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CHEMICAL CONTROL OF FUNGAL DISEASES OF STORED *SOLANUM LYCOPERSICUM* FRUIT BY POTASSIUM BICARBONATE AND CALCIUM CHLORIDE

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A B S T R A C T

The present study was carried out to see the effect of potassium bicarbonate and calcium chloride to control post-harvest diseases caused by fungi in stored tomato (*Solanum lycopersicum* L.). Samples of tomato fruit were collected from different places of Rawalpindi district. Eight fungal species namely *Alternaria alternata*, *Aspergillus niger*, *Cladosporium fulvum*, *Fusarium oxysporum*, *Penicillium oxalium*, *Rhizopus stolonifer*, *Mucor racemosus* and *Botrytis cinerea* were found in the samples. It was found that among the eight fungal species, *M. racemosus* and *B. cinerea* were responsible for significant spoilage and weight loss of stored tomato. Potassium bicarbonate and calcium chloride were applied to these samples at different concentrations viz. 1.5, 2.5 and 3%. It was found that potassium bicarbonate at 2.5% concentration resulted in 6.66% spoilage and 11% weight loss. While it was found that when concentrations of calcium chloride ($CaCl_2$) was increased from 1.5-3.5%, the degree of spoilage and weight loss decreased significantly as well. The results revealed that gradual increase in concentration of applied chemical decreased the degree of spoilage and weight loss in stored tomato.

Keywords: Calcium chloride, potassium bicarbonate, spoilage, tomato, weight loss.

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is a summer vegetable crop belongs to family Solanaceae (Saleem *et al.,* 2013a). It constitutes chiefly vitamin A, C, E and minerals i.e. Ca, P and Fe (Dhaliwal *et al.,* 2003). It is rich in antioxidants such as carotenoids (lycopene and β-carotene) (Berry, 2007) and phenolics (Rai *et al.,* 2012). It is used as an essential ingredient in preparation of several dishes and sauces (Saleem *et al.,* 2013b). In 2011 it was grown on an area of 52.3 thousand hectare in Pakistan. The 20% of the total area under vegetable cultivation constitutes *S. lycopersicum*. During last decade, the average productivity of tomato crop was 9.5-10.5 ton/ha in Pakistan (Anonymous, 2011). In modern agricultural areas the average productivity of tomato crop 33.6 ton/ha (Anonymous, 2013). There are many yield limiting constraints in *S. lycopersicum* crop production. In Pakistan, major factors for yield losses are lack of quality seed, biotic stresses (early blight, late blight, cucumber mosaic virus, aphid, fruit borer etc.), abiotic stresses (frost, heat, drought etc.) (Akhtar *et al.,* 2012). Disease and insect pest attack *owing* to imported tomato seed. So there is a need to grow and develop the pest resistant varieties (Saleem *et al.,* 2013b).

The fungal diseases during postharvest stage can cause 50% yield loss of entire product (Ippolito *et al.,* 2005). The fungal species which are responsible for diseases in stored tomato fruit are *Alternaria alternata* (Feng and Zheng, 2007), *Botrytis cinerea* (Lee *et al.,* 2006) and *Rhizopus stolonifer* (Schena *et al.,* 1999) *Monilinia* spp., *Cladosporium* spp., *Penicillium expansum* and *Mucor* spp. (Ogawa *et al.,* 1995). *R. stolonifer, A. alternata* and *B. cinerea* are most common fungal species (Wang *et al.,* 2008). *A. alternata* causes black rot at high frequency in tomato (Akhtar *et al.,* 1994). *B. cinerea* is commonly known as grey mould which is a serious fungal disease in tomato worldwide (Elad *et al.,* 1995). *B. cinerea* results destructive leaf, infections in vegetative parts, which eventually results yield losses (Menzies and Jarvis, 1994). It was reported that *R. stolonifer* spreads rapidly from the infected to adjacent fruits when the temperature is higher

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than 5°C (Ogawa *et al.,* 1995). Chemical control of *B. cinerea* involves the use of dicarboximides and benzimidazoles, but their intensive use is sometimes difficult and incomplete. The reason is the development of resistance of *B. cinerea* towards these chemicals (Elad *et al.,* 1992; Holmes and Eckert, 1999).

Sometimes use of synthetic fungicides i.e. 1- MCP (Guillen *et al.,* 2007), chitosan (Liu *et al.,* 2007), essential oils (Tzortzakis, 2007) and microbial antagonist (Xi and Tian, 2005) are used to control postharvest decay of tomato fruit. It was reported that use of fungicides is successful for control the postharvest vegetable loss but its use for a long period of time results in development of resistant strains (Rosslenbroich and Stuebler, 2000; Wang *et al.,* 2008). To meet the public demand of tomato we must decrease the intensive pesticide use and search for alternative control strategies to control fungal diseases (Mónaco *et al.,* 2013). There are many biocontrol agents which are effective against *B. cinerea* on tomato and other vegetable crops (Nicot *et al.,* 2000). These include *Trichoderma* spp. and *Gliocladium* spp., *Fusarium* sp., *Ulocladium atrum*, *Cladosporium* spp. and *Penicillium* spp. (Nicot *et al.,* 2000). Sometimes natural substances (Ippolito and Nigro, 2003), physical treatments (Juneja and Thayer, 2001) and organic or inorganic salts (Palou *et al.,* 2002) are also used.

Graham (1983) found that nutrients like calcium (Ca), boron (B) and phosphorus (P) are very important components to protect tomato plants against bacterial and fungal pathogens. It is necessary to use integrated control strategy against fungal species rather than single approach (Conway *et al.,* 2005). Bushra *et al.* (2013) reported that postharvest losses due to pest attack can be managed when good storage practices are adapted. Therefore, the present study was carried out to see the effect of potassium bicarbonate and calcium chloride to control postharvest diseases caused by microflora in stored tomato.

MATERIALS AND METHODS

Sample collection: Healthy and fully ripened tomato fruits were collected from market area of Pirwadae, Bakramandi and Saawan. From each market area 25 tomato samples were collected by using cluster random sampling technique.

Isolation by humid chamber technique: All the experiments were carried out in Department of Plant Pathology, Pir Mer Ali Shah, Arid Agriculture University, Rawalpindi, Pakistan. Five sterilized humid chambers for each location were used for fungi isolation. Hundred milliliter autoclaved distilled water was added in sterilized humid chambers to make humid environment in it. Five tomatoes were placed in each sterilized humid chamber without any washing. These chambers were placed at 25°C temperature for 5day interval. After 5 days, fungal growth was observed on fruit samples.

Fungi isolation was carried out by blotter method described by ISTA (ISTA, 1985). In this method sterile laminar flow was used. The infected tissues from periphery of each rotten tomato were cut in to 4 pieces (3-5 cm) by fine sterilized scalpel. These pieces were cultured out on potato dextrose medium (PDA) and Malt extract medium plates. The inoculated plates were incubated at 25 °C for 24 hr. Fungi produced was isolated and cultured to media plates to obtain pure culture and incubated for 3 days at 25 °C.

Detection of fungal flora: The incubated plates containing isolated fungal flora were examined under microscope at 10, 20, 40x for specie identification. The identification key derived by Samson *et al.* (2002) was followed.

Pathogenicity test: Pathogenicity test was performed by the method described by Kutama *et al.* (2007). Pathogenicity test was carried out for identification of pathogenic and nonpathogenic mycoflora. Healthy and fully ripened tomato fruits were used for incisions by using sterile 4mm cork borer. For inoculation of fungal mycelia in healthy tomatoes, Akin sterile cork borer was used to cut pallets of potato dextrose agar medium containing identified fungal cultures. Hole present on one side of each replicate was filled with identified fungal isolates in a laminar flour chamber. The inoculated gash was sealed with petroleum jelly to avoid being contaminated by opportunistic microorganisms. The incisions of water on healthy tomato fruits were inoculated as control. The inoculated material was placed in a clean sterilized polythene bags (three fruits/bag). Water soaked absorbent cotton was used to craft a humid environment and incubated for 5 days at 25°C. The inoculated fruits were observed after 5 days. The causal agents were re isolated from infected fruits and their morphological characteristics were compared with original isolates.

Chemical treatment: The efficacy of Potassium bicarbonate ($KHCO_3$) and calcium chloride ($CaCl_2$) formulations was tested by method described by (Bombelli and Wright, 2006). These chemical

formulations were applied on fungal isolates (*Mucor racemosus* and *Botrytis cineria*) on tomato fruit samples. The solutions were allowed to air dry for 3 minutes. Then, inoculation was applied with a suspension of *M. racemosus* and *B. cineria* conidia which was prepared in autoclaved distilled water by using 10 day old PDA cultures and inoculums. The PDA cultures and inoculum load was adjusted to 6.5×10^5 conidia ml/L. Each sample was inoculated by puncturing the pericarp on two opposite sides of fruit equatorial region. For inoculation, sterilized tooth picks were allowed to submerge in the conidial suspension and introduced for incisions at a distance around 3mm spaced out (Yabuki *et al.,* 1997; Sato *et al.,* 1997). Weight of all treated fruits was measured and placed in sterilized humid chambers contained 100 ml autoclaved distilled water. The treated material was incubated at 25 °C, and one daily observation was taken till 14th day. The efficacy of potassium bicarbonate and calcium chloride was measured on the basis of these observations.

Amount of spoiled fruits: The fruits which have abnormalities on their surface more than 10% due to *M. racemosus* and *B. cineria* attack were considered and counted as spoiled fruits (Aharoni *et al.,* 1997).

Loss in fruit weight: The fruit samples were weighted prior and after the chemical treatment.

Statistical Analysis

Data regarding to chemical treatment, fruit weight and spoilage was subjected to statistical analysis using ($p\leq0.05$) level of probability. DMR test was applied and means are separated using software "Statistical analysis system" (Freund *et al.,* 1986).

RESULTS AND DISCUSSIONS

Fungal prevalence at different locations: During isolation and identification, eight fungal species were identified on 25 samples in three replications from each site (Table 1). These fungal species were *A. alternata*, *A. niger*, *Cladosporium fulvum*, *F. oxysporum*, *P. oxalium*, *Rhizopus stolonifer*, *Mucor racemosus* and *Botrytis cinerea.* Baiyewu *et al.* (2007) reported that when *Aspergillus spp.* and *Rhizopus spp.* were isolated from tomato fruit, these species can cause soft rot in tomato. Efiuvwerwere (2000) found and identified the *Cladosporium* and *Alternaria* fungal species on tomato fruit. Onyia *et al.* (2005) isolated *F. oxysporum, A. niger* and *Rhizopus stolonifer* from rotten tomato. Chuku *et al.* (2008) reported the incidence of three fungal species i.e. *Fusarium, Penicillium* and *Mucor* in postharvest tomato fruits.

Postharvest loss assessment: About 50% weight loss was found due to attack of different fungal genera in Peerwadhai. But in Bakramandi and Sawan, the percent weight loss was up to 38% and 17% respectively.

Fungal species identified from isolates: Out of 109 isolates, 8 fungal species were characterized, 6 isolates were resembled to *A. alternata,* 5 isolates were related to *A. niger,* 6 isolates were associated to *Cladosporium fulvum,* 9 isolates were the member of *F. oxysporum,* 11 isolates were found as the member of *Penicillium oxalium,* 8 isolates shown the characteristics of *Rhizopus stolonifer,* 29 isolates have the identification characters of *Mucor racemosus,* 35 isolates were associated with *B. cinerea* (Table 2).

Table 1. Prevalence of Fungal Genra at different locations.

S/No.	Pathogens	Peerwadhai (%)	Bakramandi (%)	Saawan (%)	Total Mean (%)
1	*Alternaria alternata*	16	8	0	8
2	*Aspergillus niger*	20	0	0	20
3	*Cladosporium fulvum*	24	0	0	24
4	*Fusarium oxysporum*	28	0	8	12
5	*Penicillium oxalium*	20	4	20	14.6
6	*Rhizopus stolonifer*	24	0	8	10.6
7	*Mucor racemosus*	60	28	28	38.6
8	*Botrytis cinerea*	80	36	24	46.6
	Total Mean (%)	34	12	11	

Site Comparison: The data regarding to occurrence of fungal mycoflora in three sites was subjected to Analysis of variance in a complete randomized block design using ($p\leq0.05$) and their means were compared. It was found that (Site1) was statistically significantly different from (Site 2) and (Site 3) with mean value 9.12 (Table 3). The (Site 1) indicated the higher degree of prevalence of fungal mycoflora as compared to (Site 2) and (Site 3). It was found that prevalence of *M. racemosus* and *B. cinerea* were statistically at par to each other with mean value 3.11 and 3.33 respectively (Table 3). While other fungal species including *A. alternata*, *A. niger*, *C. fulvum*,

F. oxysporum, *P. oxalium*, *R. stolonifer* were statistically low as compared to *M. racemosus* and *B. cinerea.* The results revealed that *M. racemosus* and *B. cinerea* fungal species were dominant as compared to other six isolated fungi. The mycoflora which was identified from test sample is normally present in vegetable garbage and spoiled fruits. It was found that a lot of damp fruits were present in the (Site 1). Hameed *et al.* (2008) found that when unhygienic or messy water is used for irrigation of vegetables, the fungal mycoflora can be established.

Table 2. Fungal species identified from isolates of different locations.

S/No.	Species identified	Isolates
1	*Alternaria alternate*	6 isolates (AsPrw1, AsPrw2, AsPrw3, AsPrw4, Aabk1, Aabk2)
2	*Aspergillus niger*	5 isolates (AsPrw1, AsPrw2, AsPrw3, AsPrw4, AsPrw5)
3	*Cladosporium fulvum*	6 isolates (Clprw1, Clprw2, Clprw3, Clprw4, Clprw5, Clprw6)
4	*Fusarium oxysporum*	9 isolates (Fuprw1, Fuprw2, Fuprw3, Fuprw4, Fuprw5, Fuprw6, Fuprw7, FuSu1, FuSu2)
5	*Penicillium oxalium*	11 isolates (Pnprw1, Pnprw2, Pnprw3, Pnprw4, Pnprw5, PnBk1, PnSw1, PnSw2, PnSw3, PnSw4, PnSw5)
6	*Rhizopus stolonifer*	8 isolates (Rhprw1, Rhprw2, Rhprw3, Rhprw4, Rhprw5, Rhprw6, RhSw1, RhSw2)
7	*Mucor racemosus*	29 isolates (Muprw1, Muprw2, Muprw3, Muprw4, Muprw5, Muprw6, Muprw8, Muprw9, Muprw10, Muprw11, Muprw12, Muprw13, Muprw14, Muprw15, MuBk1, MuBk2, MuBk3, MuBk4, MuBk5, MuBk6, MuBk7, MuSw1, MuSw2, MuSw3, MuSw4, MuSw5, MuSw6, MuSw7)
8	*Botrytis cinerea*	35 isolates (BoPrw1, BoPrw2, BoPrw3, BoPrw4, BoPrw5, BoPrw6, BoPrw7, BoPrw8, BoPrw9, BoPrw10, BoPrw11, BoPrw12, BoPrw13, BoPrw14, BoPrw15, BoPrw16, BoPrw17, BoPrw18, BoPrw19 BoPrw20, BoBk1, BoBk2, BoBk3, BoBk4, BoBk6, BoBk7, BoBk8, BoBk9, BoSw1, BoSw2, BoSw3, BoSw4, BoSw5, BoSw6)

Pathogenecity of the isolates: The pathogenicity was calculated by the method described by Kutama *et al.* (2007). It was found that eight fungal species isolated namely *A. alternata*, *A. niger*, *C. fulvum*, *F. oxysporum*, *P. oxalium*, *R. stolonifer*, *M. racemosus* and *B. cinerea* tend to show different level of pathogenicity. The fungal isolates namely *M. racemosus* and *B. cinerea* were pathogenic among eight fungal species. The fungal species *M. racemosus* and *B. cinerea* were able to produce same spoilage signs when re inoculated. While *A. alternata*, *A. niger*, *C. fulvum*, *F. oxysporum*, *P. oxalium*, *R. stolonifer* were found to be non-pathogenic.

Efficacy of applied Chemicals: Potassium bicarbonate ($KHCO_3$) and calcium chloride ($CaCl_2$) were applied at different concentrations in test samples. About 100% spoilage (soft rotting) and weight loss was calculated in untreated tomato samples within 14 days. Purwadaria and Sinaga (2007) tested the efficacy of potassium bicarbonate at 2.5% concentration. They found significant results with 6.66% spoilage and 11% weight loss. Bombelli and Wright (2006) reported that 3.5% concentration of potassium bicarbonate applied can give the more significant results as compared to 1.5% concentration. But concentration must be increased up to a certain level. Table 4 shows that when the 3.5% of chemical concentration was applied, the deformity in fruit morphology and a significant weight loss was resulted.

Table 3. Comparison of three different locations in collection of mycoflora.

Isolate	Site 1	Site 2	Site 3	Grand Mean Isolates
1	5.33	2	0.33	2.556a
2	5.67	0.33	0.33	2.111a
3	22	8.67	7.67	12.778b
4	5.67	0	0.33	2a
5	7.33	0.67	1	3a
6	15.33	7.33	7.67	10.111b
7	6	1	2.33	3.111a
8	5.67	1.67	2.67	3.333a
Grand Mean Sites	9.125b	2.708a	2.792a	

Site LSD =0.735; Fungi LSD =3.556

Table 4. Effect of calcium chloride treatment on Spoilage and weight loss.

$CaCl_2$ (%)	*Botrytis cineria*		*Mucor racemosus*	
	Sp (%)*	Wg (%)**	Sp (%)*	Wg (%)**
0	100	100	100	100
1.5	86.66	90	93	99
2.5	46.66	51	60	68
3.5	33.33	39	46.66	52

Sp**= Mean % of tomato fruit; Wg**= Mean % weight loss of tomato fruit

It was found that when concentration of calcium chloride ($CaCl_2$) is increased from 1.5-3.5%, the degree of spoilage and weight loss decreases significantly (Table 4). Mahmud *et al.* (2008) reported that calcium chloride ($CaCl_2$) applied at different concentrations gave the significant results to control fungal species in stored fruits.

It was found that the potassium bicarbonate ($KHCO_3$) formulations applied at 2.5% concentration gave the significant results to control *M. racemosus* and *B. cinerea* for 14 days. While calcium chloride ($CaCl_2$) formulations applied at 3.5% gave the significant results to control *M. racemosus* and *B. cinerea* for 14 days (Table 4). These concentrations can retain the quality of tomato fruit commercially. When potassium bicarbonate ($KHCO_3$) was applied at 2.5% concentration, similar significant results were found in pepper (Fallik *et al.,* 1997) and melon fruit (Aharoni *et al.,* 1997).

CONCLUSION

Spoilage and rottening are important factors responsible for postharvest losses in stored tomato. Many disease controls have been devised yet but not in reach of common tomato producer and seller. Though, the only reliable and safe method to control postharvest diseases caused by fungal microflora is use of potassium bicarbonate ($KHCO_3$) and calcium chloride ($CaCl_2$). These chemicals are also safer to human health as well as increase the shelf life of stored produce.

REFERENCES

Aharoni, Y., E. Fallik, A. Copel, M. Gil, S. Grinberg and J.D. Klein. 1997. Sodium bicarbonate reduces postharvest decay development on melons. Postharvest Biol. Technol. 10: 201-206.

Akhtar, K.P., M. Matin, J.H. Mirza, A.S. Shakir and M. Rafique. 1994. Some studies on the postharvest diseases of tomato fruits and their chemical control. Pak. J. Phytopathol. 6: 125-129.

Akhtar, K.P., M.Y. Saleem, M. Asghar, S. Ali, N. Sarwar and M.T. Elahi. 2012. Resistance of *Solanum* species to *Phytophthora infestans* evaluated in the detached-leaf and whole-plant assays. Pak. J. Bot. 44: 1141-1146.

Alam, S.S., K. Sakamoto and K. Inubushi. 2011. Biocontrol efficiency of Fusarium wilt diseases by a root-colonizing fungus *Penicillium sp*. Soil Sci. Plant Nutr. 57: 204-212.

Anonymous. 2011. Agricultural Statistics of Pakistan. Government of Pakistan. Ministry of Food, Agriculture and Livestock. Islamabad.

Anonymous. 2013. FAO statistics Division. http://faostat.fao.org Chishti SAS, Khan AA, Sadia B and Khan IA. 2008. Analysis of combining ability for yield, yield components and quality characters in Tomato. J. Agric. Res. 46(4): 325-331.

Baiyewu, R.A., N.A. Amusa, O.A. Ayoola and O.O. Babalola. 2007. Survey of the postharvest diseases and aflatoxin contamination of marketed pawpaw fruit (*Carica papaya*) in southwestern Nigeria. Afr. J. Agr. Res. 2: 178-181.

Berry, S.K. 2007. Healthier living the tomato way. Proc. Food Ind. 10: 21-28.

Bombelli, E.C. and E.R. Wright. 2006. Tomato fruit quality conservation during post-harvest application of potassium bicarbonate and its effect on *Botrytis cineria*. Cien. Inv. Agric. (In English). 33: 167-172.

Bushra, S., M. Aslam, M.A. Aziz and M. Ahmed. 2013. Grain damage, viability and weight loss in different barley cultivars due to *Sitotroga cerealella* infestation. Arch. Phytopathol. Plant Prot. 46: 205-214.

Chuku, E.C., D.N. Ogbonna, B.A. Onuegbu and MT.V. Adeleke. 2008. Comparative studies on the fungi and bio-chemical characteristics of snake guard (*Trichosanthes curcumerina* Linn.) and tomato (*Lycopersicum esculentus* Mill.) in Rivers state, Nigeria. J. Appl. Sci. 8: 168-172.

Conway, W.S., B. Leverentz, W.J. Janisiewicz, R.A. Saftner and M.J. Camp. 2005. Improving biocontrol using antagonist mixtures with heat and/or sodium bicarbonate to control postharvest decay of apple fruit. Postharvest Biol. Technol. 36: 235-244.

Dhaliwal, M.S., S. Singh and D.S. Cheema. 2003. Line x tester

analysis for yield and processing attributes in tomato. J. Res. 40: 49-53.

Domsch, K.H., W. Gams and T.W. Anderson. 1993. Compendium of soil fungi. London: IHW Verlag Press.

Efiuvwerwere B.J.O. 2000. Microbial spoilage agents of tropical and assorted fruits and vegetables (an illustrated reference book). Paragraphics Publishing Company. Port Harcourt. 1-39 pp.

Elad, Y., M. Gullino, D. Shtienberg and C. Aloi. 1995. Managing *Botrytis cinerea* on tomatoes in greenhouses in the Mediterranean. Crop Prot. 14: 105-109.

Elad, Y., H. Yunis and T. Katan. 1992. Multiple resistance to benzimidazoles, dicarboximides and diethobencard in field isolates of *Botrytis cinerea* in Israel. Plant Pathol. 41:41-46.

Fallik, E., S. Greenberg and O. Ziv. 1997. Potassium bicarbonate reduces postharvest decay development on bell pepper fruits. J. Hort. Sci. 72: 35-41.

Feng, W. and X.D. Zheng. 2007. Essential oils to control *Alternaria alternata* in vitro and in vivo. Food Control 18: 1126-1130.

Freund, R.J., R.C. Littell and P.C. Spector. 1986. SAS System for Linear Models, 1986 Edition. Cary, NC: SAS Institute Inc.

Graham, R.D. 1983. Effect of nutrient stress on susceptibility of plants to disease with particular reference to the trace elements. Adv. Bot. Res. 10:221–276.

Guillen, F., S. Castillo, P.J. Zapata, D. Martinez-Romero, M. Serrano and D. Valero. 2007. Efficacy of 1-MCP treatment in tomato fruit: 1. Duration and concentration of 1-MCP treatment to gain an effective delay of postharvest ripening. Postharvest Biol. Technol. 3: 23-27.

Hameed, A.A.A., S. El-Hawarry and M.M. Kamel. 2008. Prevalence and distribution of airborne and waterborne fungi and actinomycetes in the Nile River. Aerobiologia 24: 231-240.

Holmes, G.J. and J.W. Eckert. 1999. Sensitivity of *Penicillium digitatum* and *P. italicum* to postharvest citrus fungicides in California. Phytopathol. 89: 716-721.

ISTA. 1985. International Rules for Seed Testing. Seed Sci. Technol. 13: 299-335.

Ippolito, A. and F. Nigro. 2003. Natural antimicrobials in postharvest storage of fresh fruit and vegetables. In: Natural Antimicrobials for the Minimal Processing of Foods (Roller, S. Ed.). CRC Press, Boca Raton, DC, USA. pp. 201-234.

Ippolito, A., L. Schena, I. Pentimone and F. Nigro. 2005. Control of postharvest rots of sweet cherries by pre- and postharvest applications of *Aureobasidium pullulans* in combination with calcium chloride or sodium bicarbonate. Postharvest Biol. Technol. 36: 245-252.

Jones, J.B., J.P. Jones, R.E. Stall and T.A. Zitter. 1991. Compendium of Tomato Diseases, American Phytopathological Society. St. Paul. MN.

Juneja, V.K. and D.W. Thayer. 2001. Irradiation and other physical based control strategies for foodborne pathogens. *In*: Microbial Food Contamination (Wilson, C.L., Droby, S. Eds.). CRC Press, Boca Raton, DC, USA. 171-186.

Kutama, A.S., B.S. Aliyu and I. Mohammed. 2007. Fungal pathogens associated with tomato wiker storage baskets. Sci. World J. 2: 38-39.

Lee, P.J., S. Lee, C.S. Kim, J.H. Son, J.H. Song, K.Y. Lee, H.J. Kim, S.J. Jung and B.J. Moon. 2006. Evaluation of formulations of *Bacillus licheniformis* for the biological control of tomato gray mold caused by *Botrytis cinerea*. Biol. Control 37: 329-337.

Liu, J., S. Tian, X. Meng and X. Yong. 2007. Effect of chitosan on control postharvest diseases and physiological responses of tomato fruit. Postharvest Biol. Technol. 44: 300-306.

Mahmud, T.M.M, A.A. Eryani-Raqeeb, S.S.R. Omer, M.A.R. Zaki and A.E. Abdul-Rehman. 2008. Effects of different concentrations and applications of calcium on storage life and physiological characteristics of tomato (*Solanum lycopersicum*). Am. J. Agric. Biol. Sci. 3: 526-533.

Menzies, J. and W. Jarvis. 1994. Grey Mold. In: Howard R, Garland J, Seaman W, editors. Diseases and Pests of Vegetable Crops. Ottawa, ON: The Canadian Phytopathological Society and Entomological Society or Canada. pp. 135-142.

Mónaco, C., D.G. Bello, M.C. Rollán, L. Ronco, G. Lampugnani, N. Arteta, C. Abramoff, A. Aprea, S. Larran and M. Stocco. 2009. Biological control of *Botrytis cinerea* on tomato using naturally occurring fungal antagonists. Arch. Phytopathol. Plant Prot. 42: 729-737.

Nicot, P., V. Decogenet and M. Bardin. 2000. Control of *Botrytis cinerea* in greenhouse tomato: an integrated approach -XIIth International *Botrytis* symposium. Bourgogue. France. 36p.

Onyia, V.N., C.O. Mbuka, G.O. Ihejirika, O.P. Obilor, C.I. Duruigbo and E.C. Onweremadu. 2005. Studies on

the performance incidence of Fusarium wilt of tomato under different colors of plastic mulch. Nig. Soc. Plant Proc. 32nd Ann. Conf. Book of Abstract. 23-25pp.

Ogawa, J.M., E.I. Zehr, G.W. Bird, D.F. Ritchie, K. Uriu and J.K. Uyemato. 1995. Compendium of Stone Fruit Diseases. APS Press, St. Paul, MN. USA.

Palou, L., J. Usall, J.A. Munoz, J.L. Smilanick and I. Vinas. 2002. Hot water, sodium carbonate, and sodium bicarbonate for the control of postharvest green and blue mold of clementine mandarins. Postharvest Biol. Technol. 24: 93-96.

Phuwiwat, W. and K. Soy. 2001. The effect of *Penicillium notatum* on plant growth. Fungal Divers. 8:143-148.

Purwadaria, H.K. and M.S. Sinaga. 2007. Pest and diseases in postharvest handling of fruits and vegetables. ASEAN training course on postharvest technology on fruits and vegetables. Lembang, Indonesia. 4p.

Rai, G.K., R. Kumar, A.K. Singh, P.K. Rai, M. Rai, A.K. Chaturvedi and A.B. Rai. 2012. Changes in antioxidant and phytochemical properties of tomato (*Lycopersicon esculentum* mill.) under ambient condition. Pak. J. Bot. 44: 667-670.

Rosslenbroich, H.J. and D. Stuebler. 2000. *Botrytis cinerea* – history of chemical control and novel fungicides for its management. Crop Prot. 19: 557-561.

Saleem, M.Y., M. Asghar, Q. Iqbal, Attiq-ur-Rahman and M. Akram. 2013a. Diallel analysis of yield and some yield components in tomato (*Solanum lycopersicum* L.). Pak. J. Bot. 45: 1247-1250.

Saleem, M.Y., M. Asghar and Q. Iqbal. 2013b. Augmented analysis for yield and some yield components in tomato (*Lycopersicon esculentum* Mill.). Pak. J. Bot. 45: 215-218.

Samson, R.A., E.S. Hoekstra, F. Lund, O. Filtenborgo and J.C. Frisvad. 2002. Methods for detection Isolation and characterization of food-borne fungi. *In*: Introduction of food and air borne fungi (Samson, R. A., Hoekstra E. S., Lund F., Filtenborgo O. and Frisvad J. C. Eds.). Central Bureau Voor Schimmecu-teures, utrechet. pp. 283-297.

Sami, S. and T. Masud. 2007. Effect of different packaging system on storage life and quality of tomato during different ripening stages. Int. J. Food Safety 9: 37-44.

Sato, M., M. Yamada, Y. Nakazawa and H. Horie. 1997. Rapid sensitivity test using toothpick to monitor fungicide sensitivity of *Botrytis cineria.* Proc. Kanto. Tosan. Plant Prot. Soc. 44: 97-101.

Schena, L., A. Ippolito, T. Zahavi, L. Cohen, F. Nigro and S. Droby. 1999. Genetic diversity and biocontrol activity of *Aureobasidium pullulans* isolates against postharvest rots. Postharvest Biol. Tech. 17: 189-199.

Tzortzakis, N.G. 2007. Maintaining postharvest quality of fresh produce with volatile compounds. Innov. Food Sci. Emerg. Technol. 8: 111-116.

Umemoto, S., Y. Odake, T. Takeuchi, S. Yoshida, S. Tsushima and M. Koitabashi. 2009. Blue mold of tomato caused by *Penicillium oxalicum* in Japan. J. Gen. Plant Pathol. 75: 399-400.

Valdez, J.G., M.A. Makuch, A.F. Ordovini, R.W. Masuelli, D.P. Overy and R.J. Piccolo. 2006. First report of *Penicillium allii* as a field pathogen of garlic (*Allium sativum*). Plant Pathol. 55: 583.

Wang, Y., Y. Bao, D. Shen, W. Feng, T. Yu, J. Zhang and X.D. Zheng. 2008. Biocontrol of *Alternaria alternata* on cherry tomato fruit by use of marine yeast *Rhodosporidium paludigenum* Fell & Tallman. Int. J. Food Microbiol. 123: 234-239.

Xi, L. and S.P. Tian. 2005. Control of postharvest diseases of tomato fruit by combining antagonistic yeast with sodium bicarbonate. Sci. Agric. Sinica. 38: 950-955.

Yabuki, S., I. Fukuhara, M. Yamada and Y. Nakazawa. 1997. Surveillance of fungicide sensitivity of *Botrytis cinerea* with a rapid sensitivity test using toothpick on protected fruit vegetables in Kanagawa Prefecture. Proc. Kanto. Tosan. Plant Prot. Soc. 44: 121-125.