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Prevalence of green mold disease of citrus in Punjab, Pakistan

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Abstract

Kinnow mandarin is the most important fruit crop grown in sub-tropical areas of Punjab. Several postharvest pathogens attack citrus fruit, among which *Penicillium digitatum* causing green mold of citrus is the most devastating pathogen. Disease symptoms appear initially as watery, soft and discoloured spots on the fruit surface and later on, white mycelium appears which is converted into an olive-green mass of spores. During the survey in the year 2016, maximum disease incidence (34%) was observed in Shaheenabad followed by Bhalwal (32%) and Kotmomin (30%) in district Sargodha, Punjab, Pakistan. Minimum disease incidence (14%) was observed in Chak Shahana. In 2017, maximum disease incidence was observed in Shaheenabad (36 %) and a minimum disease incidence of 16% was observed in Chak Shahana. Disease incidence of green mold was higher at all locations as compared to other rots.

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Introduction

Citrus is one of the main fruit crops grown in tropical and subtropical areas in more than 137 countries of the world (Ismail and Zhang, 2004). It has a remarkable social, cultural and economic impact on society due to its wide use as edible fruit around the globe. Citrus fruit is rich in vitamin C, B and β-carotene (Kelebek *et al*., 2008). It also contains flavonoids having beneficial effects on human health due to their antitoxic, antibacterial, antiviral, anti-inflammatory, anti-allergic and antioxidant potential (Diankov *et al.,* 2011; Prashar *et al.,* 2014). Citrus pulp and peel have been extensively used for essential oil production (Izquierdo and Sendra, 2003). Citrus fruit contains phytochemicals in a wide range that are considered to be responsible for the control of degenerative diseases (Khan *et al*., 2015). Now, in Pakistan citrus fruit is grown on an area of 183.2 thousand hectares with a yield of 2.3 million tons in 2017-18. Punjab province produces over 96% of citrus fruit and 70% of which is Kinnow mandarin. The yield of citrus in Pakistan is low (12.7 tons/ha) as compared to other citrus-producing countries like Brazil, the USA, Spain and Mexico having productivity of 30-40 tons/ha. Data of cultivated citrus varieties showed that 86 % of the total area was covered by Kinnow variety followed by Musambi (10 %), Feutral (4%) and Red Blood (1%) (Khan *et al*., 2015).

Several factors are responsible for the low yield of citrus, like poor management practices, lack of nutrition and attack of fungi, viruses and bacteria which result in massive economic losses every year. Important fungal diseases associated with citrus fruit are anthracnose (*Colletotrichum gloeosporioides*), gummosis (*Phytophthora citrophthora* and *P. parasitica*), citrus scab disease (*Elsinoe fawcettii*) and melanose (*Diaporthe citri*) while bacterial diseases include citrus greening caused by *Candidatus liberibacter asiaticus* and canker caused by *Xanthomonas axonopodis* pv. *citri*. Among viral diseases, *Citrus tristeza virus* is important and *Citrus exocortis viroid* is an important viroid disease. The number of pathogens is associated with postharvest fungal diseases causing huge losses during storage (Barkai-Golan, 2001; Plaza *et al*., 2003). Due to storage infection, 40% of total citrus has deteriorated annually (Khan *et al*., 2020). Among postharvest diseases, green mold caused by *Penicillium digitatum* is the most devastating one (Shi *et al*., 2018). The infection mostly occurs due to injuries on citrus fruit during harvesting, handling and processing. For the development of management strategy, it is necessary to calculate the incidence of citrus green mold in the major citrus growing areas of Punjab, Pakistan. This thing enforces researchers to observe incidence in different localities of citrus growing areas, which will enable policymakers to devise suitable policy against the green mold to save farmers as well as traders from severe loss of citrus. That is why a comprehensive survey was performed in citrus cultivating areas of Punjab, Pakistan to observe the prevalence of green mold.

Materials and methods

Assessment of Postharvest Diseases Associated with Kinnow in Different Localities of Punjab

Four citrus growing districts of Punjab viz. District Sargodha (32.0837° N, 72.6719° E) including three locations (Shaheenabad, Bhalwal and Kot momin), Multan (30.1984° N, 71.4687° E) three locations (Basti Khudadad, basti Jhabail and Khatti Chore), Faisalabad (31.4187° N, 73.0791° E) three locations (563 G.B., 561 G.B and 564 G.B) and Khanewal (30.3039° N, 71.9299° E) including three sites (Batian Wala, Chak Shahana and Basti Sukhera) were visited for the assessment of citrus postharvest diseases on fallen citrus fruit. The incidence of green mold on citrus fruits was calculated by the formula:

$$\text{Disease Incidence \%} = \frac{\text{Diseased Fruit observed}}{\text{Total Number of Fruits observed}} \text{ X } 100$$

Disease severity on fruits was recorded by using the scale (0-5) according to the following scale:

0= No disease

1= 1/5th of fruit part infected

2= 2/5th of fruit part infected

3= 3/5th of fruit part infected

4= 4/5th of fruit part infected

5= Whole fruit area infected

Percent disease index was calculated by adopting the formula:

$$\text{Disease index (\%)} = \frac{\text{Sum of all numerical ratings}}{\text{Number of fruit samples observed x maximum disease rating}} X\ 100$$

Results

During the survey, green mold was found present at all surveyed locations. Disease incidence and disease severity were variable in all districts. Green mold disease incidence was higher than other rots as shown in Table 1. It is evident from the Table. 1 that maximum mean disease incidence (34%) was observed in district Sargodha at location Shaheenabad and minimum disease incidence of 15% was observed at Chak Shahana in district Khanewal as shown in Table 1 and Fig.1. In district Sargodha at Shaheenabad, disease incidence was highest (34%) followed by Bhalwal (32%) and Kot Momin (30%). During 2016 and in 2017, a maximum disease incidence of 36% was observed at Shaheenabad and a minimum disease incidence of 32% was observed at Kot Momin as shown in Fig. 2. Similarly, a disease severity index of 23.7% was observed in Shaheenabad followed by Bhalwal (21.95%) and Kot Momin (18.9%) as shown in Table 2. In district Faisalabad, a maximum disease incidence of 24% was observed at village 563 G.B. followed by 561 G.B (23.5%) and 564 G.B (23%).

Disease severity was 19.1% at 563 G.B., 16% at 564 G.B. and 15.4% at 561 G.B as depicted in Table 1. During 2016, a maximum disease incidence of 23% was observed at village 563 G.B. and minimum disease incidence of 20% was observed at village 561 G.B.

Table 1. Disease incidence of Green mold and other rots during year 2016 and 2017.

District	Locations	% disease incidence					
		2016		2017		Mean	
		Green Mold	Other Rots	Green Mold	Other Rots	Green Mold	Other Rots
Sargodha	Kot Momin	30 c	15 cd	33 b	16 bc	31.5	15.5
	Bhalwal	31 c	14 de	35 b	17 b	33	15.5
	Shaheenabad	33 b	16 bc	36 a	19 a	34	17.5
Faisalabad	564 G.B	22 hi	17 b	24 fg	20 a	23	16.5
	563 G.B	23 gh	13e	25 f	16 bc	24	14.5
	561G.B	20 jk	14 de	27 e	15 cd	23.5	14.5
Khanewal	Batian Wala	16 m	10 f	17 l	11 f	16.5	10.5
	Chak Shahana	14 n	12 f	16m	14 de	15	13
	Basti Sukhera	15 mn	9 g	18 l	10 f	16.5	9.5
Multan	Basti Jhabail	21 ij	11 f	23 gh	13 e	22	12
	Khatti Chore	19 kl	13 e	22 hi	14 de	15.5	13.5
	B. Khudadad	21 ik	10 f	24 fg	11f	22.5	10.5

Maximum disease incidence of 27% was noted at 561G.B followed by 563 G.B (25%) and 564 G.B (24%) as shown in Fig. 2. During the survey of Multan district, a maximum disease incidence of 22.5% was observed at Basti Khudadad followed by Basti Jhabail (22%) and Khatti Chore (15.5%) as shown in Table 1.

A maximum disease severity index of 17% was observed at Basti Jhabail followed by Basti Khudadad (14.7%) and Khatti chore (13%) as shown in Table 2.

In district Khanewal, maximum disease incidence was observed at Basti Sukhera (21%) followed by Chak shahana (15%) and Batian wala (14%) during 2016. During the 2017 survey, a maximum disease incidence of 23% was observed at Basti Sukhera and a minimum disease incidence of 16% was noted at Batian wala as shown in Fig. 3.

Discussion

It is evident from the results that green mold of citrus is present at all locations of Sargodha, Faisalabad, Khanewal and Multan districts. During the survey, characteristic symptoms of the green mold disease on Kinnow mandarin were observed on the fruit surface at different locations.

Table 2. Severity of green mold on Kinnow mandarin observed in five districts of Punjab Province during year 2016 and 2017.

District	Locations	Percent disease index of green mold		
		2016	2017	Mean
Sargodha	Kot Momin	19.5 c	18.4 cd	18.9
	Bhalwal	21.2 b	22.7 ab	21.95
	Shaheenabad	23.4 a	24 a	23.7
Faisalabad	564 G.B	15.4 gh	16.6 efg	16
	563 G.B	18.8 cd	19.4 c	19.1
	561G.B	14.5 hi	16.3 fg	15.4
Khanewal	Batian Wala	12.3 jk	13.7 ij	13
	Chak Shahana	11.3 kl	10.5 l	10.9
	Basti Sukhera	14 hi	15.3 ghi	14.6
Multan	Basti Jhabail	17.4 def	18.2 cde	17.8
	Khatti Chore	12 kl	14 hi	13
	B. Khudadad	14.2 hi	15.6 gh	14.9

The infection started at the point of injury and spread on the rind of the fruit. Soft, little discoloured and watery spots (6-14 mm) were developed on the surface of the fruit. These wounds further got enlarged to 2-5cm in diameter followed by the manifestation of white mycelial growth of fungus covering the entire fruit surface. Olive green powdery spore mass also developed on the fruit surface. Fungal spores were produced in bulk and chains on infected fruits.

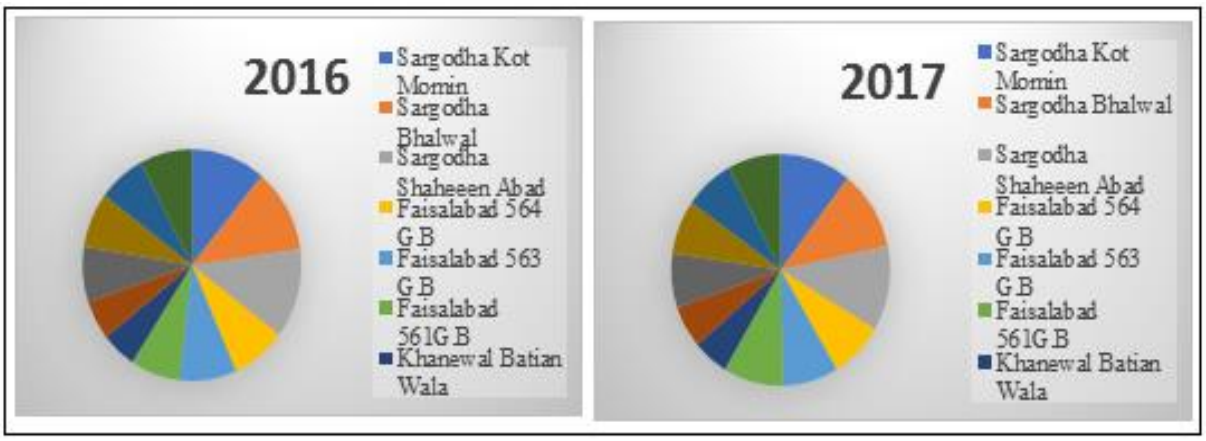

Fig. 1. Disease incidence of green mold in Punjab province of Pakistan during 2016, 2017.

The fungus persisted as spores on site of wounds on fallen fruits and also in the soil of the orchard. Later, the whole fruit showed disintegration and collapsed into a soft decaying mass.

Many findings in the literature showed the *Penicillium* spp. and *Aspergillus* spp. as the main postharvest pathogens of citrus fruit. The association of *P. digitatum* and *P. italicum* is responsible for the deterioration of citrus in Punjab, Pakistan (Moosa *et al.*, 2019). Postharvest decay due to green, blue and grey mold diseases has been reported to be the main cause of decay among which *Penicillium* spp. was reported to be the most important pathogen causing huge loss of citrus fruit (Singh *et al.*, 2003; Plaza *et al.*, 2004; Khan *et al.*, 2020). The symptoms observed in the present study were like to those of the previous studies of different researchers (Chand, 2013; Kishor

and Harender, 2018). During a survey in California, 36.3% disease incidence of *P. digitatum* was reported (Saito *et al*., 2017). Disease incidence of green mold caused by *P. digitatum* was 58.3% in Punjab as reported by Kaur and Verma (2002). About 18.5-25.9 % incidence of the green mold of Kinnow in Solan, Kangra and Sirmour districts of Himachal Pradesh, India was reported (Sharma *et al*., 2010). The loss in local mandarin ranged between 15.1 to 22.1 % and decay due to *P. digitatum* ranged from 8.5 to 12 % (Prabhakar *et al*., 2004). In Jammu, the disease incidence of 5.1 to 12% was recorded due to *P. digitatum* (Verma, 2008). Green mold was reported as a major postharvest disease in Andhra Pradesh, which caused a 20.4 % disease incidence in citrus fruit (Reddy *et al*., 2008). In the current study, average disease severity was maximum in Shaheenabad (23.7%) followed by Bhalwal (21.95%) village 563 G.B (19.1%), and Kot Momin (18.95**)**. Khan *et al*. (2015) surveyed district Sargodha, Punjab and reported varying prevalence of citrus green mold. The results of the present studies also showed that disease incidence of green mold on citrus fruit varied at various locations of Punjab.

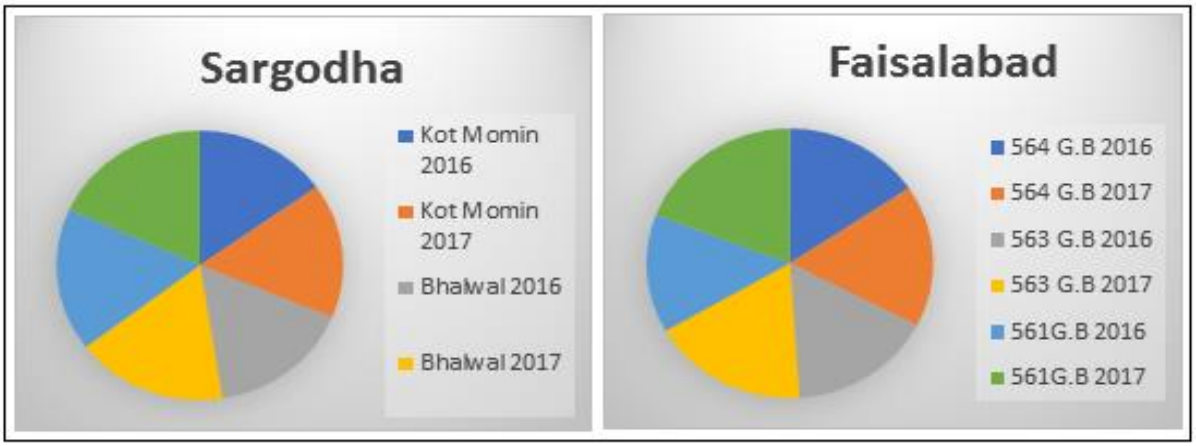

Fig. 2. Disease incidence of green mold at district Sargodha and Faisalabad during 2016, 2017.

In addition to biotic factors, the human handlings about orchard management and intercropping are provoking the disease development conditions in citrus-growing areas of Punjab, Pakistan. Most of the orchards in the Sargodha region have old citrus plantations and non-recommended intercropping of barley, berseem and wheat is mostly done. The traditional irrigation methods i.e. flood irrigation increased disease spread. However, better conditions in terms of orchard management were found in Batian wala, Chak shahana and Basti sukhera, where disease incidence was less as compared to other areas. Usually, more than 15% disease index of any disease of fruit crop at any place is alarming.

Fig. 3. Disease incidence of green mold at district Khanewal and Multan during 2016, 2017.

In all the districts, the disease index ranged from 13% to 23.75% which is an alarming situation for the citrus industry as well as for growers and needs instant attention of the researchers. There is a lack of supply chain and value chain studies and capacity building of the growers at a large scale.

Conclusion

It is concluded that citrus green mold has attained an alarming position and no orchard is free from the attack of the disease. Training of growers in pre-and post-harvest handling, as well as integrated production technology, is essentially required. Most orchards are given to contractors and they don't care about the health of trees. So, the growers should sign memorandum of understanding (MoUs) with contractors for effective management of orchards from bloom to harvest.

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