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Pre-and post-harvest management of sooty blotch disease of mango

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ABSTRACT: The field survey conducted in Odisha state during 2014-18 to document major and new diseases of mango, a kind of superficial smudgy fungal blemishes were observed on fruits of late maturing mango varieties. The new type of superficial fungal blackening referred as '*Sooty blotch'* disease wherein, group of fungi colonize on waxy layer of fruit cuticle which downgrades the fruit quality and eye appeal by spoiling green fresh look of fruits. To manage the disease, series of studies were undertaken under field condition as well as after harvest as post-harvest dip treatments. Under field condition, among various protective fungicides evaluated, spray of 0.3 % copper oxychloride-based formulation thrice at fifteen days interval (by scheduling the first spray before monsoon) provided satisfactory control by inhibiting the colonization of sooty blotch fungi. Subsequently, various post-harvest dip treatments were also evaluated to remove the superficial blackening of fruits after harvest. Among them, dipping of blemished fruits in Arka mango wash for 10-15 minutes, followed by washing in water twice removed 99% of fungal blemishes from sooty blotch infected mangoes without any peel injury and post-harvest quality of fruits.

Keywords: Mango, sooty blotch, field spray, fungicide, post-harvest dip treatment

INTRODUCTION

Number of factors affect the visual appearance of the fruits which may be physical, physiological, pathological or entomological. In market, the color of fruit, its appearance, flavor, texture and nutritional value are major attributes determining the consumer preference. In mango, anthracnose, bacterial canker, scab and sooty mould are the major diseases that affect the quality of the fruit and contributing to decreased quality in addition to insect pests and physical damages. New group of fungi referred as sooty blotch, colonise the waxy layer of mangoes, survive on fruit leachates and cause superficial skin blackening of fruits which is different from sooty mould fungi growing on sugary excretions of sap sucking insects. It causes a kind of cosmetic damage to the fruit without affecting the inside pulp quality. But its residual effect of skin blackening severely affects the consumer preference and marketability of fruits which in turn cause severe financial loss to the mango growers and traders. During survey, the sooty blotch symptoms were also recorded on banana, bael, anola, star goose berry, aou and many tree plants bordering the orchards. Skin blotching caused by sooty blotch cannot be easily removed by any water wash as that of sooty mould. In addition sooty blotch infection cannot be ignored as fresh and clean fruits are preferred for local or distant urban markets. The mid and late season mango varieties whose maturity coincides with wet summer season were more prone to incidence of sooty blotch. In India occurrence of sooty blotch on mango was confirmed from several states viz., Odisha, Tamil Nadu, Karnataka, Uttar Pradesh, Andaman and Nicobar and West Bengal.

Although there is a considerable knowledge of sooty blotch and flyspeck on other crops worldwide (Williamson and Sutton, 24; Gleason *et al*., 10), little is known about the etiology and control of sooty blotch in mango and no fungicide is having any label claim for its control in mango. In apple sooty blotch (SB) and Flyspeck (FS), are reported as major diseases. (Williamson and Sutton, 24; Batzer *et al*., 3; Diaz-Arias *et al*., 7). They grow on the epicuticular wax layer of apples (Nasu *et al*., 18; Ocamb-Basu and Sutton, 19; Johnson *et al*., 13) and complex of SBFS fungi often coexist on the same fruit in the same orchards (Johnson and Sutton, 14; Williamson and Sutton, 24). In the United States, SBFS epidemics in apple lead to downgrading fruit from premium market grade to processing use (Sutton & Sutton, (23); Williamson and Sutton, (24).Gleason *et al*.(10) reported an elaborate list of more than 50 fungi associated with SBFS fungal complex in apple. In mango, blotch has been reported to be caused by fungi like *Zasmidium* sp., *Pseudocercospora* sp., *Mycosphaerella* sp under Odisha condition (ICAR-IIHR Annual report, 2016-2017). However, fungi colonizing SBFS from other parts of the

country has to be established since it may vary according to the prevailing climatic condition as reported in apple (Gleason *et al*., 10).

In apple, strategic SBFS management strategies have been suggested by various workers based on cultural practices, chemical methods (Brown and Sutton, 4; Rosenberger *et al*., 21; Duttweiler *et al*., 8) and post-harvest treatments (Hendrix, 11; Batzer *et al*., 2). In the regions of southeastern United States where high rainfall and relative humidity prevails, weekly application of fungicide was found inadequate to completely control this disease, resulting in a 5 to 10% reduction in marketable apples (Mainand Gurtz, 16). Therefore, growers experience sporadic control failures related to poor fungicide coverage, inadequate pruning, and environmental conditions that are highly favorable for SBFS development (Cooley *et al*., 6). It has been reported that sodium hypochlorite dips reduce the population of *Botrytis cinerea*, *Mucor piriformis* and *Penicillium expansum* on fruits and vegetables (Spotts and Peters, 22; Jones and Sutton, 15; Williamson, and Sutton, 24 and reduce the severity of SBFS (Colby, 5; Hendrix, 11; Winsiewsky *et al*. (25).

For management of sooty blotch infection in mango, as such no control measures are available to control sooty blotch either at field level or after harvest. In order to adequately quantify the benefits of various post-harvest treatments, reliable and cost-efficient assessment methods are needed. Keeping the above points in view, the current study was inducted with the objective to evaluate the efficacy of various fungicides to manage the sooty blotch infection at field level and to evaluate post-harvest dip treatments to remove sooty blotch signs on mango fruits after harvest.

MATERIALS AND METHODS

Protective fungicide spray for managing sooty blotch infecting mango under field conditions

The field trial was conducted during 2016-17 in Rayagada district of Odisha on the existing mango orchard on cv. Amrapali. Rayagada district has latitude of 26^{o} N and a longitude of 94^{o} 20'E with the average rainfall of approximately 1340.0mm. The fungicides which are already in use to manage mango diseases were taken for current study. The experiments were conducted using randomized block design with three replicates. All spraying schedule were carried out in line with standard commercial orchard practice. Each replicate consisted of 5-trees. Fungicides were applied @ 7-8 L per tree targeting mainly on fruits *i.e.,* sprays were applied to runoff. Three sprays were given with an interval of 15 days from May end with two consecutive sprays at 15 days interval with fungicides as per detail given in Table 1. Ten secondary branches at mid- height (2 m) of each tree were marked, and all fruit on these branches (app. 50 per tree) were observed once in a week from the day in which disease signs were first visually detected by the naked eye in the unsprayed check. These fruits were evaluated for sooty blotch incidence on the tree itself i.e., *in situ* for symptoms of sooty blotch(proportion of affected fruit in total number of fruits observed). At harvest, 100 fruits samples were arbitrarily collected across each treatment for assessing the disease severity and brought to laboratory by maintaining replication and treatment details. In the laboratory, disease severity (percentage of fruit portion covered by symptoms) was visually estimated for individual fruit with the self-made severity scores of 0-5 scale, 0–Healthy; 1:<1% fruit surface covered with sooty blotch; 2: 1-10% fruit surface covered sooty blotch; 3: 11-25% fruit surface covered with sooty blotch; 4:26-50% fruit surface covered with sooty blotch; 5:>50% fruit surface covered with sooty blotch signs.

Post-harvest dip treatment for removal of fungal blackening caused by sooty blotch

To remove the superficial black fungal growth of mango fruits caused by sooty blotch, initial screening was carried out with certain treatments including IIHR-Pongamia soap and ordinary detergent soap. Brushing of infected fruits with detergent soap with the help of cotton or muslin cloth followed by washing with water yielded good result by removing 80-85 percent blackening but it was very laborious and tedious process. However, brushing could lead to formation of minor wounds on fruit surface. Hence some improved methods were tried subsequently. Among hence various compounds tried to remove the blackening caused by sooty blotch, a selected treatment combination showed good results in removing the fungal blackening. Therefore, it was taken for detailed evaluation at various concentration (500, 750, 1000 ppm), dipping time (5, 10, 15 mins) and pH (5.5, 6.5.7.5) with all possible combinations with five replication @20 fruits per replication. After post-harvest treatment, the fruits were washed with water twice and subjected sooty blotch severity scoring on 0-5 scale as described above.

Phytotoxicity studies of standardized technology

To know the potential effect of prolonged dipping time of selected treatment on mango skin, an experiment was

conducted on cv. Amrapali by dipping the sooty blotch infected mangoes in 1000ppm solution (with standard pH of 6.5) for 15, 30, 45, 60, 75, 90, 120 and 150 mins. After respective dipping time, fruits were washed with water and analyzed visually for peel injury. Similarly, to know the potential effect higher concentration of selected treatment (other than the recommended concentration of 1000 ppm) on peel, higher concentration 2000, 3000 and 4000 ppm with 15- and 30-mins dipping time (with standard pH of 6.5) were evaluated on cv. Amrapali and fruits were washed with water and analyzed visually for peel injury.

Evaluation of standardized post-harvest dip treatment on post-harvest quality parameters of mango

Those treatment showed best results were studied for their role on post-harvest quality parameters of mango. At IIHR-CHES, Bhubaneswar, fruits of Amrapali and Neelum were subject to analysis (after the post-harvest dip treatment with the standardized technology) for the parameters such as fruit firmness, fruit shrinkage, peel color, pulp colour and sensory evaluation for its acceptability, percent weight loss and physico-chemical parameters such as acidity (%) and TSS (^{o}Brix). Further, at Post Harvest Technology laboratory of ICAR-IIHR, Bengaluru, three mango varieties namely Alphonso, Amrapali, and Totapuri were subject to elaborate study (after the post-harvest dip treatment with the standardized technology) on ripening rate, TSS, fruit spoilage, and organoleptic quality during storage at room temperature.

RESULTS AND DISCUSSION

Sooty blotch is a new disease infecting mango fruits which was documented during recent years in many states of India. Sooty blotch (SB) colonies appear as circular to irregular, olive-green to dull black fungal growth on a waxy layer of near maturing mango fruits (Fig 1A and B). Flyspecks (FS) can be recognized by the presence of black shiny round fungal dots in groups that resemble the fly excreta (Williamson and Sutton, 24). Both SB and FS were found on the same fruits and produce respective colonies. However, the occurrence of flyspeck is negligible in Odisha even though seen in other mango growing regions (data not shown). Sooty mould is fundamentally different from sooty blotch, as sooty mold grows on sugary excretions produced by sap-sucking tiny insects and produce fungal encrustation over the sugary excretions. Sooty blotch significantly reduces the market value of mangoes (Fig 2A) due to moisture loss and shrinkage of affected area (Fig 2B). Mango twigs act as a major source of inoculum. In addition sooty blotch fungi also colonizes the twigs of jack fruit, sapota, star gooseberry, acacia, simaruba, fig, piasala and Calatropis *etc*., and other avenue trees.

Fig1. Sooty blotch incidence on mangoes (A), close up view of sooty blotch on a mango fruit (B)

Fig. 2. A. Sooty blotch infected mango fruits affects market value (2B) Moisture loss

Table 1. Impact of fungicides against sooty blotch disease severity under field condition

Fungicide treatment[#]	Sooty blotch disease severity (0-5 scale)
Copper oxychloride (0.2%)	1.91[c]
Copper oxychloride (0.3%)	0.97[a]
Thiophanate methyl (0.2%)) + Captan (0.3%))	1.31[b]
Captan (2 gm/L) + Thiophanate methyl (0.1%)	2.20[d]
Thiophanate methyl (0.2%)	3.20 [e]
Control	3.79 [f]

[#]Three spray, Replication: 3 (@5 trees/replication)
In a column means followed by a common letter are not significantly different at 5 per cent (P=0.05) level by DMRT

Different fungicides were evaluated to manage sooty blotch at field level in Kasipur block, Rayagada Dt of Odisha, on cv Amrapali. All five fungicide spray treatments significantly reduced sooty blotch severity compared to unsprayed control (Table 1). The highest sooty blotch control was achieved with a spray of 0.3% copper oxychloride thrice at an interval of 15 days starting from the end of May (Table 1; Fig 3). Besides, fruits received copper oxychloride (COC) spray, post-harvest decay was very minimal till the end of shelf-life period as against unsprayed control were partial to complete decay was observed (Fig 4 &5). The efficiency of fungicides may vary according to the dominant pathogen species involved in causing sooty blotch in a particular region/location. Further, the time of spray has to be decided according to the local weather condition and expected period of rain. To increase the efficiency of sooty blotch control, the fungicide coverage has to be improved by increasing the volume of water applied per unit area, reducing travel speed of sprayer and including a surfactant, if possible, to enhance fruit wetting. However, the time of spray (May/June/July) has to be decided for other regions/states of our country according to the expected period of rain and maturity period of mango. Therefore, region specific evaluation of fungicide regime is required for SBFS control (Duttweiller *et al*., 2008).

The better approach for sooty blotch management is to protect the mangoes with prophylactic fungicides in the field itself, knowing the fact that sooty blotch spores are available in the field (in mango twigs and reservoir hosts) and it may initiate the infections on fruits at any time if the trees are exposed to an accumulated wetting period of 5-7 days. In apple, trifloxystrobin or carbendazim applied at pre-blossom and flowering stage reduced the incidence of flyspeck at harvest by an average of 70% compared with the untreated control (McKenna *et al*., 2012)**.** In the mid western and northeastern United States, the strobilurin fungicides kresoxim-methyl and trifloxystrobin controlled SBFS in apple orchards as effectively as standard treatment of thiophanate-methyl plus captan (Babadoost *et al*., 1).

Fig. 3. Fruits received COC (0.3%) as pre harvest spray (left) and fruits without any spray (right)

Fig. 4. Fruits received copper oxychloride 0.3% spray (left) after harvest and one week after storage at room condition (right)

Fig. 5. Fruits didn't receive copper oxychloride 0.3% spray (left) after harvest and one week after storage at room condition (right)

Evaluation of post-harvest dip treatments for removal of blackening caused by sooty blotch

Efforts were intensified to find an alternate method to remove fungal blackening caused by sooty blotch on a waxy layer of fruits. Initial screening with several organic compounds and Generally Regarded As safe (GRAS) compounds were conducted including detergent soap and IIHR-Pongamia soap (data not shown). Among the various GRAS compounds evaluated, certain treatment combination gave good results in terms of removing the fungal blackening. Hence it was taken for detailed evaluation at a various concentration (500, 750, 1000 ppm), dipping time (5, 10, 15 mins) and pH (5.5, 6.5.7.5). The interaction between the concentration selected treatment and dipping time revealed 15 mins dip recorded with lesser disease grade of 1.17 among other interactions (Table 2). Interaction between pH and dipping time revealed 15 mins dip with 6.5 pH with lesser disease grade of 2.08 (Table 3). Interaction among the varied concentration and pH evaluated, 1000ppm of selected treatment with pH 6.5 resulted in a lesser disease grade of 1.00 (Table 4).

Table 2. Two-way interaction between the concentration of selected best treatment and dipping time in reducing sooty blotch disease severity grade on fruits of cv Amrapali

	Sooty blotch disease severity grade (0-5 scale)[#]		
	Dipping time		
Conc.	5 mins	10 mins	15 mins
500ppm	3.58[g]	3.04[e]	2.53[d]
750ppm	3.18[f]	2.46[d]	1.80[b]
1000ppm	2.03[c]	1.88[b]	1.17[a]
Control	5.00[h]	5.00[h]	5.00[h]
CD(0.05)	0.122		
CD(0.01)	0.160		

[#] Mean of five replication @ 20 fruits per replication

In a column means followed by a common letter are not significantly different at5 per cent (P=0.05) level by DMRT

Table 3. Two-way interaction between pH of mango wash and dipping time in reducing sooty blotch disease severity grade on fruits of cv Amrapali

	Sooty blotch disease severity grade (0-5 scale)[#]		
	pH of mango wash		
Dipping time	**5.5**	**6.5**	**7.5**
5mins	3.47[c]	3.18[d]	3.70[f]
10mins	3.11[cd]	2.75[b]	3.43[e]
15 mins	2.74[b]	2.08[a]	3.05[c]
CD(0.05)	0.105		
CD(0.01)	0.139		

[#] Mean of five replication @ 20 fruits per replication
In a column means followed by a common letter are not significantly different at5 per cent (P=0.05) level by DMRT

Table 4. Two-way interaction between mango wash concentration and pH in reducing sooty blotch disease severity grade on fruits of cv Amrapali

	Sooty blotch disease severity grade (0-5 scale)[#]		
	pH of mango wash		
Conc	**5.5**	**6.5**	**7.5**
500ppm	2.98[f]	2.76[e]	3.41[g]
750ppm	2.61[d]	1.92[b]	2.91[f]
1000ppm	1.83[b]	1.00[a]	2.25[c]
Control	5.00[h]	5.00[h]	5.00[h]
CD(0.05)	0.121		
CD(0.01)	0.160		

[#]Mean of five replication @ 20 fruits per replication
In a column means followed by a common letter are not significantly different at5 per cent (P=0.05) level by DMRT

Table 5. Post-harvest evaluation of dip treatment for removal blackening caused by sooty blotch in the varied concentration of mango wash, dipping time and pH

	Sooty blotch disease severity grade (0-5 scale)[#]		
	pH of mango wash		
Conc. x Dipping time	**5.5**	**6.5**	**7.5**
500ppm x 5 min	3.56[k]	3.36[k]	3.84[l]
500ppm x 10 min	2.88[ij]	2.76[hij]	3.48[k]
500ppm x 15 min	2.52[fg]	2.16[e]	2.92[j]
750ppm x 5 min	3.36[k]	2.68[ghi]	3.52[k]
750ppm x 10 min	2.56[fgh]	2.02[de]	2.82[ij]

750ppm x 15 min	1.92[d]	1.08[b]	2.40[f]
1000ppm x 5 min	1.98[de]	1.68[c]	2.44[f]
1000ppm x 10 min	2.00[de]	1.24[b]	2.42[f]
1000ppm x 15 min	1.52[c]	0.25[a]	1.90[d]
Control	5.00[m]	5.00[m]	5.00[m]
CD(0.05)	0.211		
CD(0.01)	0.278		

[#]Mean of five replication @ 20 fruits per replication
In a column means followed by a common letter are not significantly different at5 per cent (P=0.05) level by DMRT

Table 6. Analysis of variance for sooty blotch disease grade for 4x3x3 factorial experiment

Sources of variation	df	Mean square
Treatment	35	9.215**
Concentration (Conc.)	3	89.258**
Dipping time	2	10.279**
pH	2	7.922**
Conc. x Dipping time	6	1.424**
Dipping time x pH	4	0.307**
Conc. x pH	6	1.200**
Conc. x Dipping time x pH	12	0.116**
Err	144	0.028
Total	179	1.825

** Significant at 1% level.

The results of three-way interactions revealed mango wash concentrations of 1000ppm, having pH 6.5- and 15-mins dipping time recorded the least disease grade of 0.25 among the varied concentration, pH and dipping time evaluated. This above-said combination resulted in 95 % removal of mango blackening caused by sooty blotch colonization on fruit skin (Table 5; Fig 6). The final analysis of the variance table revealed that among the treatments involving the varied concentration of mango wash, pH and dipping time and their interaction were all significant at 1% level (Table 6).

Fig. 6. Mangoes infected with sooty blotch infection. Fruits before (left) and after (right) post-harvest dip treatment

Effect of range of dipping time and concentration on mango fruits cv. Amrapali

Mango wash was tested for maximum dipping time which may have the potential to cause peel injury of mangoes. For that, fruits were dipped in 1000ppm of mango wash having pH 6.5 with varied dipping time (15, 30, 45, 60, 90, 120, and 150 mins). There was no peel injury on mangoes up to 90 mins of dipping time. However, 120 mins dipping time resulted in 10 % peel injury and 150 mins dipping time resulted in 25 -50% peel injury of mangoes (Table 7).

Table 7. Effect of dipping time in 1000pppm of mango wash on mango fruit scv. Amrapali

Dipping time (in mins) in 1000 ppm of mango wash- 6.5 pH	15	30	45	60	90	120	150
Percent tissue damage[≠]	0	0	0	0	0	1 – 10	25-50

[≠]Mean of five replication @ ten fruits per replication

Table 8. Effect of high concentration of mango wash on mango fruits cv. Amrapali

	Conc. of mango wash (ppm)							
	1000		**2000**		**300**		**4000**	
Dipping time (min)	15	30	15	30	15	30	15	30
Percent tissue damage[≠]	0	0	0	0	0	0	0	10-25

[≠] Mean of five replication @ ten fruits per replication.

Mango wash was tested at the higher range of concentration to know the potential effect of mango wash to cause peel injury on mangoes. This can serve as the precautionary note to the growers. Mango fruits cv. Amrapali was dipped in 1000, 2000, 3000 and 4000ppm (with standard pH of 6.5) of mango wash for 15 and 30 mins respectively resulted in no peel injury up to 3000ppm. However dipping of mangoes in 4000ppm for 30 mins resulted up to 25% of peel injury (Table 8).

Validation of technology on various mango varieties

This final standardized technology was validated in other varieties of mangoes such as Alphonso, Neelum, Maylepelian (rootstock) and Totapuri including Amrapali at IIHR, Bengaluru, Karnataka state. In all variety, the above said treatment involving mango wash concentration of 1000ppm, having pH 6.5- and 15-mins dipping time resulted in 100 percent removal of mango blackening caused by sooty blotch (Table 9). However, mango wash had nil effect on fruits having spots or symptoms caused by other fungi as evidenced with totapuri fruits during experimentation at IIHR, Bengaluru.

Table 9. Experimentation of Arka mango wash at IIHR, Bengaluru on different varieties of mango

Sooty blotch Disease grade	**Mango varieties**				
	Alphonso	**Neelum**	**Amrapali**	**Totapuri**	**Maylepelian**
Before dip treatment	3	3	3	2	4
After dip treatment	0	0	0	0	0

Standardized Methodology

The required quantity of solution A has to be added in 10 L of potable water immediately before treatment in a plastic container to make 1000ppm and with pH of 6.5 by adding solution B. The sooty blotch infected mango fruits had been dipped in the solution for a maximum of

15 mins and washed twice in the water to remove the residual effect of chemicals.

Post-harvest quality studies of mangoes dipped in Standardized 'Arka mango wash'

Mango fruit varieties of Amrapali and Neelum were subjected to analysis of post-harvest quality parameters such as fruit firmness, fruit shrinkage, peel color, pulp colour and sensory evaluation for its acceptability, percent weight loss and physico-chemical parameters of mangoes such as acidity (%) and TSS (°Brix) at IIHR-CHES, Bhubaneswar. It was concluded that standardized 'Arka mango wash' had no adverse effect on fruit quality and physico-chemical properties of treated fruits of tested varieties and retained all desired parameters. (Table 9&10).

Table 9. Evaluation of standardized 'Arka Mango wash' on fruit firmness and quality parameters of mangoes

Treatment	Amrapali		Neeum	
	Treated fruits	Untreated fruits	Treated fruits	Untreated fruits
Fruit firmness (N)	20	15	6.5	6.2
Fruit shrinkage	Nil	Nil	Nil	Nil
Peel colour*	3	3	5	5
Pulp colour	Deep orange	Deep orange	Yellow	Yellow
Sensory evaluation for overall acceptability#	6	6	6	6

*Assessment of fruit colour: [Index 1-6 Dull Green-1; Light green-2; Greenish Yellow-3; Yellowish Green-4; Light Yellow-5; Yellow orange-6 (Fama, 2006)]
#Sensory evaluation for overall acceptability based on flavor, taste, and acceptance [Scale 1-10: 9-10- Excellent; 6-8 Good; 4-5 Fair; 1-3 Poor].

Table 10. Evaluation of standardized 'Arka Mango wash' on percent weight loss and physico-chemical parameters of mangoes

Treatment	Var. Amrapali				Var. Neelam			
	Treated fruits		Untreated fruits		Treated fruits		Untreated fruits	
	6d	8d	6d	8d	6d	8d	6d	8d
Percent weight loss	3.74	9.6	3.7	10.6	3.3	4.8	3.5	5.9
Acidity (%)	0.35	0.21	0.32	0.16	0.19	0.16	0.19	0.16
TSS (°Brix)	15.6	17.1	15.9	17.6	18.4	18.6	18.6	19.3

Further, three mango varieties namely Alphonso, Amrapali, and Totapuri were subjected to elaborate study at Post Harvest Technology laboratory, ICAR-IIHR, Bengaluru to know the effect of standardized 'Arka mango wash' on ripening rate, TSS, fruit spoilage, and organoleptic quality of mangoes during storage at room temperature. The ripening rate (Table 11), TSS (Table 12), organoleptic quality (Table 13), and fruit spoilage (Table 14) of all three mango varieties were found no undesirable effect on fruits subjected with 'Arka mango wash' and further it was also noted that this technology could also increase the shelf life of treated fruits by delaying the fruit spoilage compared to untreated mangoes.

Table 11. Effect of standardized 'Arka mango wash' on the ripening rate of three mango varieties

Treatment	Ripening rate (1-5 scale)						
	Alphonso						
	3d	5d	7d	9d	12d	14d	16d
Treated	1.88	2.61	3.17	4.40	4.28	4.54	4.65
Control	1.99	2.61	3.24	4.10	4.31	4.68	4.61
	Amrapali						
	3d	5d	7d	9d	12 d	14 d	16 d
Treated	1.08	1.29	2.02	4.20	4.65	4.83	5.00
Control	1.00	1.15	2.12	4.27	4.73	4.97	5.00
	Totapuri						
	3d	5d	7d	9d	12d	14d	16d
Treated	1.02	1.08	1.13	1.41	1.67	2.88	3.54
Control	1.00	1.00	1.10	1.34	2.42	3.03	3.74

(1-5 scale: 1-unripe, 2-quarter ripe; 3- half ripe; 4-3/4th ripe; 5-completely ripe)

Table 12. Effect of standardized 'Arka mango wash' on TSS of three mango varieties during storage at RT

Treatment	TSS (^{o}Brix) taken on respective days after treatment			
	9 d	**12 d**	**14 d**	**17 d**
	Alphonso			
Treated	17.17	-	18.05	-
Control	18.24	-	18.65	-
	Amrapali			
Treated	22.11	20.75	-	-
Control	23.30	22.20	-	-
	Totapuri			
Treated	-	-	16.36	17.00
Control	-	-	16.58	17.23

Table 13. Effect of standardized 'Arka mango wash' on the organoleptic quality of three mango varieties during storage at RT

Treatment	Organoleptic quality*scale of 1-5$^{\#}$				
	Appearance	**pulp colour**	**pulp texture**	**Taste**	**off flavour**
	Alphonso				
Treated	3.15	3.79	3.62	3.94	nil
Control	2.46	3.71	3.62	3.79	nil

	Amrapali				
Treated	4.17	4.04	3.75	4.19	nil
Control	3.69	4.00	3.44	3.62	nil
	Totapuri				
Treated	3.65	3.58	3.02	3.42	nil
Control	**3.33**	4.08	3.38	3.65	nil

***Evaluated with a panel of 13 members #Scale 1-5: 1- very poor; 2- poor; 3- average 4- good; 5- very good**

Table 14. Effect of standardized 'Arka mango wash' on fruit spoilage of three mango varieties during storage at RT

Treatment	**Percentage of fruit spoilage**		
	Alphonso		
	7 days	**9 days**	
Treated	0.0	15.41	
Control	0.0	29.7	
	Amrapali		
	7 days	**9 days**	
Treated	0.0	3.92	
Control	0.0	7.78	
	Totapuri		
	7days	**12 days**	**14days**
Treated	0.0	8.37	12.35
Control	0.0	10.05	15.14

Table 15. Validation of standardized 'Arka mango wash' at Experimental farm of Directorate of Horticulture (DERAS farm), Odisha farm on the bulk quantity of mango var. Amrapali

Sooty blotch disease grade of mango var. Amrapali (0-5 scale)		**Percent disease reduction over control**
Before Treatment	**After Treatment**	
2	0	100
3	0	100
4	0	100
5	0.25	95

Fig. 7. Mango fruits cv. Amrapali with disease grade 4 before and after treatment at Experimental farm of Directorate of Horticulture (DERAS farm), Odisha

The standardized 'Arka mango wash' has been validated on around 80 tonnes of Amrapali mangoes (received from the Tribal sub-plan (TSP) villages of Rayagada district of Odisha) at Experimental farm of Directorate of Horticulture, Odisha (DERAS farm) and at farmer's orchard at Kasipur, Rayagada. The received infected mangoes were separated into groups based in their disease grades. Fruits up to disease grade of 4 resulted in 100% removal of mango blackening after treatment and disease grade 5 fruits resulted in 95% removal after treatment compared to control groups (Fig 7, 8and 9). After removal of sooty blotch blemishes, these mangoes were sold at a fair price as appearance looks good when compared to untreated blackened mangoes. The untreated blackened mangos fetches for poor price, wherein buyers and traders were reluctant to purchase them from the farmers.

Fig. 8. Large scale validation of 'Arka mango wash technology' on var. Amrapali at Experimental farm of Directorate of Horticulture, Odisha (DERAS farm), Bhubaneswar.

Fig. 9. 'Arka mango wash technology' at a farmer orchard, Rayagada, Odisha

Economics of standardized 'Arka mango wash'

Rate on 1 kg of healthy mango cv. Amrapali = Rs. 20/-;

Rate of 1 kg of mango with blackened appearance = less than Rs. 10/-

The cost involved for chemicals to treat one tonne of mango = Rs. 750/-

Labour charge for treating one tonne of mango = Rs 250/-

The total cost involved for treating one tonne of mangoes = Rs.1000/- (Rs. 1/kg of fruits)

Precautions to be noted

To ensure the availability of sufficient concentration of chemical, the water condition has to be monitored, and it is advised to change the water after every 3-4 washes. The water used for the treatment should be of potable water quality (water quality parameters have to be as per drinking water guideline mainly concerning pH, hardness, turbidity, dissolved solids, sodium, chlorine, etc.,) to get the desirable result of this above technology. As the deep bore well water having increased dissolved solids and undesirable parameter that interfere in achieving the desirable results as observed in our course of experiments too. Therefore, before initiating the treatment on large scale, the treatment has to be done on small scale to ensure the desired results as the treatment largely depends on the use of good quality water.

In the case of apple, five-to-seven-minute dip in 500

ppm chlorine, followed by brushing and a freshwater rinse, reduced incidence of SB from 100 to 0% and FS from 100 to 27% (Hendrix, 11). Batzer *et al*. (2) reported that a 7-min dip of apple infected with SBFS in 800 ppm chlorine resulted in a mean increase from 25 and 55% to 100% Extra Fancy grade for 'Jonathan' and 'Golden Delicious' apples, respectively, and increased market value by 31 and 14%, respectively.

For holistic sooty blotch management in mango, the orchard should always have full sunlight, good air circulation, with proper water drainage. Further, a regular pruning schedule has to be followed as per recommendation, which will eliminate unnecessary plant growth and excessive shading thereby increase the air movement. Further in the author's view, controlling of fungal blackening caused by sooty blotch infection at field level found to be the better option to retain the freshness of mangoes as the post-harvest treatment removes the waxy layer available on the fruit along with the fungal growth because sooty blotch fungi colonize on the waxy layer to utilize the fruit leachates leaked out of the fruit. Hence the mangoes will lose the glossy appearance even though the blackening is removed. However, the Arka Mango wash technology can be used as a feasible option for sooty blotch removal to increase the retail value of the fresh-market fruits, if the grower missed to take the advantage of fungicide management program.

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