation to which the analysis is conducted (the pest risk analysis area) is provided in the initiation stage. Stage 2- Pest risk assessment. There are three steps to the assessment of pest risk, which are i) pest categorization, ii) assessment of pest entry, establishment and spread, iii) Assessment of potential consequences resulting from pest entry, establishment and spread. Stage 3- Pest risk management. Pest risk management is the process of evaluation and selection of options to reduce the risk of introduction and spread of the pest [11].

Although Bangladesh is an important center of origin, especially for lemon and lime, the overall production is not satisfactory and cannot fulfill the country requirement. Among the factors responsible for low production and also low fruit quality, insect pests are of major concern. Ebeling [12] listed 823 species of insects and mites reported on *Citrus* trees around the world. In India, 250 species of insects have been reported on various *Citrus* species. Batool et al. [13] reported that *Citrus* diseases has founded as probable denunciation to the production of *Citrus* globally. Important insect-pests of lemon are the leaf miner (*Phyllocnistis citrella* St.), the *Citrus* thrips (*Scirtothrips dorsalis* Hood), the bark eating caterpillar (*Indarbela quadrinotata* Walker), scale insects (*Aonidiella citrina* Coq.), mites (*Panonychus citri*), the fruit fly (Bactrocera dorsalis Hendel) etc. According to Patel and Patel [14] temperature helped psylla population while leaf miner favoured mass of the weather factors but sunshine hours. Other pests such as nematodes (*Pratylenchus* sp.) and mealybugs (*Pseudococcus filamentosus* Cockrell) attacks *Citrus* (such as mandarins), especially in moist climates [12]. Where lemon butterfly (*Papilio demoleus* L) is distributed widely throughout East

Pakistan now Bangladesh [15]. *Citrus* aphid (*Toxoptera aurantii*) is found throughout the year in East Pakistan now Bangladesh [15]. According to Tariq et al. [16] production and quality of *Citrus* fruit become affected due to lack of information about control of diseases and plant protection measures.

To prevent this pest risks out of the track, farmers need to take some management practices. There are mainly four types of management practices such as cultural, mechanical, biological, and chemical. Cultural control skills address how someone cultivates plants and are conducted for reducing and avoiding pests. According to Ashraf et al. [17], disease free nursery usage; adjustment of transplantation, hoeing and weeding time; resistant varieties, and selecting well-adapted plants are some of example of cultural practices. Mechanical control directly removes or kills pests, or physically prevent insect pests from reaching their hosts using a barrier or trap [17]. Adoption of pruning and removing of disease plants, trapping pests, hand removal, and mulching are mechanical control practices [17]. Use of predators, parasitoids, and pathogens are some examples of biological control [17]. A large number of people consider chemicals do not have a space in IPM, but pesticides can be fit well into an IPM program when it is used responsibly. Yet, extensive use of chemical has caused the spread of resistant strains of phytophatogens, accommodate the effectiveness of the treatment [18]. Chemical pesticides may act as the last support for IPM program.

The majority of lemon varieties are grown abundantly in the country, although a few of them such as Eureka lemons, Femminello lemons are not yet widely cultivated. However, efforts are being made to increase the cultivation of those lemon varieties. Since Bangladesh is one of the most vulnerable countries experiencing bad consequences of climate change [19,20,21] it is essentially important to investigate the level

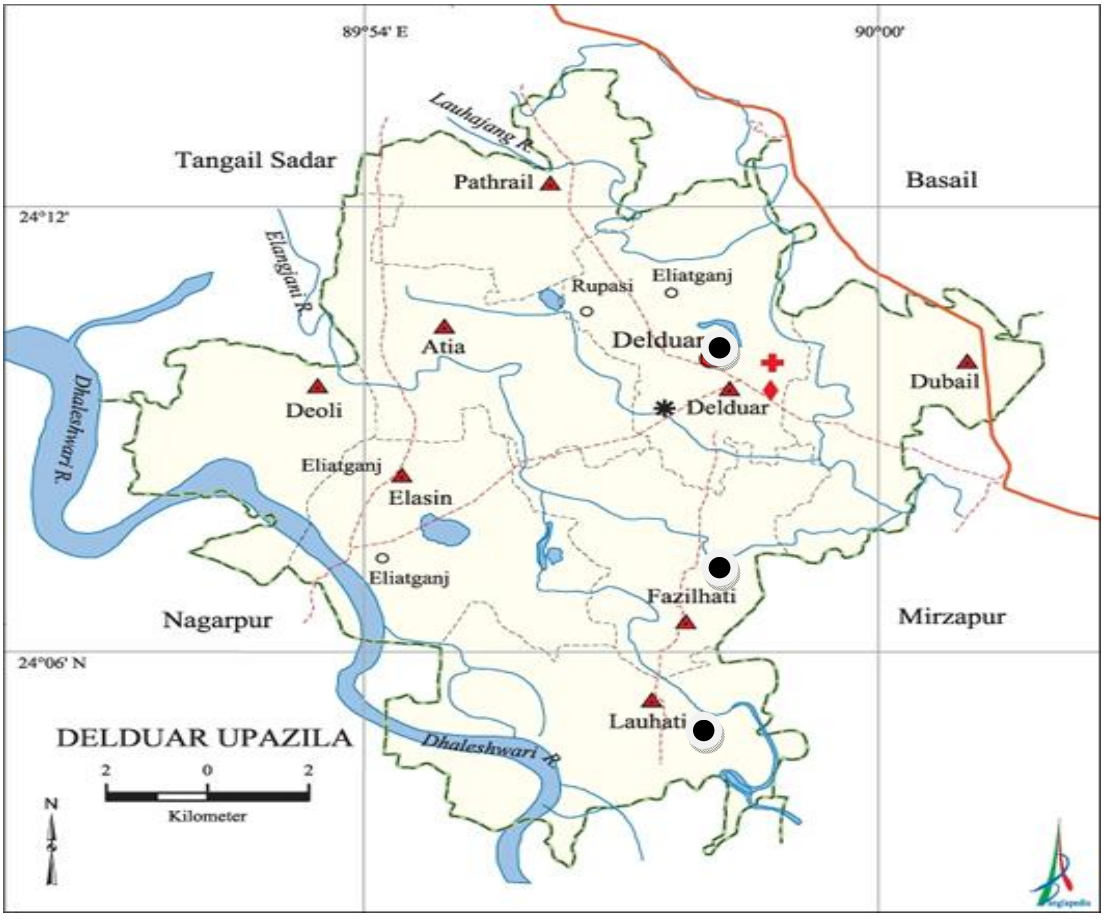

Fig. 1. Map showing Delduar upazila (●) indicating the study area [22]

of pest risks and their management at farmers' field for a better adaptation of different lemon cultivars with the changing environment. Hence this study focuses on various factors to conduct a pest risk analysis and suggest management practices aiming to increase the profitability of lemon production. The study aimed to (i) find out the management strategies practiced by the growers for controlling major lemon pests, and (ii) measure the impact of pest management practices on the profitability of lemon production.

2. MATERIALS AND METHODS

The study was conducted in Delduar Upazila under Tangail district which is located in between 24°05' and 24°14' north latitudes and in between 89°50' and 89°59' east longitudes [22]. The study area was selected because of the high intensity of lemon cultivation in Tangail district, a high level of extension activities such as training, technology transfer, and easy accessibility of the researcher to the study area. A map of Delduar Upazila (Tangail) has been presented in Figure 1.

Diagnostic and descriptive research design was followed in this study. All the lemon growers of the selected villages were the population of the study. Among them, 120 lemon growers were selected as sample respondents following the proportionate random sampling technique [23, 24]. Face to face interviewing by using a structured interview schedule was used to collect data [25].

Pest risks of lemon were measured on the principle of the nature of the pest, and their attack rates. Opinions about the intensity of pest attacks on different lemon varieties were collected and a score was assigned as '3' for frequent attack, '2' for occasional attack, '1' for rare attack and '0' for no attack. On the other hand, respondents' opinions about intensity of pests in different lemon varieties was measured using a summated rating i.e. 5 points Likert-type scale [26]. The total score of a respondent was attained by adding the individual score of each item which was then cumulated and classified into very high, high, medium, low and not harmful, and a score of 4,3,2,1, and 0 was assigned, respectively.

Management practices was measured on the principle of the use of different management strategies. A Four-point scale with their score as '4' for regular practice, '3' for frequent practice, '2' for occasional practice, '1' for rare practice was used. The total score of a respondent was calculated by adding the scores of each item. Among the four pest management practices, a rank order was prepared based on farmers' use.

After collection, all the raw data were then checked and cross-checked, compiled, coded, and entered into the computer for analysis and interpretation using Statistical Packages for Social Sciences (SPSS) software [27]. Various descriptive statistical measures such as range, mean, number and percentage distribution, and standard deviation were used to describe and interpret the data [24]. To test the differences among the three (low, medium and high) categories of adoption of pest management practices 'F-test' was employed. Throughout the study, a five percent (0.05) level of probability was used.

3. RESULTS AND DISCUSSION

3.1 Insect Pests Attacking Lemon

Respondents of the study area mainly cultivate five different Lemon varieties such as Elachi lemon, Satkara-2, Ada lemon -3, Jara lemon, and Kagozi lemon. They opined that leaf miner, lemon butterfly, stem borer, leaf folder, citrus whitefly, citrus fruitfly, thrips, citrus red scale, leaf roller, red mite, citrus mealybug, and aphids are some of the insect pests that hampering their lemon production Table 1.

The most frequently occuring important insect pest as opined by the repondents was lemon butterfly with highest infestation rate (70.0% in Elachi lemon and 57.0% in Kagozi lemon) in the two major cultivated varieties. The next important insect pest was leaf miner which caused 58.3 percent infestation in Elachi lemon and 55.0 percent in Kagozi lemon. Side by side 43.3 percent respondents found stem borer infestation in Elachi lemon and 30.0 percent respondent found aphid infestation in Kagozi lemon Table 1.

3.2 Diseases Attack on Lemon

The recorded diseases were dieback, canker, scab, black rot, *Citrus* greening, gummosis, and anthracnose Table 2. The most frequently occurring disease was Dieback with the highest infestation rate of 49.3% in Elachi lemon, 38.0% in Kagozi lemon and 33.3% in Sakara-2 variety. The next important identified disease was canker which infect in Elachi lemon and Kagozi lemon.

3.3 Intensity of Pests in Lemon Cultivation

Comparing with other field crops and horticultural crops lemon is less affected by the pest. But nowadays due to some adverse climatic conditions, both insect pests and diseases become a major threat to lemon production. For some pests the intensity was too high to cause total loss of yield while some pests' intensity was not that harmful. However, Elachi lemon and Kagozi lemon were found major cultivated varieties of lemon and found the higher intensity of attack on these varieties Table 3.

Table 3 revealed that majority (62.5%) of the farmers opined that the intensity of pest attack in Elachi lemon was high and 51.7 percent of them opined that the intensity of pest attack on Kagozi lemon also found high. It may be due to the higher commercial cultivation of those varieties compared to other cultivars. The more the cultivation of a variety in a certain area, the more was the acclimatization of a pest. That's why the intensity of pest in Elachi and Kagozi lemon varieties were found higher.

3.4 Management Practices in Lemon Cultivation

Pest management decisions affect the producer's profitability, as well as the environment. Preventing pest problems using the appropriate crop management program is often an economic alternative to pesticide use. Pest management is a complex process because producers must deal with various pest species at any given time. To mitigate the risk of these pests farmers took different management strategies. Some respondents were highly motivated to use all the management practices which are best suited to get rid of the pests. But, some of them did not take any initiative because of a lack of time and money.

Information presented in Fig. 2 showed that 67.5 percent respondents had medium adoption of pest management practices, which is interrelated to the respondence age and education. Because majority of the respondence were middle aged and had secondary level of education, while 17.5 percent of them had low adoption of management practices and 15.0 percent having high adoption of management practices. It was found that almost 82.5 percent of them had medium to high adoption of management practices which lead them to make a profit from lemon cultivation having good yield.

Results presented in Table 4 showed that highest percentage (79.1) of respondents used chemical control measures, which stood rank first. Because the chemical control method is not time consuming as compared to the others method as well as it takes rapid action and in most cases farmers focus on crop yields rather than crop quality control. Though physical control

Table 1. Status of insect pest's attack in different lemon varieties

Serial no	Name of variety	Name of insect pests	Insect attack (% respondent opined)
01	Elachi lemon	Stem borer	43.3
		Leaf miner	58.3
		Lemon butterfly	70.0
		Leaf folder	25.8
02	Satkara-2	citrus whitefly	33.3
		citrus mealybug	16.6
		Stem borer	18.8
03	Ada lemon-3	citrus fruit fly	19.1
		Thrips	14.1
		Red mite	12.5
04	Jara lemon	citrus red scale	19.1
		citrus leaf folder	19.1
05	Kagozi lemon	Lemon butterfly	57.0
		Leaf miner	55.0
		Leaf roller	15.0
		Aphid	31.5
		Orange bug	18.6

measure was less expensive than the other methods 72.5 percent respondents used it. Nobody used biological control measures as they did not know the procedure of utilizing biological control measures.

Farmers used different chemicals against different pests. When a pesticide was applied within a few days the pests develop resistance against the pesticide. So, a particular pesticide does not work against the pest after some time. Then the experts suggested new formulations. To get rapid action against pests, farmers mixed two or more different chemicals and apply it to the plant. They apply different pesticides at high doses to get rapid action against pests though it is harmful to the environment. Therefore, the numbers of chemicals used by the farmer are higher. As shown in Table 5 almost 80 percent of respondents used 'Thiovit' followed by 73.33 percent used 'Tilth', 60.00 percent of them used 'Ripcord', and so on.

Along with chemical control measure respondents were used several physical control measures such as pruning, hand picking, removal of diseased plant, cutting of branches and use of ash. As shown in Table 6 more than 80 percent of respondents used 'removal of diseased plant' followed by 72.5 percent of them used 'pruning', 53.3 percent of them practiced 'cutting of branches' and so on. It revealed that 'removal of diseased plant and 'pruning' were extensively used in controlling the pest in lemon.

Side by side, farmers were also attentive about the use of cultural practices for pest management in lemon. Majority of respondents (64.1%) used to keep 'healthy plants followed by 43.3 percent of them maintained 'cleanliness of field' and 35.8 percent of them cultivated 'resistant variety' Table 7.

3.5 Impact of Pest Management Practices on the Profitability

Pest management practices were taken to get higher profit from lemon cultivation. Since lemon production is highly sensitive to insect pests and diseases, farmers were eager to take proper management practices at an appropriate time to get rid of those pests and diseases. It is assumed that a farmer could make the highest profit when he took proper management practices.

Table 8 revealed that per hectare annual income of respondents from their lemon cultivation varied based on their adoption of management practices. Respondents who adopted high management practices earned Tk 101052 ha^{-1} $year^{-1}$ followed by medium adopters made Tk 61172 ha^{-1} $year^{-1}$ and low adopters earned Tk 40500 ha^{-1} $year^{-1}$. Computed F-value (34.19^{**}) exhibited significant differences among them at 1% level. So, it may be concluded that the higher the management practice taken by the respondents the higher was their profitability in lemon cultivation.

Table 2. Status of disease infection in different lemon varieties

Serial no	Name of variety	Name of disease	Disease attack (% respondent opined)
01	Elachi lemon	Dieback	49.3
		Canker	41.3
		Scab	20.0
		Black rot	25.8
02	Satkara-2	Dieback	33.3
		Citrus greening	16.6
		Scab	18.8
03	Kagozi lemon	Dieback	38.0
		Gummosis	16.6
		Anthracnose	12.3
		Black rot	31.5
		Canker	18.6

Table 3. Respondents' opinions about intensity of pests in different lemon varieties

Name of variety	Intensity of pest(% respondents opined)				
	Very high	High	Medium	Low	Not harmful
Elachi lemon	35.0	27.5	9.2	5.0	8.3
Satkara-2	16.7	18.3	14.2	5.8	3.3
Ada lemon -3	19.2	14.2	10.0	5.0	15
Jara lemon	16.7	10.8	24.2	10.0	4.2
Kagozi lemon	25.0	26.7	8.3	11.7	5.0

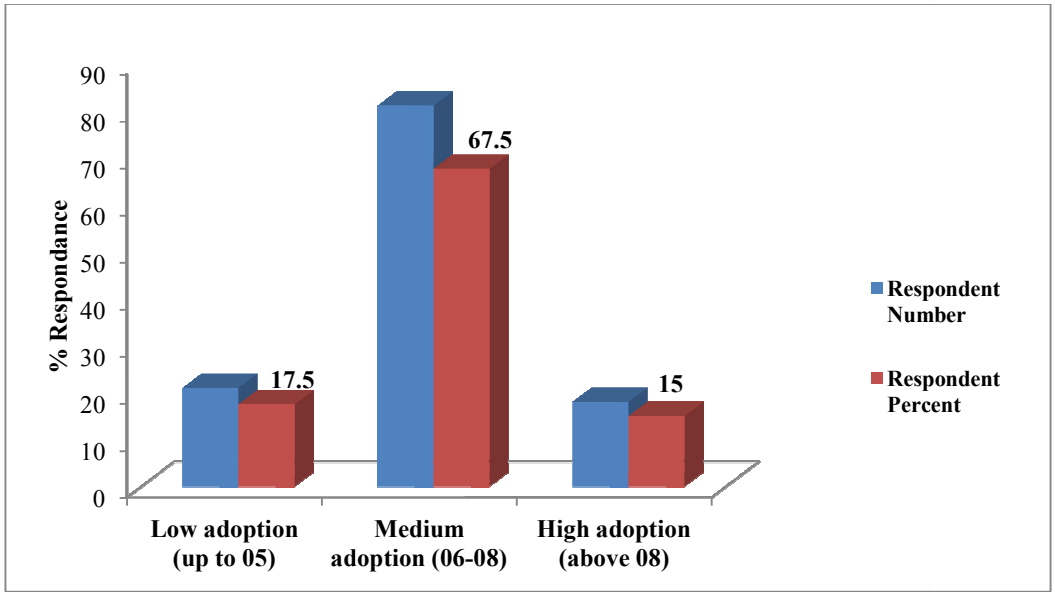

Fig. 2. Distribution of the respondent according to their adoption of pest management practices

Table 4. Distribution of the respondent according to their use of different pest management practices

Serial no.	Pest management practices	Number	Percent	Rank
01	Chemical control	95	79.1	I
02	Physical control	87	72.5	II
03	Cultural control	58	48.3	III

Table 5. Chemical methods used by farmers for different pest management

Serial no.	Name of the chemicals	Number	Percent
01	Bordeaux mixture	48	40.0
03	Thiovit	95	79.1
04	Actara	29	24.1
05	Malathion	36	30.0
06	Furadan	37	30.8

07	Ripcord	72	60.0
08	Dursban	29	24.1
09	Bavistin	56	46.6
10	Ridomil gold	41	34.1
11	Tilth	88	73.3
12	Indofil	30	25.0

Table 6. Physical methods used by farmers for different pest management

Serial No.	Physical methods used	Number	Percent
01	Pruning	87	72.5
02	Hand picking	23	19.1
03	Remove disease plant	97	80.8
04	Cutting of branch	64	53.3
05	Ash	48	40.0

Table 7. Cultural methods practiced by farmers for different pest management

Serial No.	Cultural methods used	Number	Percent
01	Healthy plant	77	64.1
02	Cleanliness of field	52	43.3
03	Resistant variety	43	35.8

Table 8. Respondents' annual income from lemon cultivation and their adoption levels of pest management practices

Categories	Annual income (Tk ha^{-1})	F- value
Low adoption of management practices	40500	34.19^{**}
Medium adoption of management practices	61172	
High adoption of management practices	101052	

*Note: ** p<0.01*

4. CONCLUSION

Elachi and Kagozi lemon were found the most widely cultivated varieties of lemon in the study area with high intensity of pest attack. Lemon butterfly, leaf miner, dieback, and canker were identified as major insects and diseases causing high risk for lemon cultivation. Regarding pest management, farmers mostly used chemical control measures along with some physical and cultural methods which means that farmers have not yet made full use of the IPM method. Nonetheless, the adoption of pest management practices had a significant impact on the

profitability of lemon cultivation. This means that the better the farmers' management practices, the more they get benefitted from lemon cultivation

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Ladaniya MS. *Citrus* fruit biology, technology and evaluation. Academic Press, San Diego, CA, USA. 2008;558.
2. Ismail M, Zhang J. Post-harvest *citrus* diseases and their control. Outlooks Pest Manage. 2004;15:29–35.
3. Julia F. Morton. "Lemon in Fruits of Warm Climates". Purdue University. 1987;160–168.
4. Spreen, Thomas H. "The Free Trade Area of the Americas and the Market for Processed Citrus Products." Paper to be presented at the 13th Intergovernmental Meeting on Citrus, Food and Agriculture Organization, Beijing, China, May, 2001.
5. Kozlowska A, Szostak-Wegierek D. Flavonoids--food sources and health benefits. Rocz Panstw Zakl Hig. 2014; 65(2):79-85.
6. Sfgate (2017). Do Lemons Provide Vitamin C Like Oranges Do? Available:http://healthyeating.sfgate.com/lemonsprovide-vitamin-c-like-oranges-do-3508.html, access on April 9, 2017.
7. BARC (Bangladesh Agricultural Research Council). Fruit production manual: Horticultural research and development project (FAO/UNDB/AsDB Project). Department of Agril Extension. 1995;225-231.
8. BBS. Statistical yearbook of Bangladesh. Bangladesh Bureau of Statistics, Ministry of Planning, Dhaka, Bangladesh; 2017.
9. Knoema. Bangladesh - *Citrus* fruit production quantity. Retrieved February 24,2021; 2019. Available:https://knoema.com/atlas/Bangladesh/topics/Agriculture/Crops-Production-Quantity-tonnes/*Citrus*-fruitproduction?fbclid=IwAR1W8II79SsOnr0IoXxrWpdRmD2xt9vEXo590mWEOiO6R6wW5eLhSC1Gw0w
10. Yara (2017). Crop nutrition: world citrus production, Available:http://www.yara.us/agriculture/crops/citrus/keyfacts/world-citrus-production/ access on April 9, 2017.
11. IPPC. International standards for phytosanitary measures, publication no. 5: Glossary of phytosanitary terms. Secretariat of the International Plant Protection Convention (IPPC). Food and Agriculture Organization of the United Nations, Rome, Italy; 2012.
12. Ebeling W. Sub-tropical fruit pests. University of California Press, Los Angeles. 1959;(123,138,147).
13. Batool AY, Iftikhar SM, Mughal MM, Khan MJ, Jaskani M, Abbas, et al. *Citrus* greening disease – A major cause of *Citrus* decline in the world – A review, hort. sci. (Prague). 2007;34(4):159–166.
14. Patel PS, Patel GM. Population dynamics of important pests of *Citrus*. *Citrus aurantifolia* Swingle. Indian J. Ent. 2006;68(3):255-259.
15. Alam MZ. Insect and mite pest of fruits and trees in east Pakistan and their control. East Pakistan Govt. Press, Department of Agriculture, Dacca. 1962;48-59.
16. Tariq M, Sharif M, Shah Z, Khan R. Effect of foliar application of micronutrients on the yield and quality of sweet orange (*Citrus sinensis* L.). Pak. J. Biol. Sci., 10: 1823-1828.
17. Ashraf S, Khan GA, Ali S, Iftikhar M, Mehmood N. Managing insect pests & diseases of *Citrus*: On farm analysis from Pakistan. Pakistan Journal of Phytopathology. 2014;26(2):301-307.
18. Palou L, Smilanick JL, Droby S. Alternatives to conventional fungicides for the control of *Citrus* postharvest green and blue moulds. Stewart Postharvest Rev. 2008;4:1–16.
19. Hoque MZ, Cui S, Xu L, Islam I, Tang J, Ding S. Assessing agricultural livelihood vulnerability to climate change in coastal Bangladesh. International Journal of Environmental Research and Public Health. 2019a;16(22):4552.
20. Hoque MZ, Cui S, Lilai X, Islam I, Ali G, Tang J. Resilience of coastal communities to climate change in Bangladesh: Research gaps and future directions. Watershed Ecology and the Environment. 2019b;1:42-56.
21. Nasim FA, Hoque MZ, Haque ME, Islam MS, Parveen N, Chakma S, Afrad MSI. How does adoption of crop variety reduce

the impact of drought in agriculture and mitigate food insecurity of smallholder farmers?. A case study on BUdhan1 rice variety in Bangladesh. Asian Journal of Agricultural Extension, Economics and Sociology. 20191-12.
22. Banglapedia. Delduar Upazila. Retrieved February 24, 2021; 2015. Available: http://en.banglapedia.org/index.php?title=Delduar_Upazila
23. Khalil MI, Haque ME, Hoque MZ. Adoption of bari recommended potato (Solanum tuberosum) varieties by the potato farmers of Bangladesh. The Agriculturists. 2013;11(2):79-86.
24. Saha S, Hasan SS, Haque ME, and Ahamed T. Perception based assessment of ecosystem services of Madhupur sal forest in Bangladesh. . European Journal of Agriculture and Food Sciences. 2021;3(1):39-44.
25. Hoque MZ, Rahman MA, Haque ME, Afrad MSI, Rahman MM. Comparative contribution of crops and homestead forest enterprises to rural household economy: A case study of Keshorita village in Bangladesh. Asian Journal of Advances in Agricultural Research. 2018;1-16.
26. Ghosh MK, Hasan SS. Farmers' attitude towards sustainable agricultural practices. Bangladesh. Research Publications Journal. 2013;8(4):227-235.
27. Barau AA, Naznin N, Haque ME, Zakaria M, Afrad MSI. Extent of adoption and knowledge on pesticide use in vegetable production in Narsingdi district, Bangladesh. Sri Lankan Journal of Agriculture and Ecosystems. 2020:2(1).

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