PAPER • **OPEN ACCESS**

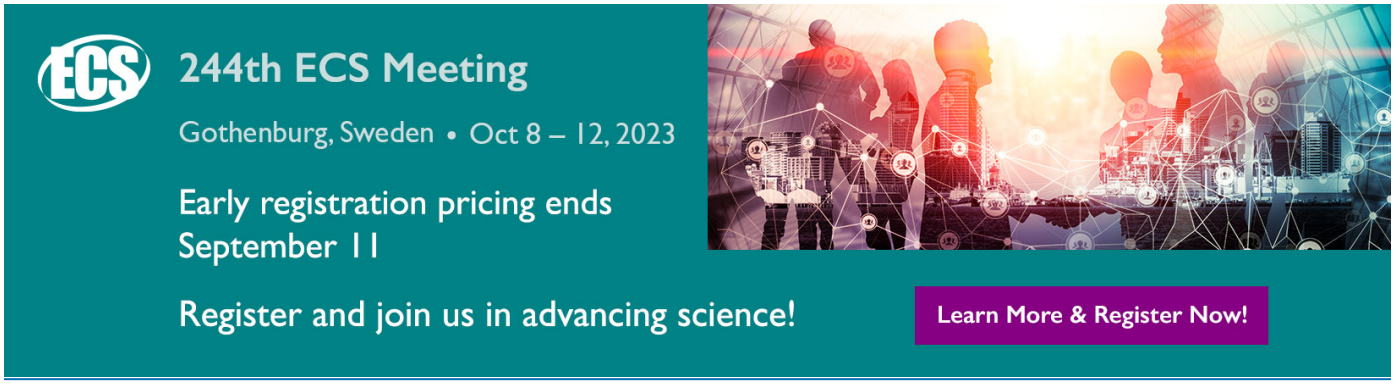
Controlling Strategies of Citrus to Increase The Yield in The Country: A step Towards The Fight Against COVID-19

To cite this article: Ghulam Abbas *et al* 2021 *IOP Conf. Ser.: Earth Environ. Sci.* **910** 012045

View the article online for updates and enhancements.

You may also like

- The Effect of Organic Fertilization on Leaf Mineral Content of Three Citrus Species
N. H. Khalil
- Identification of Morphological and Physiochemical Characteristics, Flowering Periods, and Genetic Relationship of Citrus Species
Hardiyanto, N. F. Devy and A. Sugiyatno
- Citrus fruit peels extracts as light harvesters for efficient ZnO-based dye-sensitized solar cells
Oluwaseun Adedokun, Olufunke Lydia Adedeji, Mojoyinola Kofoworola Awodele et al.



This content was downloaded from IP address 193.255.89.16 on 31/07/2023 at 11:29

Controlling Strategies of Citrus to Increase The Yield in The Country: A step Towards The Fight Against COVID-19

Ghulam Abbas [1], Duraid K.A. AL-Taey[2], Saad S.M.AL-Azawi[2], Mohammad Mehdizadeh[4], Razia A. M. Qureshi[3], Ammar K Jasman[2], Ali K Slomy[2], Mumtaz A. Khan[1], Makhdoom Abdul Jabbar[1], Asif Iqbal[1], Maria Arshad, Jalees Ur Rehman[1], Yusuf Konca[5], Muhammad Arshad[1] and Mehmood Ahmad[1]

[1]Riphah College of Veterinary Science, Riphah International University, Pakistan.
[2]Depratment of Horticulture Science ,Faculty of Agriculture, University of AL-Qasim Green, Iraq.
[3]Department of Physics University of Lahore, Pakistan.
[4]Department of Agronomy and Plant Breeding, Faculty of Agriculture and Natural Resources, University of Mohaghegh Ardabili, Iran.
[5]department of Animal Science , Faculty of Agriculture, University OF Erciyes, Turkey.

[1]Email: ghulamabbas_hashmi@yahoo.com

Abstract

Citrus (oranges, lemon, mandarin, limes and tangarines) has significant nutritional value in human foods. It is rich source of vitamin C, sugar, organic acids, amino acids, minerals like Ca, Mg and various other phytochemicals (flavonoids, hesperidin etc) compounds that are responsible for good health. Citrus is growing in more than one forty countries of the world including Pakistan, Brazil, China, Mexico, USA, Spain and India.Viral infection and inflammation triggers the production of oxygen free radicals and these radicals severely damage the cells, however hesperidin and vitamin C is reported to counteract these damages. Intake of plentiful citrus fruits is one of amongst the many possible approaches to prevent from COVID-19 role of nutrition. Citrus fruit are very rich in important substances with a potential beneficial for health such as modulating the immunity and in protecting cells from oxidative stress related with infection. Flavonoids and hesperidin two major key compound found in citrus have affinity to treat Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). Hesperidin has a low binding energy, both with the coronavirus "spike" protein, and with the fundamental protease that alters the primary proteins of the virus (pp1a and ppa1b) into the complex liable for viral replication hence these compounds could work as an antiviral function. Pakistan is amongst top ten citrus producers in the world. Citrus is one of the best commercial fruits of Pakistan cultivated on a large area, however, in Pakistan yield of citrus has been affected due to attack of insects and pathogens (nematode, fungal, bacterial and viral) which causes heavy losses both in quality and quantity. The purpose of this article is to focusing on the controlling the pathogens of citrus to boost citrus production in country as these beneficial plants are well known for its essential vitamin and flavonoid contents to control COVID-19 .

Keywords: Citrus, Insects, Nematodes, Fungus, Yield, COVID-19

1. Introduction

The agriculture sector plays vital role in Pakistan's economy. It contributes 18.9 % to Gross Domestic Production of Pakistan. Agriculture provides employment for 42.3% of the country's people, and 75% of rural population is dependent on agriculture in Pakistan (Pakistan economic survey 2017-2018). Citrus production is very important in Pakistan's agriculture industry, Citrus is one of the major fruit of the world due to its popularity and nutritional value in human foods. The generic name originated from Latin, where it specifically referred to the plant now known as Citron (*C. medica*), derived from the ancient Greek word for cedar (kedros) [1]. The commercially available citrus species are oranges, lemon, mandarin, limes and tangarines. Citrus fruits are grown in tropical and sub-tropical regions (35°N and 35°S) latitude in north [2,3]. Citrus is growing in more than one forty countries of the world. Main citrus growing countries of the world are Brazil, China, Mexico, USA, Spain and India. Pakistan stands among top ten citrus producing countries of the world (Source: FAOSTAT). Kinnow (*Citrus reticulate*)is the major species in Pakistan among other citrus species with 95% share. Punjab shares 94% and 96% in area and production of citrus, respectively [4,5].
Citrus is extreme necessity for human health because of its high nutritional value and a rich source of vitamin C, sugar, organic acids, amino acids and minerals like Ca and Mg. In Pakistan average yield is 2.36 million tonnes, grown over 199,000 hectares and having export of 282,000 tons per year and fetching 7,313 million rupees [6,7]. On the other hand the

Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.
Published under licence by IOP Publishing Ltd

potential yield of citrus is 12-15 tons per hectare and hence there is a big difference between its average and potential yield in Pakistan. It is because of the reason that citrus has been attacked by many insects and pathogens (nematode, fungal, bacterial and viral) causing heavy losses both in quality and quantity [8,9].

2. Effect of Nematodes on the Yield of Citrus Fruit

Citrus fruit nematodes are worm like, tapering on both ends and have all main well developed physiological systems except circulatory and respiratory system. Many different genera and species of nematodes are involved to infest citrus plant [10] These include Root-knot nematodes (*Meloidogyne spp*); Sting nematodes (*Belonolaimus spp.*); Stubby-root nematodes (*Trichodorus spp.*); Root-lesion nematodes (*Pratylenchus spp.*); Cyst nematodes (*Heterodera spp.*); Awl nematodes (*Dolichodorus spp.*); Stunt nematodes (*Tylenchorhynchus spp.*); Lance nematodes (*Hoplolaimus spp.*); Spiral nematodes (*Helicotylenchusspp; Scutellonema spp.*); Ring nematodes (*Criconemoides spp.*); Dagger nematodes (*Xiphinema spp.*); Bud and leaf nematodes (*Aphelenchoides spp.*); Reniform nematodes (*Rotylenchulus spp*); *Tylenchulussemipenetrans; Paratylenchus sp.; Psilenchus sp.; Radopholus sp.; Trichodorus sp.; Xiphinema sp.; Zygotylenchulussp; Longidorussp; Alamidsp; Araeolamidsp;Cephalobidsp; Diplogastridsp; Monhysteridsp; Mononchidsp; Plectus; Rhabditid* . Citrus nematode inflicts damage to over 50 species of citrus causing yield loss approximately 43.3% worldwide [11]. Plant parasitic nematodes have stylet which penetrates into host plant and punctures its tissues for the absorption of nutrients. These live in the soil and attack the roots of plants causing production problems occur as a result of root dysfunction, reducing rooting volume and foraging reducing efficiency of water and nutrients uptake. Plant parasitic nematodes possess non-segmented microscopic body with cylindrical shape. The host range of these nematodes, as with others, includes most if not all of the commercially grown vegetables within the state. Yield reductions can be extensive but vary significantly between plant and nematode species.

The first report of an association between a nematode and citrus was reported by [12]. *Tylenchulus semipenetrans* was discovered by Hodeges in 1912 on roots of citrus trees in southern California. The citrus root nematode (later referred to as citrus nematode) was first reported by Thomas in 1913. Cobb described *T. semipenetrans* as the causal agent of citrus slow decline in 1913. In Pakistan *T. semipenetrans* firstly reported in [13] . [14], reported citrus root nematode as major contributor of decline of citrus plantation after surveying the major citrus growing areas in Punjab. Several nematodes are beneficial for citrus i.e. associated with [15]. Few of these are of economic importance (*Tylenchulus semipenetrans*) causing 'slow decline' of citrus, whereas most nematode species may cause serious damages to mature citrus. Incidence of *Tylenchulus semipenetrans* can be reduced by spreading out/growing citrus into new geographical areas. Nematodes parasitism cause gradual reduction in tree quality so that infested trees are smaller over a long period, become less vigorous and may yield apparently less fruit [16]. Symptoms of nematodes infestation include poor root development, smaller chlorotic leaves, and slower development. However, in saline environment, undue sodium may accumulate in leaves [17] and wilting can occur earlier during periods of water stress. Loss of integrity at the epidermis and at feeding sites in the cortex causes feeder roots putrefy quicker resultantly attacked by secondary organisms [18] causing lesions on lightly infected roots, while heavy infections result in cortical sloughing and root death. The life cycle of *T. semipenetrans*is regulated by host phenology, interrelated with geographic variation and temporal changes in the soil environment. Many studies reported one [19], or three [20] distinctive periods of active population growth per annum.

The economic life of citrus trees in some countries is about fifty years and in some cases in good positions they can live 100 years. Due to its geographical location, climatic conditions and soil type, citrus population of Pakistan is more prone towards nematode infestation. In Pakistan, the normal age of citrus tree is considered to be 25 years. The reason is that citrus orchard, in majority of cases starts declining.*T. semipenetrans* infestation of citrus was first reported in Faisalabad (Punjab) in 1962 (Brown, 1962). According to different studies, estimated yield losses due to *T. semipenetrans* to be in the range of 10% to 30% depending on the level of infestation [21]. However, the nematode can be of great economic importance in orchards where the fruit has marketed fresh rather than processed as *T. semipenetrans* often reduces fruit size [22].

3. Symptoms of T. semipenetrans infestation

The disease caused by *T. semipenetrans* referred to a "slow decline" which showed the symptoms on citrus trees. There is continuous decline in growth of tree and reduction in fruit size. As the population of nematode increases in the soil and e roots, over all yields becomes low every year. When young trees were planted in land harshly infested with nematode, damage symptoms appeared more rapidly [23]. Leaves Of seriously infected trees showed deficiency of nutrients concentrations such as potassium, which showed the importance of fertilization [24]. During the time of water stress, fibrous roots were less abundant so that wilting occurred and dropping of leaves caused thinner tree canopies in high infested trees [25]. Feeder roots rotten faster due to damage of integrity at the epidermis and at feeding sites in the cortex, resulting in attack by secondary organisms [26]. This may be expressed as lesions on lightly infected roots, while heavy infections cause cortical sloughing and feeder roots became slightly thicker than healthy roots and showed a dirty appearance, due to soil

particles that adhere to gelatinous egg masses on the root surface. Symptoms depend on the favorable environmental conditions and cultural practices for citrus health. Infested trees under optimum conditions may seem healthy [27,28].

4. Effects of Other Pathogens on Citrus Fruit

These requirements involve pests of quarantine concern for the importing countries, which risks are diminished by the application of phytosanitary measures. Gamma radiations are used as sanitation treatment with no significant effect on fresh fruit quality. The Gamma radiations as quarantine treatment is a phytosanitary measure under the IPPC (International Plant Protection Convention), approved by an international standard, Viral Species Different viral species caused various illnesses in citrus plant. Citrus mosaic disease is caused by Satsuma dwarf-related virus [29,30] Bud union crease caused by Virus for some combinations; Citrus leaf rugose caused by Citrus leaf rugose virus (CLRV) [31]. Citrus yellow mosaic disease caused by genus *Badnavirus* [32,33]. Crinkly leaf and Infectious variegation is caused by Citrus variegation virus [34]. Navel infectious mottling caused by Satsuma dwarf-related virus whereas CPsV (Citrus psorosis virus) cause Psorosis and SDV (Satsuma dwarf virus) cause Satsuma dwarf [35-38]. Genus *Capillo* also known as Citrus tatter leaf virus cause Tatter leaf (citrange stunt) and CTV (Citrus tristeza virus) of genus Clostero virus cause Tristeza [39-41]. Control strategies for these viral diseases include evading or keeping out of these pathogens from the area. Use of certified bud wood, and/or eradication or suppression of these pathogens, use of tolerant or resistant cultivars and/or cross protection [42]. Cultural practices that reduce infection are also helpful to control viral diseases [43]. However success of control strategies depends on knowledge of the causal agent of the disease, symptoms and mode of propagation etc

5.Bacterial Species

Xanthomonas euvesicatoria pv. citrumelo, species of proteobacteria cause bacterial spot; *Pseudomonas syringae* cause Black pit (fruit) and Blast; *Xanthomonas citri pv. citri* cause Citrus canker ; Citrus variegated chlorosis is caused by *Xylella fastidiosa* and Huanglongbing is caused by *Candidatus Liberibacter asiaticus* and *Candidatus L. africanus* Bacterial spot of citrus plant caused by bacterium Xanthomonas alfalfa . Bacterium spreads tree to tree via wind-blown rain, dropping dew or overhead irrigation through natural pores on leaves and/or the lenticels on bark [44]. It affects mainly trifoliate orange and its hybrids. Pathological lesions formed are flat or sunken and not raised. Prevalence of pathogen is less when the weather is hot and dry. To control bacterial diseases preventive measures along with biological treatments are usually advised. Copper based sprays and/or application of spray together with oxytetracycline/streptomycin and/or the chemical mancozeb may be used to control the disease. However chemical sprays and medicines should always use within recommended prescribed dose to avoid damage to leaves and the development of resistance.

6. Fusarium Spp.

Citrus fruit begins to expose a critical period after harvest because numerous pathogens such as fungi (i.e. *Penicillium, Elsinoe spp.*) may cause fruit rots during this period [45]. Thirteen different types of fungi including *Fusarium spp., Penicillium sp., Curvuleria sp., Aspergillus spp., Alternaria sp., Guignardia sp. Diplodia sp. and Colletotrichum sp. Fusarium*spp are almost found in every region and is mostly soil born pathogen. It has been estimated to affect 11.6% of mandarin trees and caused 39.6% loss in fruit yield [46]. *F. solani* disease of citrus was reported to attack all citrus varieties [47,48].

Fusarium solani causes two types of diseases, dry root rot and chronic feeder root rot and both cause citrus slow decline [49]. Dry root rot of citrus caused by *F. solani*(Mart.) is one of the most serious diseases of citrus attack orchards especially that cultivated in new reclaimed lands. *F. solani* produces two types of root rots on citrus trees. Firstly, dry root rot limited to the crown and roots scaffold. Secondly fibrous and feeder root rots associated with continuing decline of the canopy, leaf curl like wilting, dieback, defoliation; Fibrous roots become soft, and seem like water soaked, slough their cortex easily by hand[50-53].

F. solani caused fibrous and scaffold root rot on citrus at various extents in the field [54-56]. *F. solani* entered the root system and the entire root turned reddish-purple to greyish-black [57]. The wood below the bark has no rottening but may be marked dark [58], and when the cross section of an infected trunk was examined a greyish-brown discoloration in the wood tissue could be detected [59]. Studies by [60,61], showed that the fungus caused on inoculated seedlings symptoms that are identical to those on field trees. On adult plants, the most conspicuous symptom above the soil level is a fatal collapse of the tree [62]; leaves suddenly wilt and dry up in a few days, remaining attached on the tree. Normally, the course of the disease is chronic and symptoms look like those provoked by other root rot agents. Trees showed a lingering decline, progressing for years, with the only initial symptoms being a slight wilt under dry conditions and poor vegetation flush [63]. At more advanced stage of the decline, the canopy has a thin and sparse appearance.

7. Interaction of Fusarium with Nematode

Fusarium has most important group of fungus because *Fusarium* caused many serious diseases of plants. Citrus roots which are infested with the nematode are also mostly infested with [64]. *T. semipenetrans* interacts with soil organisms which can regulate or influence *fusarium*spp. population. In fact, Walker and Morey [65] showed that the nematode may increase the pathogenicity of *F. solani* under favourable conditions. *Phytophthora nicotianae* is a virulent pathogen of citrus roots. It was shown that pre-infection of citrus roots by *T. semipenetrans* can reduce the rate of infection by [66]. There are some evidences that growth of the fungus is inhibited in the vicinity of the nematode eggs, but a mechanism has unknown. Dry root rot caused by *Fusarium* spp. has a serious threat in some countries [67]; when it remains an interaction with root rot disease caused by *Phytophthora* spp. [6], and with citrus nematode *T. semipenetrans* [36]. Dry root rot of citrus occurs on trees that usually are weakened by some other factor (root damage caused by Phytophthora, over-watering, poor soil drainage, excess fertilizer, heat stress and root injury due to plowing, herbicides or nematodes [68].

During COVID-19 pandemic, the significance of citrus fruits has been increased exponentially due to its increased demand. Use of citrus fruits (oranges, lemon, grapefruit etc.) is generally recommended by health officials to improve the immunity as one of the preventive measures of COVID-19 [64, 65]. Citrus fruits such as orange are enriched with 9.9 g of carbohydrates (45 kcal of energy per 100 g), 0.7 g of proteins, 0.2 g of fats, [69,70]. Two major components found in citrus fruits are hesperidin and vitamin C which have multiple biological actions which appear to be effective to respond the cells to modulate the systemic immunopathological phases of COVID-19 Infection [71-74].

Citrus fruits are the rich source of flavonoids (phenolic compounds) which are associated with immunomodulatory as well as anti-viral activities. Naringenin is a flavonoid found in citrus fruits [75,76]. Its anti-viral activity might be helpful to cope up with viral infections including COVID-19 by either regulating the production of cytokines or preventing the replication of viruses [77,78]. Among Citrus fruits, grapefruits, pummelo and oranges have excess amount of naringenin [64,74]. It was reported that naringenin may prevent COVID-19 either by binding with angiotensin converting enzyme-2 (ACE-2) receptor that is the possible binding site for novel corona virus or by attenuating the inflammatory responses [67; 66;64; 75]. Another study also reported that lemon oil contains limonene as an active ingredient and it was found to down regulate the ACE-2 receptors [79]. However, further preclinical, clinical and epidemiological studies are required to verify the hypothesis .

the best approaches to prevent COVID-19 is to boost the immune system of the body through optimal nutrition intake [70,71]. Citrus fruits are known to up regulate the immune response by regulating the production of cytokines (signaling molecules) and hence, helpful in the prevention and control of viral infections. These are considered the economical nutritional therapy to fight with COVID-19 global threat [80,81].

Conclusion and Recommendation

Citrus is one of the important food crop of Pakistan that play pivotal role in the economy of Pakistan. However, in Pakistan yield of citrus is affected due to attack of insects and pathogens (nematode, fungal, bacterial and viral) which causes heavy losses both in quality and quantity. It is strongly recommended that effect/interaction of these insects and pathogens on performance of citrus fruit must be evaluated. For this purpose research should be conducted to investigate prevalence and pathogenicity of these pathogens. These pathogens should be identified at species level by molecular markers and control strategies should be devised to prevent the fruits from disease.

References

[1] Al-Taey, D. K. A., S. S. M. AlAzawi and M. H. Husien .2010. Effect of Spraying Acetyl Salicylic Acid on the Plant Tolerance for Salt Stress & Survival Percentage after Transplanting of Orange (Citrus sinensis). Babylon Journal University -Pure and Applied science, 18 (4) : 1513-1520
[2] Anwar, S. A., Saeed, M. A., Gorsi, S., Khan, H. A. and Tahir, M. (1991). Occurrence of citrus root nematode with decline citrus plants and its chemical control. Pakistan J. Agric. Res., 12(3): 197-201.
[3] Bender, G. S., Menge, J.A., Ohr, H.D. and Burns, R.M., 1982. Dry root rot of citrus: it's meaning for the grower. Calif. Citroger. 67: 249-254.
[4] Catara, A. and Polizzi, G. (1999). Dry root rot of citrus: symptoms, causing and susceptibility of rootstocks. Rivisto di Fruticolture., 6 (11): 38-41.
[5] Conzulex, W., Ramallo, J. and Ploper, L. D. (1997). Identification of Fusariumsolani (Mart.) associated with decline and root rot of grapefruit (Citrus paradisi). AvanaAgroindustrial, 18: 7-8.
[6] Dandurand, L. M. and Menge, J. A. (1992). Influence of Fusariumsolani on citrus root rot caused by Phytophtoraparasitica and Phytophtoracitrophtora. Plant and soil, 144(1): 13-21.
[7] Duncan, L. W., and Cohn, E. (1990). Nematode parasites of citrus. In: Luc M., Sikora R.A. and Bridge J. (eds). Plant-

parasitic nematodes in subtropical and tropical agriculture. Wallingford, UK: CAB International, 437-466.
[8] Duncan, L. W. and Eissenstat D. M. (1993). Responses of Tylenchulussemipenetrans to citrus fruit removal: Implications for carbohydrate competition. J of Nematol, n. 25: 7-14.
[9] Duncan, L. W., Graham J. H. and Timmer, L. W. (1993). Seasonal patterns associated with Tylenchulussemipenetrans and Phytophthoraparasitica in the citrus rhizosphere. Phytopathology, n. 83: 573-581.
[10] Duncan, L. W., Mashela, P., Ferguson, J., Graham, J., Abou-Setta, M. M. and El-Morshedy, M. M. (1995). Estimating crop loss in orchards with patches of mature citrus trees infected by Tylenchulussemipenetrans. Nematropica, n. 25: 43-51.
[11] El-Borai, F. E., Duncan, L. W. and J. H. Graham. (2002). Infection of Citrus Roots by Tylenchulussemipenetrans Reduces Root Infection by Phytophthoranicotianae. J of Nematol, 34(4): 384–389.
[12] EL-Mohamedy, R.S.R. and Hasabo, S.A., 2005. Response of some citrus rootstocks to infection with Fusariumsolani and citrus nematode Tylenchulussemipenetrans under greenhouse conditions. Egypt. J. Phytopathol., 33: 11-25.
[13] Hasan, A.M., T.J.Mohamed Ali .,D.K.A.Al-Taey (2019). Effects of Winter Foliar Fertilizing and Plant Growth Promoters on Element and Carbohydrate Contents on the Shoot of Navel Orange Sapling. International Journal of Fruit Science.,19(1)1-10. https://doi.org/10.1080/15538362.2019.1668331
[14] Hamid, G.A., Gundy, S.P., Lovett, C.J. and Van. Gundy, S.D., 1985. Citrus nematode alter carbohydrates partitioning in the "Washington" Navel orange. J. Am. Soc. Hort. Sci., 110: 642- 646.
[15] Heald, C. M. and O'Bannon, J. H. (1987). Citrus declines caused by nematodes. V. Slow decline. Nematology Circular n. 143. Florida Department of Agriculture and Consumer Services. Division of Plant Industry.
[16] Ippolito, A. and De Cicco, V. (1995). Dry root rot of citrus in Apulia and Basilicata, Italy. Informatorefitopatologico., 12: 51-53.
[17] Al-Taey D.K.A. (2009) Effect of spraying acetyl salicylic acid to reduce the damaging effects of salt water stress on orange plants (Citrus sinensis L.). Journal of Kerbala University; 7 (2): 192-202.
[18] Kore, S. S. and Mane, A. V. (1992). A dry root rot disease of kagzilime (Citrus auranfifolia) seedling caused by Fusariumsolani. Hournak of Maha. Agric. India, 17: 276-278.
[19] Labuschagne, N. KotzeA, J. M. and Putterill, J. F. (1987). Incidence of Fusariumsolani and Fusariumoxysporum in citrus roots and infection by Fusariumsolani. Phytophylactica, n. 19: 315-318.
[20] Labuschagne, N., Vegte, F.A.V. and Kotze, J.M., 1989. Interaction between Fusariumsolani and Tylenchulussemipenetrans on citrus roots. Phytophylactica, 21: 29-33.
[21] Mashela, P. W. and Nthangeni M. E. (2002). Osmolyteallocation in response to Tylenchulussemipenetrans infection, stem girdling, and root pruning in citrus. J of Nematol, 34: 273-277.
[22] McClure, M. A. and Schmitt, M. E. (1996). Control of citrus nematode, Tylenchulussemipenetrans, with cadusafos. Supplement to the Journal of Nematology, 28(4): 624-628.
[23] Naqvi, S. A. M. H. (2004). Diagnosis and Management of Certain Important Fungal Diseases of citrus. Diseases of fruits and vegetables I. Springer, Netherlands.
[24] Nemec, S., Baker, R., Burnett, H. (1980). Pathogenicity of Fusariumsolani to citrus roots and its possible role in blight etiology. Proceedings of the Florida State Horticultural Society 93: 36-41.
[25] Nemec, S. (1978). Symptomatology and histopathology of fibrous roots of rough lemon (Citrus jambhiri) infected with Fusariumsolani. Mycopathologia, 63: 35-40.
[26] Nemec, S. (1984). Characteristics of Fusariumsolani-infected pioneer roots on blightdiseased and Healthy citrus. Proc. Soil and Crop. Sci. Fla, 43: 177-183.
[27] Neal, J. C. (1889). Root knot disease of peach, orange and other plants in Florida, due to the work of Anguillula. Government Printing Office, Washington.
[28] Niaz, A. C, Maken, M. N, Malik, S. A. (2004). Native home, historical background and importance of citrus fruits in Pakistan. In: Proc. 1st Int. Conf. on Citriculture. Uni. Agric., Faisalabad. 28-29 April, pp. 4856.
[29] O'Bannon, J.H., Reynold, H.W. and Leathers, G.R. (1966) "Effects of temperature on penetration, development and reproduction of Tylenchulussemipenetrans", Nematol., 12: 483-487.
[30] Olsen, M., Matheron, M., McClure, M. and Xiong Z. (2000). Diseases of Citrus in arizona. University of Arizona, USA.
[31] Mohammed, M.A., Salman, S.R., (2017), Structural and surface roughness effects on sensing properties of ZnO doping with Al thin films deposited by spray pyrolysis technique, Journal of Engineering and Applied Sciences, 12 (Specialissue6), pp. 7912-7918.
[32] Praksasm, V., Jeyarajan, A. and Hambur, S. R. (1992). Occurrence of dry root rot disease in mandarin plantations in ShevrayHils. South Indian Hort. Cult., 40: 234 – 235.
[33] Sakovich, N. (2003). Dry Root Rot of Citrus. Topics in Subtropics. University of California Cooperative Extension,
[34] Verma, K. S., Nartey, S. and Singh, N. (1999). Occurrence and control of dry root rot of citrus seedlings. Plant Disease Research., 14 (2): 31-34.
[35] Walker, G. E. and Morey, B. G. (1999). Effect of brassica and weed manures on abundance of Tylenchulussemipenetrans and fungi in citrus orchard soil gal pathogens of citrus roots. Aust J Exp Agric., 39(1): 65-72.
[36] Inserra RN, Duncan LW, O'Bannon JH, Fuller SA, (2003). Citrus Nematode Biotypes and Resistant Citrus Rootstocks in Florida, Florida Department of Agriculture and Consumer Services, Division of Plant Industry pp. 32614-7100.
[37] Irshad U, Mukhtar T, Ashfaq M, KayaniMZ, Kayani SB, Hanif M, Aslam S (2012). Pathogenicity of citrus nematode (tylenchulussemipenetrans) on Citrus jambhiri, J. Anim Plant Sci. 22(4):1014-1018
[38] Gebreslasie, A. and H Meresa. 2018. Identification of insect and disease associated to citrus in Northern Ethiopia. African J Microb Res, 12(13), 312-320.
[39] Yosef H, Dejene G, Mohammed K (2014). Assessment and identification of insect pests on sweet oranges (Citrus sinensis) in

Tony Farm, Dire Dawa, Ethiopia. Int. J. Innov. Sci. Res.12(2): 509-514.
[40] Batool, A., Y. Iftikhar, S.M. Mughal, M.M. Khan, M.J. Jaskani, M. Abbas and I.A. Khan. 2007. Citrus Greening Disease – A major cause of citrus decline in the world – A Review, Hort. Sci. (Prague) , 34, 2007 (4): 159–166.
[41] Johnson G. Pakistan citrus industry challenges: opportunities for Australia-Pakistan collaboration in research, development & extension. (2006). www.aciar.gov.au/.../ASLP%20citrus%20scoping%20 study%20report.pdf http://aciar.gov.au/files/node/739/ASLP%20citrus%20s coping%20study%20report.pdf.
[42] Memon, N.A. 2017. Citrus Fruit (Kino): Punjab produced 98% of production, Exclusive on Kino. Pak. Food J. JanFeb, 2017. Available online at https://bit.ly/2GTs4lP
[43] Naseer, M.A.u.R., M. Ashfaq, S. Hassan, A. Abbas, A. Razzaq, M. Mehdi, A. Ariyawardana and M. Anwar. 2019a. Critical issues at the upstream level in sustainable supply chain management of agri-food industries: Evidence from Pakistan's Citrus Industry. Sustainability 11:1326.
[44] Aatif, H. M., T. A. Yasir , C. M. S. Hanif , T. Abbas, A. W. Baloch, A. Wasaya, S. K. Abbas, and S. P. Lali. 2017. Evaluation of prevalence and incidence ofcitrus slow decline disease in citrusorchards in district Layyah. Pure Appl. Biol., 6(2): 664-668.
[45] Gottwald, T. R., Graham, J. H., and Schubert, T. S. 2002. Citrus canker: The pathogen and its impact. Online. Plant Health Progress doi:10.1094/PHP-2002-0812-01-RV.
[46] Alberca RW, Teixeira FME, Beserra DR, de Oliveira EA, de Souza Andrade MM, Pietrobon AJ, Sato MN. 2020. Perspective: The potential effects of naringenin in COVID-19. Frontiers in Immunology. 11.
[47] Banerjee S, Srivastava S, Giri AK. 2020. Possible nutritional approach to cope with COVID-19 in Indian perspective. Adv Res J Med Clin Sci. 6(06): 207-219.
[48] Cheng L, Zheng W, Li M, Huang J, Bao S, Xu Q, Ma Z. 2020. Citrus fruits are rich in flavonoids for immunoregulation and potential targeting ACE2.
[49] de Faria Coelho-Ravagnani C, Corgosinho FC, Sanches FLFZ, Prado CMM, Laviano A, Mota JF. 2020. Dietary recommendations during the COVID-19 pandemic. Nutrition Reviews.
[50] Den Hartogh DJ, Tsiani E. 2019. Antidiabetic properties of naringenin: A citrus fruit polyphenol. Biomolecules. 9(3): 99.
[51] Gupta SC, Tyagi AK, Deshmukh-Taskar P, Hinojosa M, Prasad S, Aggarwal BB. 2014. Downregulation of tumor necrosis factor and other proinflammatory biomarkers by polyphenols. Archives of Biochemistry and Biophysics. 559: 91-99.
[52] Naja F, Hamadeh R. 2020. Nutrition amid the COVID-19 pandemic: a multi-level framework for action. European journal of clinical nutrition. 74(8): 1117-1121.
[53] Senthil Kumar K, Gokila Vani M, Wang C-S, Chen C-C, Chen Y-C, Lu L-P, Huang C-H, Lai C-S, Wang S-Y. 2020. Geranium and lemon essential oils and their active compounds downregulate angiotensin-converting enzyme 2 (ACE2), a SARS-CoV-2 spike receptor-binding domain, in epithelial cells. Plants. 9(6): 770.
[54] Thota SM, Balan V, Sivaramakrishnan V. 2020. Natural products as home-based prophylactic and symptom management agents in the setting of COVID-19. Phytotherapy Research. 34(12): 3148-3167.
[55] Tutunchi H, Naeini F, Ostadrahimi A, Hosseinzadeh-Attar MJ. 2020. Naringenin, a flavanone with antiviral and anti-inflammatory effects: A promising treatment strategy against COVID-19. Phytotherapy Research. 34(12): 3137-3147.
[56] Valdés-Ramos R, Martínez-Carrillo BE, Aranda-González II, Guadarrama AL, Pardo-Morales RV, Tlatempa P, Jarillo-Luna RA. 2010. Diet, exercise and gut mucosal immunity. Proceedings of the Nutrition Society. 69(4): 644-650.
[57] Sanchez-Moreno, C.; Cano, M.P.; De Ancos, B.; Plaza, L.; Olmedilla-Alonso, B.; Granado, F.; Martín, A. Effect of orange juice intake on vitamin C concentrations and biomarkers of antioxidant status in humans. Am. J. Clin. Nutr. 2003, 78, 454–460.
[58] Salman, S.R., Hassan, H.B., Mohammed, M.A., (2018), The Hydrogen and Sulfur Surfaces Effect on the Structural and Electronic Properties of Graphene Nano Ribbon, Journal of Global Pharma Technology, 10 (6), pp. 386-392.
[59] Barreca, D.; Mandalari, G.; Calderaro, A.; Smeriglio, A.; Trombetta, D.; Felice, M.R.; Gattuso, G. Citrus Flavones: An Update on Sources, Biological Functions, and Health Promoting Properties. Plants 2020, 9, 288.
[60] Gupta, A.; Madhavan, M.V.; Sehgal, K.; Nair, N.; Mahajan, S.; Sehrawat, T.S.; Bikdeli, B.; Ahluwalia, N.; Ausiello, J.C.; Wan, E.Y.; et al. Extrapulmonary manifestations of COVID-19. Nat. Med. 2020, 26, 1017–1032.
[61] Chen, Y.W.; Yiu, C.B.; Wong, K.Y. Prediction of the SARS-CoV-2 (2019-nCoV) 3C-like protease (3CL (pro)) structure: Virtual screening reveals velpatasvir, ledipasvir, and other drug repurposing candidates.F1000Research 2020, 9, 129
[62] Utomo, R.Y.; Ikawati, M.; Meiyanto, E. Revealing the Potency of Citrus and Galangal Constituents to HaltSARS-CoV-2 Infection. Preprints 2020, 2020, 12.
[63] Miler, M.; Živanovi´c, J.; Ajdžanovi´c, V.; Oreš˘canin-Duši´c, Z.; Milenkovi´c, D.; Koni´c-Risti´c, A.; Blagojevic, D.; Miloševi´c, V.; Šoši´c-Jurjevi´c, B. Citrus flavanones naringenin and hesperetin improve antioxidant status and membrane lipid compositions in the liver of old-aged Wistar rats. Exp. Gerontol. 2016, 84, 49–60.
[64] Cheng, R.Z. Can early and high intravenous dose of vitamin C prevent and treat coronavirus disease 2019 (COVID-19)? Med. Drug Discov. 2020, 5, 100028.
[65] Liu, F.; Zhu, Y.; Zhang, J.; Li, Y.; Peng, Z. Intravenous high-dose vitamin C for the treatment of severe COVID-19: Study protocol for a multicentre randomised controlled trial. BMJ Open 2020, 10, e039519.
[66] Tejada, S.; Pinya, S.; Martorell, M.; Capó, X.; Tur, J.A.; Pons, A.; Sureda, A. Potential Anti-inflammatory E_ects of Hesperidin from the Genus Citrus. Curr. Med. Chem. 2019, 25, 4929–4945.
[67] Khan, A.; Khan, M.S.; Hahm, J.R.; Kim, M.O. Antioxidant and Anti-Inflammatory E_ects of Citrus Flavonoid Hesperetin: Special Focus on Neurological Disorders. Antioxidants 2020, 9, 609.
[68] Mohammed, M.A., Abdulridha, W.M., Abd, A.N., (2018), Thickness effect on some physical properties of the Ag thin films prepared by thermal evaporation technique, Journal of Global Pharma Technologythis , 10(3), pp. 613–619.
[69] Al-Rikabi, R.; Al-Shmgani, H.; Dewir, Y.H.; El-Hendawy, S. In Vivo and In Vitro Evaluation of the Protective E_ects of

Hesperidin in Lipopolysaccharide-Induced Inflammation and Cytotoxicity of Cell. Molecules 2020, 5, 478.
[70] Thota S.M., Balan V. 2020. Natural Products as home-based Prophylactic and Symptom Management Agents in the Setting of COVID-19.
[71] de Faria Coelho-Ravagnani, C., Corgosinho, F. C., Sanches, F., Prado, C., Laviano, A., & Mota, J. F. (2021). Dietary recommendations during the COVID-19 pandemic. Nutrition reviews, 79(4), 382–393. https://doi.org/10.1093/nutrit/nuaa067
[72] Valdés Ramos E, Bencosme Rodríguez N. Las complicaciones macrovasculares y su relación con algunas variables clínicas y bioquímicas en diabéticos tipo 2. Rev Cubana Endocrinol 2010; 21(3): 256-268.
[73] Naja, F., Hamadeh, R. Nutrition amid the COVID-19 pandemic: a multi-level framework for action. Eur J Clin Nutr 74, 1117–1121 (2020). https://doi.org/10.1038/s41430-020-0634-3
[74] Den Hartogh DJ, Tsiani E. Antidiabetic Properties of Naringenin: A Citrus Fruit Polyphenol. Biomolecules. 2019 Mar 12;9(3):99. doi: 10.3390/biom9030099. PMID: 30871083; PMCID: PMC6468535.
[75] Mohammed, M.A., Salman, S.R., Abdulridha, W.M., (2020), Structural, optical, electrical and gas sensor properties of zro2 thin films prepared by sol-gel technique, NeuroQuantology, 18(3), pp. 22–27.
[76] Senthil Kumar, Kj & Vani, M. & Wang, Chung-Shuan & Chen, Chia-Chi & Chen, Yu-Chien & Lu, Li-Ping & Huang, Ching-Hsiang & Lai, Chien-Sing & Wang, Sheng-Yang. (2020). Geranium and Lemon Essential Oils and Their Active Compounds Downregulate Angiotensin-Converting Enzyme 2 (ACE2), a SARS-CoV-2 Spike Receptor-Binding Domain, in Epithelial Cells. Plants. 9. 770. 10.3390/plants9060770.
[77] Kishi, K. 1967. Studies on indicator plant for cit1·us viruses. IV. On the properties of the sap-transmissible virus associated with Satsuma dwarf and same other virns-Jike diseases. Bull. Hort. Res. Sta., Series A-G: 115-131.
[78] Hyun JW, Hwang RY, Choi CW, Jung KE, Han SG. Symptomatology of Citrus mosaic sadwavirus (CiMV) in Some Citrus Cultivars and Effect of CiMV Infection on Citrus Fruit Quality. Plant Pathol J. 2020;36(1):106-110. doi:10.5423/PPJ.NT.07.2019.0192
[79] Roistacher, C.N. Psorosis complex: Psorosis-A, psorosis-B and ringspot. In Graft-Transmissible Diseases of Citrus (Handbook for Detection and Diagnosis); FAO: Rome, Italy, 1991; pp. 115–126
[80] Kumar PV, Sharma SK, Rishi N, Baranwal VK. Efficient immunodiagnosis of Citrus yellow mosaic virus using polyclonal antibodies with an expressed recombinant virion-associated protein. 3 Biotech. 2018;8(1):39. doi:10.1007/s13205-017-1063-4
[81] Ahlawat YS, Chenulu VV, Viswanath SM, Pandey PK, Bhagabathi KN. Mosaic disease of citrus in India. Curr Sci. 1985;54:873–874.