

Research Article



Management of Citrus Green Mould through the Use of Allelochemicals and Salicylic Acid

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Abstract | The study was conducted to check the effect of different plant extracts /allelochemicals and salicylic acid on the growth of *Penicillium digitatum* causes citrus green mould by using 7 plant extracts alone and in combination with wax and 3 concentrations of salicylic acid alone and in combination with wax. The study revealed that in case of plant extracts maximum growth inhibition (35.90 %) was shown by Anar followed by Chabir (33.60%) and Garlic (29.16%), while minimum growth inhibition was recorded from Parthanium (17.43%) and Ginger (19.94 %). In case of plant extracts + wax maximum growth inhibition (44.36%) was shown by Anar+Wax followed by Chabir+Wax (42.78%) and Fungicide + Wax (37.45%), while minimum growth inhibition % was recorded from Fungicide (15.49 %) and Kortuma + Wax (17.48%). In case of salicylic acid concentrations maximum growth inhibition (34.73 %) was shown by Salicylic acid concentration of 6 mm followed by Salicylic acid (33.40 %) at 3 mm concentration and Salicylic acid (28.51%) at 9 mm concentration, while minimum growth inhibition % was recorded from SA + Wax (-13.37%). So it was concluded that allelochemicals + wax showed maximum growth inhibition of green mould.

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1. Introduction

Postharvest diseases cause substantial losses to harvested fruits during transportation and storage (Sharma *et al.*, 2009). Green mould caused by *Penicillium digitatum* (Pers. Fr.) Saac is the major postharvest disease of citrus which is accountable for causing severe losses up to 80% during favorable conditions which result in production of green spores and fruit shrink with the passage of time (Palou, 2009; Ballester *et al.*, 2010; Iqbal *et al.*, 2012).

Control of postharvest citrus diseases mostly depends upon the use of synthetic fungicides through different protocols used like dipping of citrus fruits in soak

tanks, by spraying aqueous solution and as well as in the form of fumigants (Janisiewicz, 2004). Health and environmental hazards of these chemicals shifted the plant pathologists towards finding valuable alternatives of these chemicals (Leroux, 2003; Calvo *et al.*, 2007; Cunningham and Taverner, 2007). The other drawback of continuous and indiscriminate use of chemicals resulted development of resistant strains of the pathogens (Leroux, 2003).

Therefore, the most promising alternative to chemicals is the use of organic elicitors to induce resistance in plants and the use of allelochemical. Mostly, induce resistance is the application of chemical compounds that result in triggers of plant defense systems

(Olivieri *et al.*, 2009; Iqbal *et al.*, 2012). Allelochemical extracts isolated from the plants have been evaluated against various plant pathogens (Stephan *et al.*, 2005). Natural plant products are the most efficient and cost-effective alternatives of plant pathogens (Lira *et al.*, 2003; Jasso de Rodríguez *et al.*, 2007; Castillo *et al.*, 2010; Osorio *et al.*, 2010).

The effectiveness of different organic salts and plant extracts to inhibit the pathogen growth may vary from plant to plant (Castillo *et al.*, 2010). Hence, possible alternatives of chemical fungicides such as biologically based approaches that must be equally or more effective, economical and non-hazardous to consumers and eco-friendly have been much needed to be evaluated against postharvest diseases. Therefore, treatments with allelochemicals and chemical elicitors could be recommended to control citrus green mould (*P. digitatum*) and their use may be an effective method to improve the integrated pest management strategy.

2. Materials and Methods

The present research work was done in the laboratory of Plant Pathology, College of Agriculture, University of Sargodha during 2015-16 in order to evaluate the efficacy of chemical elicitors and different plant extracts against postharvest disease of citrus. The samples of green mould were collected from different locations of district Sargodha and pathogen was isolated from diseased fruit samples and then these fruits cut into small pieces of about 1.5-2cm. Surface of these cuttings sterilized with 0.1% bleach for approximately 2 minutes and then washed three times with distilled water and placed on petri plates containing potato dextrose agar (PDA). These petri plates were incubated for one week to check the sporulation for further studies. Pathogenicity of isolated pathogens to confirm the association with host was done according to Koch's postulates. Pure culture of pathogen was preserved at 4°C for experiments and cultures were replaced by new one after a month.

2.1 Inoculum preparation

Morphological characterization of the pathogen, *P. digitatum* was done on the basis of conidial size and shape and colony characteristics and was confirmed as described by Mills *et al.* (2004) and conidial suspension was prepared by culturing on PDA media

containing petri plates. Sterilized distilled water (10mm) was added to seven days pure old culture. The petri plates were gently shivered and suspension was filtered with 3 layers of cheesen cloth to remove debris as reported by Janisiewicz *et al.* 2000.



Preparation of inoculum

2.2 Preparation of plant extracts

Fresh leaves of different plants e.g Kurtuma (*Citrullus colocynthis*), Chabir, Ginger (*Zingiber officinale*), Puthkanda (*Achyranthes aspera* L.), Garlic (*Allium sativum*), Parthenium (*Parthenium hysterophorus*) and Pomegranate (*Punica granatum*) were collected from research area, College of Agriculture and then washed with distilled water to remove surface pollutant. Leaves of all tested plants were blended in distilled water with 1:1(w/v) to obtain its crude extract. After blending this crude extract was passing through double layer of muslin cloth and then centrifuged at 8500 rpm for 8 min and supernatant was obtained in 1000ml glass flask as reported by (Chohan *et al.*, 2011).

2.3 Postharvest application of allelochemicals

The efficacy of six plant extracts (Table 1) on green mold of kinnow was done on 1st week of April 2015. Healthy, uniform and blemish free fruits were taken

from local market of Sargodha and their surface sterilization was done by dipping of fruits in 0.5% commercial bleach solution for 5 minutes. Five fruits for each replication were used and each treatment was replicated three times. Fifteen micro liter spore suspension of *P. digitatum* was injected with micropipette. Inoculated fruits were set in ridged boxes and maintained at 85% relative humidity and 20°C temperature. Data were taken on daily basis.

Table 1: List of Plant used for Postharvest Disease Control.

Sr.#	Common Name	Botanical Name	Family
1	Kortuma	<i>Citrullus colocynthis</i>	cucurbitaceae
2	parthenium	<i>Parthenium hysterophorus</i>	Asteraceae
3	Ginger	<i>Zingiber officinale</i>	Zingiberaceae
4	Garlic	<i>Allium sativum</i>	Amaryllidaceae
5	Anar	<i>Punica granatum</i>	Lythraceae
6	Puthkanda	<i>Achyranthes aspera L.</i>	Amaranthaceae
7	Chabir	<i>Melaleuca genus</i>	Myrtaceae

2.4 Postharvest application of allelochemicals with wax

Each fruit was coated with plant extract with 0.73ml concentration of wax and dried under shade for 30 minutes. Spore suspension (15 µ L) of *P. digitatum* was injected with micropipette and fruits were incubated at 20°C temperature and 90% relative humidity in growth room.

2.5 Evaluation of salicylic acid and with wax

Effectiveness of salicylic acid was evaluated by amending 0mM (control), 3 mm, 6 mm and 9 mm into potato dextrose agar and each treatment was replicated three times. Fruits were wounded by making puncture by using sterilized borer and inoculated with 5 micro liter of conidial suspension of fungi. Inoculated fruits were arranged in rigid boxes and maintained at 90% relative humidity at 20°C. Fifteen fruits of citrus for each treatment were coated with wax and 0.73ml wax used for each fruit and then amended with different dose of elicitors to check their efficacy against green mould.

Data were recorded for lesion diameter on each fruit of each treatment with the help of scale in millimeters while experiments was repeated two times.

3. Results and Discussion

3.1 Postharvest applications of allelochemicals/plant extracts

The maximum growth inhibition percentage (35.90%) was shown by Anar followed by Chabir (33.60%) and Garlic (29.16%), while minimum growth inhibition % was recorded from Parthanium (17.43%) and Ginger (19.94%). In case of lesion diameter minimum mean lesion diameter (48.06 mm) was recorded from Anar followed by Chabir (49.78 mm). In case of lesion diameter, the maximum lesion diameter (61.90 mm and 60.02 mm) was recorded of Parthanium and Ginger extracts. Based on our experimental results, we can conclude that for obtaining maximum growth inhibition % plant extracts of Anar, Chabir and Garlic was the best as they showed highest growth inhibition percentage of *P. digitatum* (Table 2, Figure 1 and 2).

Table 2: Effect of plant extracts on colony growth of *P. digitatum*.

Treatments	Lesion diameter (mm) on Kinnow fruit							Growth Inhibition %
	Time (days)							
	1 st	2 nd	3 rd	4 th	5 th	6 th	Mean	
Kortuma	3.00	28.43	68.47	75.47	87.37	94.60	59.56	20.56
Ginger	3.77	37.93	65.87	77.13	85.33	90.07	60.02	19.94
Chabir	1.67	25.40	52.73	64.50	72.93	81.43	49.78	33.60
Garlic	3.53	26.33	60.33	62.00	78.77	87.67	53.11	29.16
Parthanium	13.37	41.43	65.60	74.27	85.27	91.47	61.90	17.43
Anar	4.57	36.20	43.60	56.27	67.47	80.23	48.06	35.90
Pathkanda	6.47	33.07	49.67	71.20	83.33	88.87	55.43	26.06
Fungicide	3.40	25.93	55.47	71.13	83.73	93.00	55.44	26.04
Wax	3.03	32.47	60.13	69.27	80.93	92.00	56.31	24.89
Control	20.40	65.47	78.20	90.07	97.33	98.33	74.97	

3.2 Postharvest Applications of Allelochemicals + Wax

The experiment was conducted on postharvest application of Plant Extracts/ Allelochemicals + Wax against *P. digitatum*. Results were presented Table 3 and Figure 3, 4 for growth inhibition percentage and lesion diameter on kinnow fruit after each day after treatment. Results showed that maximum growth inhibition (44.36 %) was shown by Anar+Wax followed by Chabir+Wax (42.78%) and Fungicide+Wax (37.45%), while minimum growth inhibition % was recorded from Fungicide (15.49%) and Kortuma+Wax (17.48%). In case of lesion diameter minimum mean lesion diameter (36.71 mm) was recorded from Anar+Wax followed by Chabir+Wax (37.76 mm). Maximum lesion diameter (55.76 mm and 54.44 mm) was recorded from

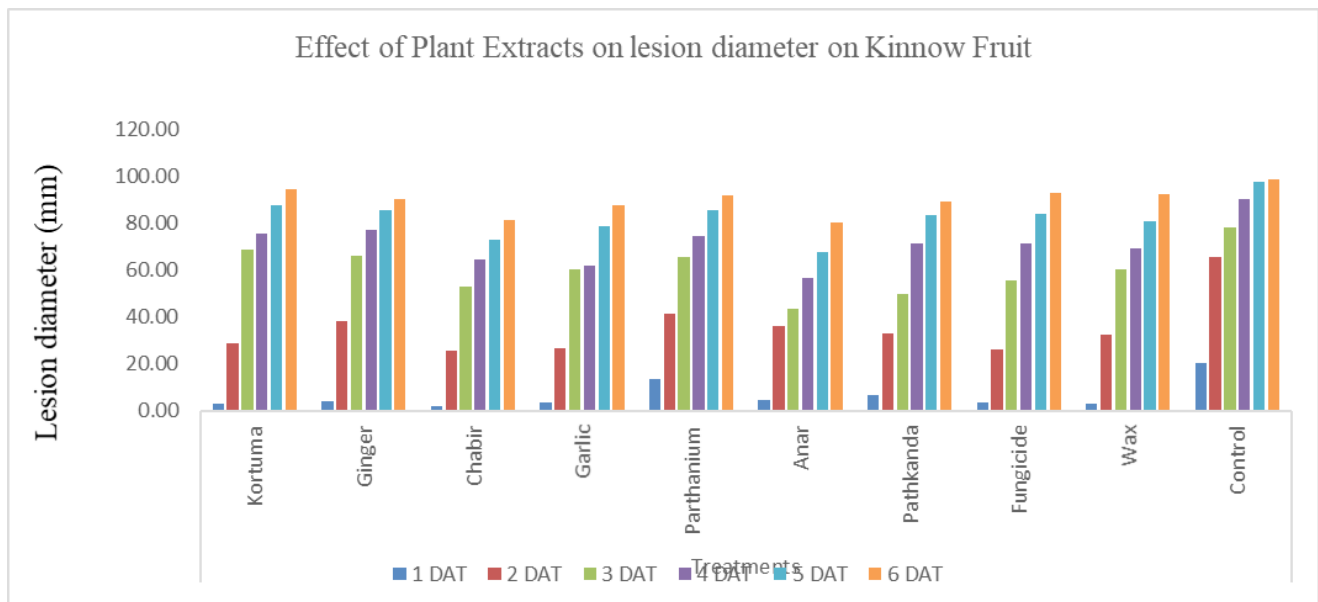


Figure 1: Effect of different plant extracts on lesion diameter (mm) on kinnow fruit.

Table 3: Effect of allelochemicals + Wax on colony growth of *P. digitatum*.

Treatments	Lesion diameter (mm) on Kinnow fruit							Growth Inhibition %
	Time (days)							
	1 st	2 nd	3 rd	4 th	5 th	6 th	Mean	
Kortuma+Wax	11.67	28.80	58.60	70.87	76.13	80.60	54.44	17.48
Ginger+Wax	7.53	25.27	41.10	59.27	69.40	73.33	45.98	30.30
Chabir+Wax	5.20	18.87	37.67	42.77	56.23	65.80	37.76	42.78
Garlic+Wax	11.73	28.87	39.60	60.93	69.03	76.73	47.82	27.53
Parthanium+Wax	15.40	29.00	50.27	63.27	77.93	81.20	52.84	19.91
Anar+Wax	5.27	18.07	34.00	44.83	55.70	62.40	36.71	44.36
Pathkanda+Wax	13.80	34.20	51.13	68.87	74.13	81.00	53.86	18.37
Fungicide	3.40	27.80	55.47	71.13	83.73	93.00	55.76	15.49
Fungicide+Wax	5.27	16.27	33.93	54.20	64.00	73.93	41.27	37.45
Control	23.93	46.20	65.73	79.00	86.00	95.00	65.98	

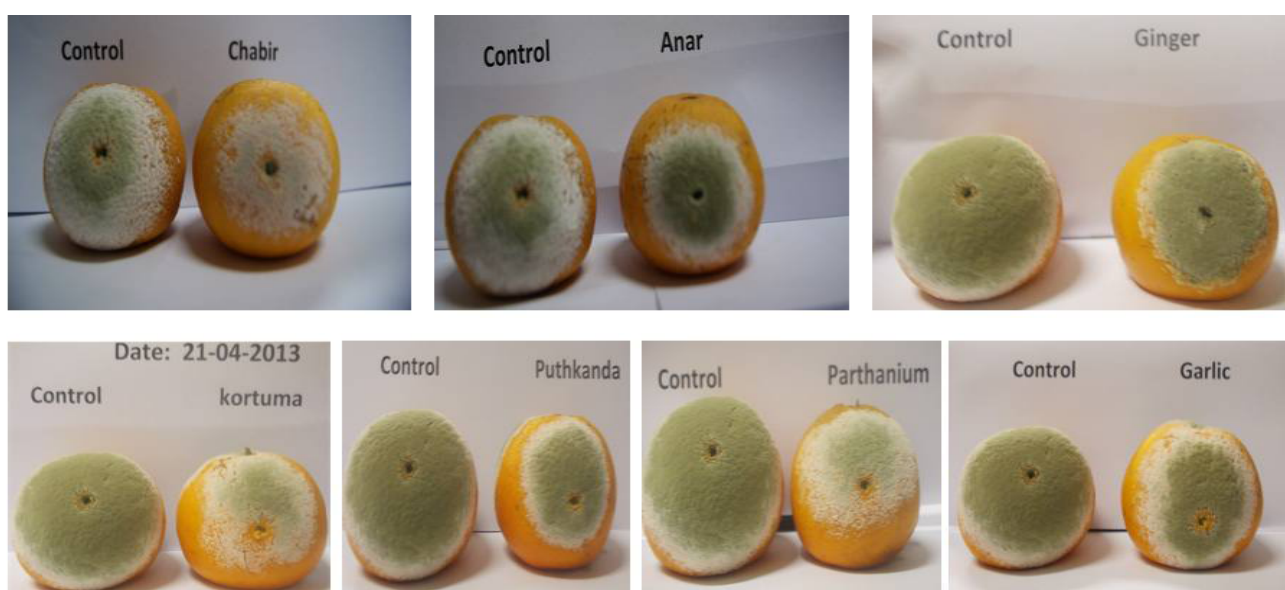


Figure 2: Comparison of application of different plant extract with control.

Table 4: Postharvest application of salicylic acid on colony growth of *P. digitatum*.

Treatments	Lesion diameter (mm) on Kinnow fruit							Growth Inhibition %
	Time (days)							
	1	2	3	4	5	6	Mean	
SA 3 mm	0.00	8.67	19.05	31.64	58.68	78.51	32.76	33.40
SA 6 mm	0.00	8.47	21.34	36.65	53.12	73.03	32.10	34.73
SA 9 mm	4.93	17.33	30.00	40.41	49.67	68.62	35.16	28.51
Fungicide10%	3.40	27.80	55.47	71.13	83.73	93.00	55.76	-13.37
Control	15.33	25.33	35.30	54.49	70.77	93.87	49.18	

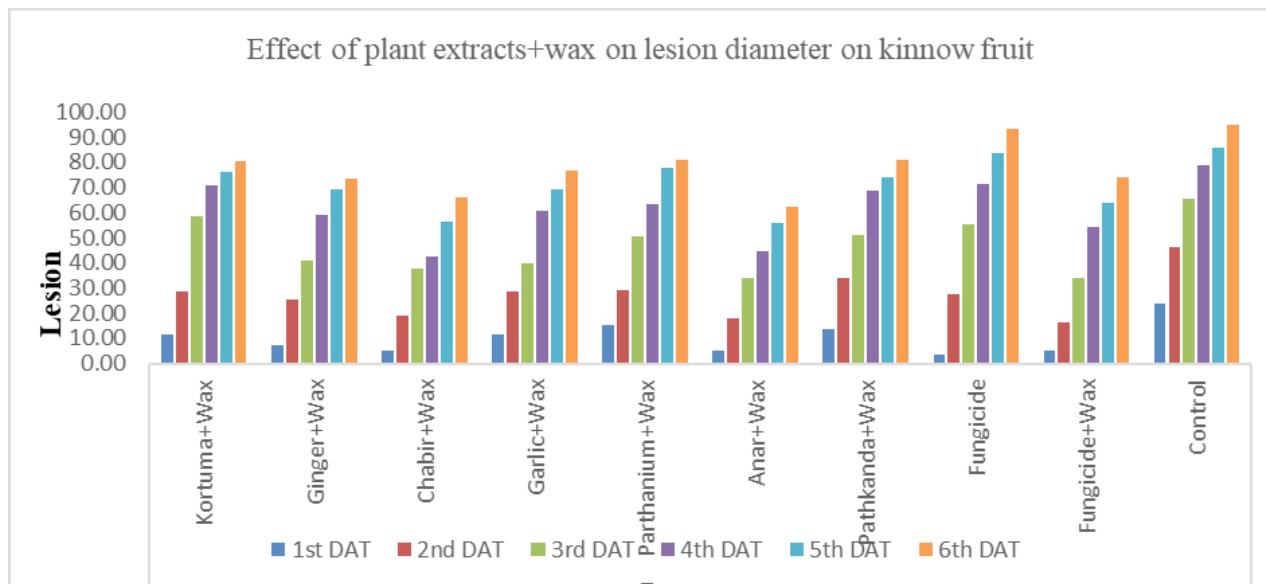


Figure 3: Effect of different allelechemicals+Wax on lesion diameter (mm) on kinnow fruit.

Fungicide and Kortuma+Wax extracts. So it was concluded that for obtaining maximum growth inhibition % plant extracts of Anar+Wax,Chabir+Wax and Fungicide+Wax was the best as they showed highest growth inhibition percentage of *P. digitatum*.

3.3 Postharvest applications of salicylic acid

The present study was conducted to evaluate the effect of different concentrations of salicylic acid against *P. digitatum*. The results revealed that (Table 4 and Figure 5, 6) the growth inhibition % and lesion diameter (mm) on kinnow fruit, respectively. It was observed that maximum growth inhibition (34.73 %) was shown by Salicylic acid concentration of 6 mm followed by Salicylic acid (33.40 %) at 3 mm concentration and Salicylic acid (28.51 %) at 9 mm concentration, while minimum growth inhibition % was recorded from Fungicide 10 % (-13.37 %). In case of lesion diameter minimum mean lesion diameter (32.10 mm) was recorded from salicylic acid at concentration of 6 mm, followed by Salicylic acid (32.76 mm) at concentration of 3 mm. Maximum lesion diameter (49.18 mm and 55.76

mm) was recorded from control and fungicide 10%. So it was concluded that for obtaining maximum growth inhibition salicylic concentration of 3 mm and 6 mm was the best as they showed highest growth inhibition percentage of pathogen.

Discussion

Postharvest pathogens significantly reduce the production of crops by lowering both fruit quality and quantity. Pathogens multiply on fruits during storage as a result of latent infection or through wound injury during handling operations. Results showed that in case of plant extracts, maximum growth inhibition (35.90 %) was shown by Anar followed by Chabir (33.60%) and Garlic (29.16%), while minimum growth inhibition was recorded from Parthanium (17.4 %) and Ginger (19.94 %). In case of plant extracts + wax maximum growth inhibition (44.36%) was shown by Anar+Wax followed by Chabir + Wax (42.78 %) and Fungicide + Wax (37.45%), while minimum growth inhibition was recorded from Fungicide (15.49 %) and Kortuma + Wax (17.48 %) while salicylic acid

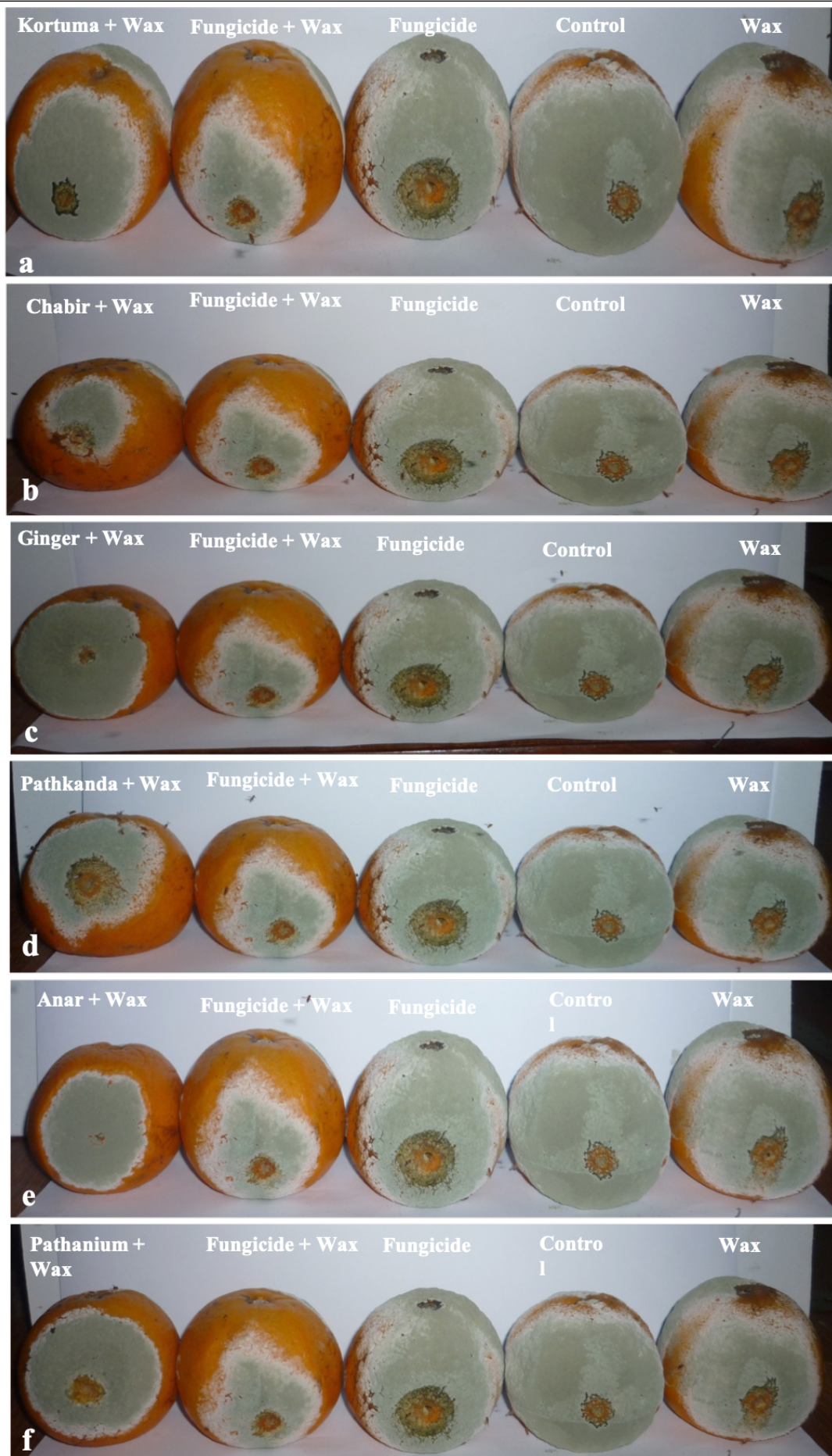


Figure 4 : Effect of plant extracts on lesion diameter: a) Kortuma+Wax; b) Chabir+Wax; c) Ginger+Wax; d) Pathkanda+Wax; e) Anar+Wax; f) Pathanium+Wax.

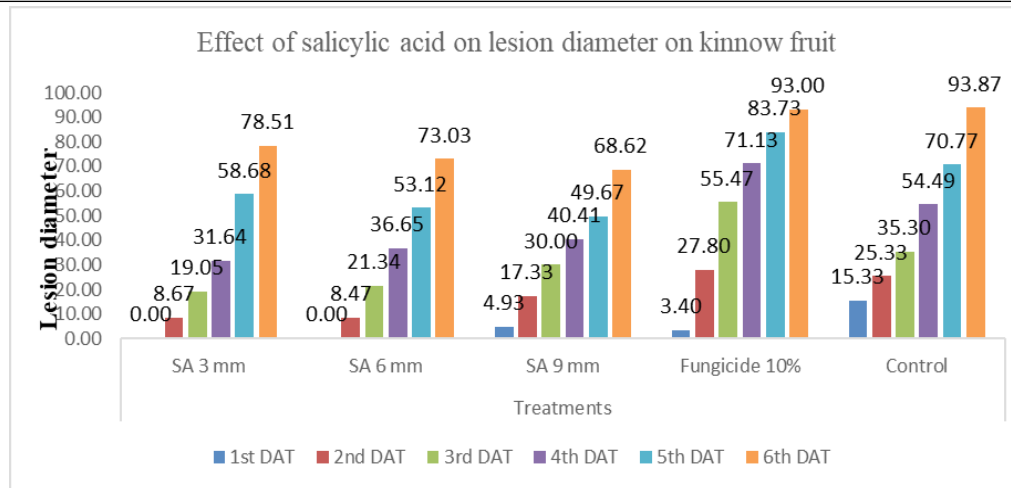


Figure 5: Effect of different concentrations of salicylic acid on lesion diameter (mm) on kinnow fruit.



Figure 6: Effect of salicylic acid (SA) concentrations on lesion diameter on kinnow.

when used @ different concentrations, maximum growth inhibition % (34.73 %) was shown by Salicylic acid concentration of 6 mm followed by (33.40 %) at 3 mm concentration and (28.51 %) at 9 mm concentration, while minimum growth inhibition was recorded from Fungicide 10 % (-13.37 %). Almost similar results were documented in case of plant extracts when different plant extracts e.g: garlic, lemon, ginger, chillies, kortumba and pomegranate showed effective control as observed by [El-Ghouth *et al.* \(2000\)](#) when they performed an experiment by using different extracts of to control the fungal growth while [Obagwu and Korsten \(2003\)](#), [Seeram *et al.* \(2006\)](#), [Ikeura *et al.* \(2011\)](#) and [Tunwari and Nahunnaro \(2014\)](#) performed experiments to check the efficacy of garlic extracts on control of green moulds. They observed that all the treatments significantly reduced the both fungal growth. Contrary to our results, [Al-Samarrai *et al.* \(2013\)](#) observed that the application of Neem and Chili extracts at the rate of 3000 ppm resulted in complete (100%) reduction in growth of *Panicillium digitatum* in lab conditions. [Abo-Elnaga \(2013\)](#) studied growth

inhibition percentage of *P. digitatum* on by application of garlic extract and powder and observed that application of 1% garlic resulted reduction in disease incidence and disease severity after 7 days from inoculation as compared to control. Natural resistance in fruit crops induced by the application of physical, chemical and biological elicitors have received much concentration and considered a potential strategy in postharvest disease control ([Terry and Joyce, 2004](#)). Post-harvest storage losses can be minimized by the application of SA if it will spray pre harvest as observed by [Ahmad *et al.* \(2014\)](#). Treatments of elicitor's could affect the induced systemic resistance and play a key role in natural disease control and used in IPM approach ([Terry and Joyce, 2004](#)). Similar findings also observed by [El-Mougy \(2002\)](#) who observed that increasing SA concentration up to 80mM caused complete inhibition to the growth of the storage pathogen such as *P. digitatum* of different fruit crops. Application of salicylic acid resulted in significantly reduction of spore formation and germination of spores of green mould as compared to control. Application of salicylic acid at the rate of

6 mM resulted in complete stoppage and reduction in growth, sporulation and conidial germination resulted by Iqbal *et al.* (2012). The results of the present study lined with all above mentioned reports that the tested plant extracts and SA significantly reduced the mycelial inhibition of the pathogen.

Conclusion

The present study suggests a potential for the control of postharvest diseases of citrus fruit by using allelochemicals and chemical elicitors. The increase in fruit resistance to fungal infection through the use of natural and low toxicity substances has become a more acceptable and an effective strategy for the management of pre- and postharvest fungal pathogens. The present findings concluded that Anar + Wax showed maximum growth inhibition (44.36 %), so it was recommended that for getting maximum growth inhibition percentage and minimum lesion diameter on fruit the combination of plant extracts with wax showed maximum growth reduction of pathogen, *P. digitatum* caused of citrus green mould.

Recommendations

The major challenge of the widespread use of alternatives to control green mould is to meet the requirement of a low production cost. Therefore, it is necessary to develop eco-friendly approaches with no or little toxicity that control post-harvest pathogens even when applied at low concentrations.

Future Prospective

More studies related to chemical elicitors and plant extracts concerning their mode of action might contribute to expand their application in the field and packinghouses.

Author's Contribution

Dr. Iqbal conceived the idea and supervised the experiment. Mr. Hafiz Abdullah Akbar executed the field visits and took the experimental data while Dr. Ghazanfar and Dr. Ahmed help to facilitate and guided the research activities in laboratory of Plant Pathology and Mr. Raza compiled the data and finalized the manuscript.

References

- Abo-Elnaga, H.I.G. 2013. Control of green mould of citrus by using *Trichoderma harzianum*, humic acid or garlic. *Archives of Phytopathology and Plant Protection*, 46: 1118-1126. <https://doi.org/10.1080/03235408.2012.760226>
- Agrios, G.N. 2005. Plant Pathology. London: Elsevier Academic Press.
- Ahmad, S., Iqbal, Z., Singh, Z. and Khangura, R. 2012. Management of citrus blue and green moulds through application of organic elicitors. *Australasian Journal Plant Pathology*. 41: 69- 77.
- Ahmad, I., Basra, S.M.A. and Wahid, A. 2014. Exogenous application of ascorbic acid, salicylic acid and hydrogen peroxide improves the productivity of hybrid maize at low temperature stress. *International Journal of Agriculture and Biology*, 16: 825-830.
- Al-Samarrai, G.F., Singh, H. and Syarhabil, M. 2013. Extracts some plants on controlling green mold of orange and on postharvest quality parameters. *World Applied Sciences Journal*, 22: 564-570.
- Ballester, A.R., Izquierdo, A., Lafuente, M.T. and González-Candela, L. 2010. Biochemical and molecular characterization of induced resistance against *Penicillium digitatum* in citrus fruit. *Postharvest Biology and Technology*, 56: 31-38. <https://doi.org/10.1016/j.postharvbio.2009.10.002>
- Bautista-Baños, S., Hernández-López, M., Díaz-Pérez, J.C. and Cano-Ochoa, C.F. 2000. Evaluation of the fungicidal properties of plant extracts to reduce *Rhizopus stolonifer* of 'ciruela'fruit (*Spondias purpurea* L.) during storage. *Postharvest Biology and Technology*, 20: 99-106. [https://doi.org/10.1016/S0925-5214\(00\)00109-5](https://doi.org/10.1016/S0925-5214(00)00109-5)
- Bergeron, C., Marston, A., Hakizamungu, E. and Hostettmann, K. 1995. Antifungal constituents of *Chenopodium procerum*. *International Journal of Pharmacognosy*, 33:115-119. <https://doi.org/10.3109/13880209509055209>
- Brown, G.E. 1979. Biology and control of *Geotrichum candidum* the cause of citrus sour rot. *Florida State Horticultural Society*, 92:186-189.
- Brown, G.E. 1989. Baseline sensitivity of Florida isolates of *Penicillium digitatum* to imazalil. *Plant Disease*, 73: 773-774. <https://doi.org/10.1094/PD-73-0773>

- Burt, S. 2004. Essential oils: their antibacterial properties and potential applications in foods a review. *International Journal of Food Microbiology*, 94: 223-253. <https://doi.org/10.1016/j.ijfoodmicro.2004.03.022>
- Calvo, J., Calvente, V., de Orellano, M.E., Benuzzi, D. and Sanz de Tosetti, M.I. 2007. Biological control of postharvest spoilage caused by *Penicillium expansum* and *Botrytis cinerea* in apple by using the bacterium *Rahnella aquatilis*. *International Journal of Food Microbiology*, 113: 251-257. <https://doi.org/10.1016/j.ijfoodmicro.2006.07.003>
- Cao, J.K., Zeng, K.F. and Jiang, W.B. 2006. Enhancement of postharvest disease resistance in Yali pear (*Pyrus bretschneideri*) fruit by salicylic acid sprays on the trees during fruit growth. *European Journal of Plant Pathology*, 114: 363-370. <https://doi.org/10.1007/s10658-005-5401-8>
- Cao, J.K., Bi, Y. and Li, Y.C. 2001. Effect of salicylic acid treatment on black spot and quality of harvested Pingguoli. *Journal of Gansu Agricultural University*, 36: 438-442.
- Cao, S., Hu, Z., Zheng, Y. and Lu, B. 2010. Synergistic effect of heat treatment and salicylic acid on alleviating internal browning in cold-stored peach fruit. *Postharvest Biology and Technology*, 58:93-97. <https://doi.org/10.1016/j.postharvbio.2010.05.010>
- Castillo, F., Hernández, D., Gallegos, G., Mendez, M., Rodríguez, R., Reyes, A. and Aguilar, C.N. 2010. *In vitro* antifungal activity of plant extracts obtained with alternative organic solvents against *Rhizoctonia solani* Kühn. *Industrial Crops and Products*, 32: 324-328. <https://doi.org/10.1016/j.indcrop.2010.05.013>
- Chauhan, P., Shivakuma, M.S., Muthusamy, R. and Kumar, D. 2011. Larvicidal activity of solvent leaf extracts of *Cassia fistula* (Linn.) and *Clerodendron inerme* (Gaer) on the *Spodoptera litura* (Insecta: Noctuidae): A potential botanical alternative. *Journal of Ecobiotechnology*, 3: 01-04. <https://updatepublishing.com/journal/index.php/jebt/article/view/179>
- Coates, L.M. and Johnson, G. 1997. Postharvest diseases of fruit and vegetables. In: *Plant Pathogens and Plant Diseases*. Rockvale Publications, Armidale, Australia, 533-548.
- Cohen, Y.R. 2002. β -aminobutyric acid-induced resistance against plant pathogens. *Plant Disease*, 86: 448-457. <https://doi.org/10.1094/PDIS.2002.86.5.448>
- Conway, W.S., Janisiewicz, W.J., Klein, J.D. and Sams, C.E. 1999. Strategy for Combining Heat Treatment, Calcium Infiltration, and Biological Control to Reduce Postharvest Decay of Gala Apples. *Hortscience*, 34: 700-704. <https://doi.org/10.21273/HORTSCI.34.4.700>
- Cun-fei, F.A.N., Yang, B.I., Yun-fei, W.A.N.G., Ya-lin, R.E.N., Zhi-min, Y.A.N.G. and Yi, W.A.N.G. 2012. Effect of salicylic acid dipping on postharvest diseases and phenylpropanoid pathway in muskmelon fruits. *Scientia Agricultura Sinica*, 3: 021.
- Cunningham, N.M. and Taverner, P.D. 2007. Efficacy of integrated postharvest treatments against mixed inoculations of *Penicillium digitatum* and *Geotrichum citri-aurantii* in 'leng' navel oranges (*Citrus sinensis*). *New Zealand Journal of Crop and Horticultural Science*, 35: 187-192. <https://doi.org/10.1080/01140670709510184>
- Curtis, H., Noll, U., Stormann, J. and Slusarenko, A.J. 2004. Broad-spectrum activity of the volatile phyto antocipinallicin in extracts of garlic (*Allium sativum* L.) against plant pathogenic bacteria, fungi and oomycetes. *Physiological and Molecular Plant Pathology*, 65: 79-89. <https://doi.org/10.1016/j.pmpp.2004.11.006>
- Dann, E., Diers, B., Byrum, J. and Hammerschmidt, R. 1998. Effect of treating soybean with 2, 6-dichloroisonicotinic acid (INA) and benzothiadiazole (BTH) on seed yields and the level of disease caused by *Sclerotinia sclerotiorum* in field and greenhouse studies. *European Journal Of Plant Pathology*, 104: 271-278. <https://doi.org/10.1023/A:1008683316629>
- Dessalegn, Y., Ayalew, A. and Woldetsadik, K. 2013. Integrating plant defense inducing chemical, inorganic salt and hot water treatments for the management of postharvest mango anthracnose. *Postharvest Biology and Technology*, 85: 83-88. <https://doi.org/10.1016/j.postharvbio.2013.05.003>
- Devi, A.N. and Arumugam, T. 2005. Studies on the shelf life and quality of Rasthali banana as affected by postharvest treatments. *Postharvest Biology and Technology*, 33: 3-6.
- Droby, S. 2006. Improving quality and safety of fresh fruit and vegetables after harvest by the use of biocontrol agents and natural materials. *International Symposium On Natural*

- Preservatives in Food Systems*, 709: 45–52. <https://doi.org/10.17660/ActaHortic.2006.709.5>
- Droby, S., Porat, R., Cohen, L., Weiss, B., Shapiro, B., Philosoph-Hadas, S. and Meir, S. 1999. Suppressing green mold decay in grapefruit with postharvest jasmonate application. *Journal Of The American Society For Horticultural Science*, 124: 184–188. <https://doi.org/10.21273/JASHS.124.2.184>
- Droby, S., Wisniewski, M.E., Macarasin, D. and Wilson, C. 2009. Twenty years of postharvest biocontrol research: is it time for a new paradigm? *Postharvest Biology and Technology*, 52: 137–145. <https://doi.org/10.1016/j.postharvbio.2008.11.009>
- Eckert, J.W. 1988. Dynamics of benzimidazole-resistant *Penicillia* in the development of postharvest decays of citrus and pome fruits. Fungicides resistance in North America. Delp, C.J. (Ed) *American Phytopathological Society St. Paul MN*. pp. 31–35.
- Eckert, J.W. 1990. Impact of fungicide resistance on citrus fruit decay control. In: Green MB, LeBaron HM, Moberg WK (eds) Managing resistance to agrochemicals, *American Chemical Society Symposium Series* 421, pp. 286–302. <https://doi.org/10.1021/bk-1990-0421.ch020>
- Eckert, J.W. and Eaks, I.L. 1989. Postharvest disorders and diseases of citrus fruits. *The Citrus Industry*, 5: 179–260.
- Eckert, J.W. and Ogawa, J.M. 1985. The chemical control of postharvest diseases: subtropical and tropical fruits. *Annual Review of Phytopathology*, 23: 421–54. <https://doi.org/10.1146/annurev.py.23.090185.002225>
- Eckert, J.W. and Ogawa, J.M. 1988. The chemical control of postharvest diseases: deciduous fruits, berries, vegetables and root tuber crops. *Annual Review of Phytopathology*, 26: 433–469. <https://doi.org/10.1146/annurev.py.26.090188.002245>
- Eckert, J.W., Sievert, J.R. and Ratnayake, M. 1994. Reduction of imazalil effectiveness against citrus green mold in California packing houses by resistant biotypes of *Penicillium digitatum*. *Plant Disease*, 78: 971–974. <https://doi.org/10.1094/PD-78-0971>
- El Ghaouth, A., Arul, J., Asselin, A. and Benhamou, N. 1997. Biochemical and cytochemical events associated with the interaction of chitosan and *Botrytis cinerea* in bell pepper fruit. *Postharvest Biology and Technology*, 12: 183–194. [https://doi.org/10.1016/S0925-5214\(97\)00056-2](https://doi.org/10.1016/S0925-5214(97)00056-2)
- El-Ghaouth A., Smilanick J.L., Wilson C.L. 2000. Enhancement of the performance of *Candida sitona* by the addition of glycolchitosan for the control of postharvest decay of apple and citrus fruit. *Postharvest Biology and Technology*, 19: 103–110. [https://doi.org/10.1016/S0925-5214\(00\)00076-4](https://doi.org/10.1016/S0925-5214(00)00076-4)
- El-Ghaouth, A., Wilson, C.L. and Wisniewski, M.E. 2004. Biologically based alternatives to synthetic fungicides for the postharvest diseases of fruit and vegetables. In: Naqvi, S.A.M.H. (Ed.), *Diseases of Fruit and Vegetables*, vol. 2. Kluwer Academic Publishers, *The Netherlands*, pp. 511–535. https://doi.org/10.1007/1-4020-2607-2_14
- El-Mougy, N.S. 2002. In vitro studies on antimicrobial activity of salicylic acid and acetylsalicylic acid as pesticidal alternatives against some soil borne plant pathogens. *Egyptian Journal of Phytopathology*, 30: 41–55.
- El-Mougy, N.S., El-Gamal, N.G. and Abd-El-Kareem, F. 2008. Use of organic acids and salts to control postharvest diseases of lemon fruits in Egypt. *Archives of Phytopathology and Plant Protection*, 41: 467–476. <https://doi.org/10.1080/03235400600813532>
- Gatto, M.A., Ippolito, A., Linsalata, V., Cascarano, N.A., Nigro, F., Vanadia, S. and Di Venere, D. 2011. Activity of extracts from wild edible herbs against postharvest fungal diseases of fruit and vegetables. *Postharvest Biology and Technology*, 61: 72–82. <https://doi.org/10.1016/j.postharvbio.2011.02.005>
- Hernández, C.F.D., Lira, S.R.H., Cruz, C.L., Gallegos, M.G., Galindo, C.M.E., Padrón, C.E. and Hernández, S.M. 2008. Antifungal potential of *Bacillus* spp. strains and *Larreatri dentata* extract against *Rhizoctonia solani* on potato (*Solanum tuberosum* L.) crop. *International Journal Of Experimental Botany*, 77: 241–252.
- Ikeura, H., Somsak, N. and Kabayashi, F. 2011. Application of selected plant extracts to inhibit growth of *Penicillium expansum* on apple fruit. *Plant Pathology*, 10: 79–84. <https://doi.org/10.3923/ppj.2011.79.84>
- Ippolito, A. and Nigro, F. 2003. Natural antimicrobials in postharvest storage of fresh fruit and vegetables. In: Roller, S. (Ed.), *Natural Antimicrobials for the Minimal Processing of Foods. Natural Antimicrobials for The Minimal*

- Processing of Foods, pp. 201-234. <https://doi.org/10.1533/9781855737037.201>
- Ippolito, A., El-Ghaouth, A., Wilson, C.L. and Wisniewski, M.A. 2000. Control of postharvest decay of apple fruit by *Aureobasidium pullulans* and induction of defense responses. *Postharvest Biology And Technology*, 19: 265-272. [https://doi.org/10.1016/S0925-5214\(00\)00104-6](https://doi.org/10.1016/S0925-5214(00)00104-6)
- Iqbal, Z., Singh, Z., Khangura, R. and Ahmad, S. 2012. Management of citrus blue and green moulds through application of organic elicitors. *Australasian Plant Pathology*, 41: 69-77. <https://doi.org/10.1007/s13313-011-0091-5>
- Janisiewicz, W.J. 2004. Control of Postharvest Diseases of Fruits Using Microbes. Fungal biotechnology in agricultural, food, and environmental applications. US department of agriculture-agriculture research service, Kearneysville, West Virginia, USA: 173.
- Janisiewicz, W.J., Tworowski, T.J., Sharer, C. 2000. Characterizing the mechanism of biological control of postharvest diseases on fruits with a simple method to study competition for nutrients. *Phytopathology*, 1: 1196-1200. <https://doi.org/10.1094/PHYTO.2000.90.11.1196>
- Jasso de Rodríguez, D., Hernández, C.F.D., Angulo, S.J.L., Rodríguez, G.R., Villarreal, Q.J.A. and Lira, S. R.H. 2007. Antifungal activity in vitro of *Flourensia* spp. extracts on *Alternaria* sp., *Rhizoctonia solani*, and *Fusarium oxysporum*. *Industrial Crops and Products*. 25: 111-116. <https://doi.org/10.1016/j.indcrop.2006.08.007>
- Jayaprakash, G.K., Negi, P.S. and Jena, B.S. 2006. Antimicrobial activities of pomegranate. In: N.P. Seeram, R.N. Schulman, D. Heber (eds.): Pomegranates: Ancient Roots to Modern Medicine. CRC Press, Boca Raton, FL, USA, pp.167-183.
- Korsten, L. 2006. Advances in control of postharvest diseases in tropical fresh produce. *International Journal of Postharvest Technology and Innovation*, 1: 48-61. <https://doi.org/10.1504/IJPTI.2006.009181>
- Leroux, P. 2003. Mode of action of agrochemical towards plant pathogens. *Comptes Rendus Biologies*, 326:9-21. [https://doi.org/10.1016/S1631-0691\(03\)00005-2](https://doi.org/10.1016/S1631-0691(03)00005-2)
- Leroux, P. 2003. Mode of action of agrochemical towards plant pathogens. *Comptes Rendus Biologies*, 326: 9-21. [https://doi.org/10.1016/S1631-0691\(03\)00005-2](https://doi.org/10.1016/S1631-0691(03)00005-2)
- Lira, S.R.H., Balvanti, G.G.F., Hernández, C.F.D., Gamboa, A.R., Jasso-de Rodríguez, D. and Jiménez, D. H. 2003. Evaluation of resin content and the antifungal effect of *Larreatridentata* (Sesse and Moc. Ex DC) Coville extracts from two Mexican deserts against *Pythium* sp. Pringsh. *Revista Mex. Revista Mexicana De Fitopatología*, 21: 97-101.
- Lopez-Reyes, J.G., Spadaro, D., Prella, A., Garibald, A. and Gullino, M.L. 2013. Efficacy of plant essential oils on postharvest control of rots caused by fungi on different stone fruits *in vivo*. *Journal Of Food Protection*, 6: 631-639. <https://doi.org/10.4315/0362-028X.JFP-12-342>
- Mari, M., Neri, F. and Bertolini, P. 2007. Novel Approaches to Prevent and Control Postharvest Diseases of Fruit. *Stewart Postharvest Review*, 3:1-7. <https://doi.org/10.2212/spr.2007.6.4>
- Mari, M., Neri, F. and Bertolini, P. 2010. New approaches for postharvest disease control in Europe. In: Prusky, D., Gullino, M.L. (Eds.), Postharvest Pathology. Springer, The Netherlands, pp. 119-135.
- Mills, A.A.S., Platt, H.W. and Hurta, R.A.R. 2004. Effect of salt compounds on mycelial growth, sporulation and spore germination of various potato pathogens. *Postharvest Biology and Technology*. 34: 341-350. <https://doi.org/10.1016/j.postharvbio.2004.05.022>
- Moscato-Ramírez, P.A. and Palou, L. 2013. Evaluation of postharvest treatments with chemical resistance inducers to control green and blue molds on orange fruit. *Postharvest Biology and Technology*. 85: 132-135. <https://doi.org/10.1016/j.postharvbio.2013.05.013>
- Musto, M., Giovanna, P. and Francesco, C. 2014. Inhibition of *Penicillium digitatum* by a crude extract from *Solanum nigrum* leaves. *Biotechnology, Agronomy, Society and Environment*, 18: 174-180.
- Obagwu, J. and Korsten, L. 2003. Control of citrus green and blue molds with garlic extracts. *European Journal of Plant Pathology*, 109:221-225. <https://doi.org/10.1023/A:1022839921289>
- Obagwu, J., Emechebe, A.M. and Adeoti, A.A. 1997. Effects of extracts of garlic (*Allium sativum* L.) bulb and neem *Azadirachta indica* Juss seed on mycelial growth and sporulation

- of *Collectorichum capsici*. *Journal of Agricultural Technology*, 5: 51-55.
- Olivieri, F.P., Lobato, M.C., Altamiranda, E.G., Daleo, G.R., Huarte, M., Guevara, M.G. and Andreu, A.B. 2009. BABA effects on the behaviour of potato cultivars infected by *Phytophthora infestans* and *Fusarium solani*. *European Journal of Plant Pathology*, 123: 47-56. <https://doi.org/10.1007/s10658-008-9340-z>
- Orober, M., Siegrist, J. and Buchenauer, H. 2002. Mechanisms of phosphate-induced disease resistance in cucumber. *European Journal of Plant Pathology*, 108: 345-353. <https://doi.org/10.1023/A:1015696408402>
- Osorio, E., Flores, M., Hernández, D., Ventura, J., Rodríguez, R. and Aguilar, C.N. 2010. Biological efficiency of polyphenolic extracts from pecan nuts shell (*Carya illinoensis*), pomegranate husk (*Punica granatum*) & creosote bush leaves (*Larrea tridentate* Cov.) against plant pathogenic fungi. *Industrial Crops and Products*, 31:153-157. <https://doi.org/10.1016/j.indcrop.2009.09.017>
- Palou, L. 2009. Control of citrus postharvest diseases by physical means. *Tree And Forestry Science And Biotechnology*, 3: 127-142.
- Palou, L., Smilanick, J.L. and Droby, S. 2008. Alternatives to conventional fungicides for the control of citrus postharvest green and blue moulds. *Stewart Postharvest Review*, 4: 1-16.
- Palou, L., Usall, J., Munoz, J.A., Smilanick, J.L. and Vinas, I. 2002. Hot water, sodium carbonate, and sodium bicarbonate for the control of postharvest green and blue molds of clementine mandarins. *Postharvest Biology and Technology*, 24: 93-96. [https://doi.org/10.1016/S0925-5214\(01\)00178-8](https://doi.org/10.1016/S0925-5214(01)00178-8)
- Panahirad, S., Zaare-Nahandi, F., Safaralizadeh, R. and Alizadeh- Salteh, S. 2012. Postharvest control of *Rhizopus stolonifer* in Peach (*Prunuspersica* L. Batsch) fruits using salicylic acid. *Journal of Food Safety*, 32: 502-507. <https://doi.org/10.1111/jfs.12013>
- Parello, A., Gruhlke, M. and Slusarenko, A.J. 2013. Effect of garlic extract on seed germination, seedling health and vigour of pathogen-infected wheat. *JOURNAL OF PLANT PROTECTION RESEARCH*. 53: 317-323. <https://doi.org/10.2478/jppr-2013-0048>
- Pusey, P.L. 1994. Enhancement of biocontrol agents for postharvest disease and their integration with other control strategies. In: Wilson, C.L. and M.E. Wisniewski (Ed) Biological control of postharvest diseases. *CRC press, Boca Raton*, pp. 77-88.
- Reglinski, T., Lyon, G.D. and Newton, A.C. 1994. Assessment of the ability of yeast-derived elicitors to control barley powdery mildew in the field. *Journal of Plant Diseases and Protection*, 101:1-10.
- Rosslénbroich, H.J. and Stuebler, D. 2000. Botrytis cinerea—history of chemical control and novel fungicides for its management. *Crop Protection*, 19: 557-561. [https://doi.org/10.1016/S0261-2194\(00\)00072-7](https://doi.org/10.1016/S0261-2194(00)00072-7)
- Seeram, N.P., Schulman, R.N. and Heber, D. 2006. Pomegranates: Ancient Roots to Modern Medicine. *CRC Press, Boca Raton, FL, USA*.
- Sharma, R.R., Singh, D., Singh, R. 2009. Biological control of postharvest diseases of fruits and vegetables by microbial antagonists: A review. *Biological Control*, 50: 205-221. <https://doi.org/10.1016/j.biocontrol.2009.05.001>
- Sinha, P. and Saxena, S.K. 1999. Inhibition of fruit rot fungus and fruit fly by leaf extracts of onion (*Allium cepa*) and garlic (*Allium sativum*). *Indian Journal of Agricultural Sciences*, 69: 651-653.
- Smilanick, J.L. and Denis-Arrue, R. 1992. Control of green molds of lemons with *Pseudomonas* species. *Plant Disease*, 76: 481-485. <https://doi.org/10.1094/PD-76-0481>
- Smilanick, J.L., Mansour, M.F. and Sorenson, D. 2006. Pre- and postharvest treatments to control green mold of citrus fruit during ethylene degreening. *Plant Disease*, 90: 89-96. <https://doi.org/10.1094/PD-90-0089>
- Snowdon, A.L. 2010. Post-harvest diseases and disorders of fruits and vegetables: Volume 2: Vegetables (Vol. 2). *Manson Publishing*. p. 80.
- Snowdon, A.L. 1990. A colour atlas of postharvest diseases and disorders of fruits and vegetables. *Wolfe Scientific, Spain*.
- Stephan, D., Schmitt, A., Carvalho, S.M., Seddon, B. and Koch, E. 2005. Evaluation of biocontrol preparations and plant extracts for the control of *Phytophthora infestans* on potato leaves. *European Journal of Plant Pathology*, 112: 235-246. <https://doi.org/10.1007/s10658-005-2083-1>
- Sticher, L., Mauch-Mani, B. and Métraux, A.J. 1997. Systemic acquired resistance. *Annual Review of Phytopathology*, 35: 235-270. <https://doi.org/10.1007/s10658-005-2083-1>

- doi.org/10.1146/annurev.phyto.35.1.235
- Sukorini, H., Sangchote, S. and Khewkhom, N. 2013. Control of postharvest green mold of citrus fruit with yeasts, medicinal plants, and their combination. *Postharvest Biology and Technology*, 79: 24-31. <https://doi.org/10.1016/j.postharvbio.2013.01.001>
- Tayel, A.A., El-Baz, A.F., Salem, M.F. and El-Hadary, M.H. 2009. Potential applications of pomegranate peel extract for the control of citrus green mould. *Journal of Plant Diseases and Protection*, 116: 252-256. <https://doi.org/10.1007/BF03356318>
- Terry, L.A. and Joyce, D.C. 2004. Elicitors of induced disease resistance in postharvest horticultural crops: a brief review. *Postharvest Biology and Technology*, 32: 1-13. <https://doi.org/10.1016/j.postharvbio.2003.09.016>
- Tunwari, B.A. and Nahunnaro, H. 2014. Effects of botanical extracts and a synthetic fungicide on severity of cercospora leaf spot (*Cercospora SesameZimm*) on sesame (*Sesamum Indicum* L.) yield attributes under screen house condition InArdo-Kola, Taraba State, Nigeria. *International Journal Of Scientific & Technology Research*, 3: 17-22.
- Wilson, C.L., ElGhaouth, A. and Wisniewski, M.E. 1999. Prospecting in nature's storehouse for biopesticides. *Mexico Journal of Phytopathology*, 17: 49-53.
- Yaghmour, M.A., Bostock, R.M., Morgan, D.P. and Michailides, T.J. 2012. Biology and sources of inoculum of *Geotrichum candidum* causing sour rot of peach and nectarine fruit in California. *Plant Disease*, 96: 204-210. <https://doi.org/10.1094/PDIS-09-11-0796>
- Yan, Z., Reddy, M.S., Ryu, C.M., McInroy, J.A., Wilson, M. and Kloepper, J.W. 2002. Induced systemic protection against tomato late blight elicited by plant growth-promoting rhizobacteria. *Phytopathology*, 92: 1329-1333. <https://doi.org/10.1094/PHYTO.2002.92.12.1329>
- Yao, H. and Tian, S. 2005. Effects of pre-and post-harvest application of salicylic acid or methyl jasmonate on inducing disease resistance of sweet cherry fruit in storage. *Postharvest Biology and Technology*. 35: 253-262. <https://doi.org/10.1016/j.postharvbio.2004.09.001>
- Zamani, M., Sharifi, A., Tehrani, Ahmadzadeh, M., Hosseininaveh, V. and Mostofy, Y. 2009. Control of *Paniclium digitatum* on orange fruit combining *Pantoea gglomerans* with hot sodium bicarbonate dipping. *Journal of Plant Pathology*, 91: 437-442.