Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2018; 7(4): 1883-1888
Received: 05-05-2018
Accepted: 10-06-2018

Manasa B
Ph.D (Horticulture), Kittur Rani Chennamma College of Horticulture, Arabhavi, University of Horticultural Sciences, Bagalkot, Karnataka, India

SL Jagadeesh
Professor & Head, Department of Postharvest Technology, College of Horticulture, Udyanagiri, Bagalkot, University of Horticultural Sciences, Bagalkot, Karnataka, India

N Thammaiah
Professor & Head, Department of Plant Pathology, College Of Horticulture, Mysuru, University of Horticultural Sciences, Bagalkot, Karnataka, India

Sandhyarani Nishani
Assistant Professor & In charge Head, Department of Biotechnology and crop improvement, Kittur Rani Chennamma College Of Horticulture, Arabhavi, Bagalkot, University of Horticultural Sciences, Bagalkot, Karnataka, India

PM Gangadharappa
Dean, College Of Horticulture, Munirabad, University of Horticultural Sciences, Bagalkot, Karnataka, India

RC Jagadeesha
Professor & Head, Department of Biotechnology and Crop Improvement, College of Horticulture, Udyanagiri, Bagalkot, University of Horticultural Sciences, Bagalkot Karnataka, India

Netravati
Assistant Professor, Department of Postharvest Technology, College of Horticulture, Udyanagiri, Bagalkot, University of Horticultural Sciences, Bagalkot, Karnataka, India

Correspondence
Manasa B
Ph.D (Horticulture), Kittur Rani Chennamma College Of Horticulture, Arabhavi, University of Horticultural Sciences, Bagalkot, Karnataka, India

Evaluation of fungicides, bioagents and botanicals on postharvest disease, shelf life and physico-chemical properties of 'Alphonso' mango

Manasa B, SL Jagadeesh, N Thammaiah, Sandhyarani Nishani, PM Gangadharappa, RC Jagadeesha and Netravati

Abstract
The experiment involved pre-harvest sprays of fungicides, bioagents and botanicals at three growth stages of mango fruit cv. Alphonso *viz.,* before the onset of flowering, at peanut and marble stages. In general, pooled data of two consecutive years (2013 and 2014) revealed better performance of fungicides over bioagents and botanicals in minimising anthracnose decay in storage and retaining quality of mango fruits. Azoxystrobin sprays (0.1%) suppressed field inocula on mango leaves resulting in significant reduction of latent infection of anthracnose in fruits. Postharvest disease index in the fruits were declined to 1.00%. The least PLW, delayed ripening (14.78 days) and maximum shelf life (18.69 days) were obtained in fruits under this treatment signifying better quality of fruits. Such fruits at optimum ripe stage had maximum firmness, titratable acidity, TSS (20.49%), total sugars, reducing, non-reducing sugars and sugar acid ratio pointing to the unhindered and coordinated ripening process favoured by azoxystrobin.

Keywords: mango, anthracnose, azoxystrobin, *Eupatorium odoratum*, ripening, shelf life, sugars

Introduction
Mango engrosses a predominant place among fruit crops in India and is rightly acknowledged as the 'King of fruits' (Sharma *et al*., 2001) [27]. India grows many of the finest mangoes in the world. Although more than 1000 cultivars and selections exist, only few cultivars are grown on commercial scale. 'Alphonso' mango is one of the most important commercial cultivar of *Mangifera indica* L., belonging to the family Anacardiaceae. It is considered as the 'King of mango cultivars' and highly suited to the coastal climate of the west coast of India. The fruit is oval in shape and is about 10 to 15 cm long. The skin is inedible and upon ripening, it turns golden yellow in colour. The pulp is golden yellow in colour with warm sweet taste, sometimes pleasantly tart and rich in aromatic flavour. Owing to these qualities, this cultivar is widely considered to be the tastiest fruit among mango fruits in India. This fruit is also an excellent source of vitamins A and C (Vasanthaiah *et al*., 2008) [31]. However, mango fruit quality and shelf life are limited by many postharvest diseases. Anthracnose caused by *Colletotrichum gloesporioides* was found to be one of the most serious field and postharvest diseases of the crop and it has been accounted in almost all the mango cultivars including Alphonso (Sangeetha and Rawal., 2009; Chowdhury *et al*., 2008) [25, 6]. In the field, the disease occurs on leaves, flowers and fruits (Ridgway, 1989) [24]. Fruit infected at pre-harvest stage develop disease symptoms during ripening (Persley, 1993) [21]. The disease occurs on the ripened fruit as sunken blackish brown blotches on which salmon buff masses of spores develop (Prakash and Srivastava, 1987) [22] resulting in rotting of the fruits. Upon ripening fruit looses its natural resistance that ultimately results in decay at the market end (Arauz, 2000) [4]. Management of mango anthracnose mainly involves selection of resistant cultivars, cultural practices and the use of fungicidal sprays (Akem, 2006) [2]. None of the commercial cultivars of mango are significantly resistant to anthracnose so as to produce without fungicidal sprays (Litz, 1997) [10]. Cultural control including flower manipulation is not possible in all situations and field sanitation though potential, not practiced due to difficulty and expense. Much of the attention and efforts on anthracnose control has concentrated mostly on fungicides. These synthetic fungicides when applied as pre-harvest sprays minimise field inoculum and thereby protect fruits from rotting during storage (Sonkar and Ladaniya, 1999; Blackarski *et al.*, 2001) [29, 5]. Fungicidal groups like dithio-carbamates, benzimidazoles, triazoles etc were found to minimise anthracnose of mango (Kapse *et al*., 2009; Zhang and Timmer, 2006; Kumar *et al.*, 2006) [14, 35, 15]. However pathogen resistance to a fungicide like benomyl resulted in search of

new fungicides (Dodd *et al.*, 1991; Adhikary *et al*., 2013) [9, 1]. Azoxystrobin, a new strobilurin fungicide is effectual against pathogens that are resistant to other fungicides (Hewitt, 1998) [13]. Postharvest diseases of various fruits as well as mango was successfully managed by this fungicide (Swart *et al*., 2009; Diedhiou *et al*., 2014) [30, 8]. However, extensive research has not been carried out using this fungicide in controlling the anthracnose of mango especially on Alphonso. On the other hand, chemical fungicides are toxic in nature with a threat of residual effect and resistance development by pathogens. Hence there is a need of hour to rely on non-toxic and non-pollutant biological disease control. Bioagents and botanicals (plant extracts) are generally used biological components for disease control. Bioagents *Trichoderma* spp as soil applications were proven to be effective against postharvest anthracnose of fruits (Mandhare *et al.*, 1996) [18] but their use as foliar sprays is very scarce. Botanicals are generally used as dipping treatments rather pre-harvest sprays for managing postharvest diseases. Dubey *et al.* (2007) [11] reported the antimicrobial activity of botanical *Eupatorium* spp applied as oil against anthracnose disease during ripening. In this study, *Eupatorium odoratum* that was copiously available as a weed and considered menace to main crops was introduced as a new botanical along with other locally available botanical as sprays before harvest. In view of all these points, an effort was made to assess the effectiveness of new element like azoxystrobin with other formerly used fungicides along with bioagents *Trichoderma* spp, introduced *Eupatorium* and other botanicals as pre-harvest sprays on anthracnose disease, ripening behavior, shelf life and physico-chemical properties of mango fruits in particular Alphonso during storage.

Materials and Methods

The present investigation was conducted in a mango orchard situated in Kittur taluk, Dharwad district, India. Mango trees of variety 'Alphonso' were given three sprays *viz*., December (before flowering), February (peanut stage) and March (marble stage) with fungicides like Carbendazim, Tricyclazole, Azoxystrobin, Thiophanate methyl at 0.1% each and Zineb at 0.2%; botanicals like *Eupatorium odoratum* and *Nerium oleander* each at 5% and bioagents like *Trichoderma viride* and *Trichoderma harzianum* each at 0.5% in 2012-13 (year I). Unsprayed trees served as control. The experiment was repeated in 2013-14 (year II). Each treatment had two replications and two trees were selected per replication. Regular cultural practices were followed for the crop. The healthy fruits of uniform maturity and size, 24 in number per treatment from the sprayed and non-sprayed trees were harvested in the fortnight of May during both the years (2013 and 2014). They were packed in CFB (corrugated fibre board) boxes of two dozen capacities, commercially used for packing mangoes and were brought to the laboratory, Department of Post Harvest Technology, Kittur Rani Channamma College of Horticulture (KRCCH), Arabhavi, India.

Preparation of fungicides

Fungicides were obtained from Karnataka Agro Chemicals, Dharwad. Systemic fungicides like azoxystobin (Amistar, 250 SC), thiophanate methyl (Topsin-M, 70 WP), carbendazim (Bavistin, 50 DF), tricyclazole (Beam, 75 WP) each at 0.1 per cent and a contact fungicide zineb (Dithane Z-78) at 0.2 per cent were used as pre-harvest fungicides in this study. Systemic fungicides were prepared by dissolving 1 g/ 1 ml of each fungicide was dissolved in 100 ml of water and volume made up to 1000 ml. While zineb of 0.2% was prepared with 2 g of zineb in 100 ml of water and then making up the volume to 1000 ml.

Preparation of bio agents

The cultures of bioagents *Trichoderma viride and Trichoderma harzianum* were obtained from the Department of plant pathology, University of Agricultural Sciences, Dharwad. The concentration of 0.5% of each culture was prepared by dissolving 5 g of respective culture in 100 ml of water and then making up the volume to 1000 ml.

Preparation of botanicals

Botanicals namely *Eupatorium odoratum* (Siam weed) and *Nerium oleander* (Oleander) that were grown abundantly as weed in and around Dharwad were collected at random and taken to the laboratory. The fresh leaves (200 g) of each botanical free from damage or disease were collected, rinsed in tap water, extracted juice and sieved through a muslin cloth to get the clear extract. The obtained juice from 200g leaf sample was made up to 1000 ml volume with distilled water. For the complete coverage of the canopy, 6 litres of spray solution were required per tree. Hence, as per the concentration adopted each for fungicides, bioagents and botanicals, 6 litres of spray solution were prepared.

Anthracnose disease index (%)

The degree of anthracnose disease index in fruit was indicated based on the extent of peel damage. Score was assessed by the percentage of total surface area affected, where 0= absence of disease, 1=1-5% disease affected area, 2= 6-25% disease affected area, 3= 26-50% disease affected area, 4 = 51-75% disease affected area, and 5 = 75-100% disease affected area. It was calculated by using the formula given below (Wheeler, 1969) [33].

$$\text{Anthracnose disease index (\%)} = \frac{\text{Total score}}{\text{Number of fruits observed x maximum score}} \times 100$$

Respiration rate (ml CO_2/kg/h)

Respiration rate was measured with a CO_2 gas analyzer in static method, wherein, whole fruit was weighed and incubated in a hermetically sealed container of 1250 ml capacity for 15 minutes. At the end of incubation period, gas sample was drawn from the container head space using a gas tight syringe and measured in the analyzer. The change in CO_2 concentration in the head space and time was recorded. The respiration rate of the fruit was calculated using the following formula and expressed as ml CO_2/kg/h.

$$\text{Respiration rate (ml } CO_2\text{/kg/h)} = \frac{CO_2\ (\%) \text{ in the sample x Volume of container (ml)}}{100 \text{ x Weight of the sample (kg) x Time (h)}}$$

Physiological loss in weight (PLW%)

The fruits in each replication of respective treatment were weighed at the beginning of storage which was recorded as initial weight and at ripe stage as final weight. Per cent physiological loss in weight was calculated using the formula given below.

$$\text{Physiological loss in weight (\%)} = \frac{\text{Raw weight (g)} - \text{Ripe weight (g)}}{\text{Raw weight (g)}} \times 100$$

Number of days taken for ripening and shelf life (days)
Number of days taken for ripening was obtained by taking the difference in days between the date of harvest and date of ripening. The shelf life of fruits was determined by counting the number of days from harvesting till the fruits were edible without spoilage.

Firmness (g/cm^2)
Firmness of mango was measured on both sides of the cheek at regular intervals by using Lutron FG-5000A tenderometer. The fruit was held steady on a firm surface and the probe was pushed into the fruit to a depth of 0.5 mm, corresponding to a mark inscribed on the shaft of the probe with a homogenous pressure.

Total Soluble Solids (TSS) (^{0}B)
The juice extracted by squeezing the homogenized fruit pulp through muslin cloth was used to measure the TSS. It was determined by using ERMA hand refractometer, replicated three times and the mean was expressed in ^{0}B.

Total sugars (%)
Non-reducing sugars were first hydrolyzed with sulphuric acid to reducing sugars. Then, the total sugar was estimated using Dinitrosalicylic acid (DNSA) method (Malhotra and Sarkar, 1979) [16] and values were expressed as per cent.

Reducing sugars and Non-reducing sugars (%)
Reducing sugars in the samples were estimated as per the Dinitrosalicylic acid method (Miller, 1972) [20]. The values obtained were expressed as per cent. The per cent non-reducing sugars were obtained by subtracting the value of reducing sugars from that of total sugars.

Titratable acidity (%) and Sugar acid ratio
A known weight of fruit pulp (5g) was homogenized with distilled water and filtered using muslin cloth followed by Whatman No. 1 filter paper. An aliquot of 10 ml was taken and titrated against standard 0.1N NaOH using phenolphthalein indicator. The appearance of light pink colour was marked as the end point. The value was expressed in terms of citric acid as per cent titratable acidity of juice (William, 1984) [34]. Sugar acid ratio of fruit pulp was computed as the ratio of total sugars to the titratable acidity.

Results

Effect of pre-harvest treatments on anthracnose disease index (%) and respiration rate (ml CO_2 /kg/h) of mango fruits
The anthracnose symptoms were apparent during ripening of mangoes irrespective of the treatments. As shown in table 1, significant differences were seen with respect to efficacy of applied treatments to the disease. In general fungicides performed better over biological treatments in treating the disease, nevertheless the latter showed significance to control. Pre-harvest sprays of fungicide azoxystrobin significantly minimized disease index of mango fruits to 1.00%, while the control fruits had maximum disease index (21. 33%). Though biological treatments were statistically similar to each other, fruits of trees treated with *Eupatorium odoratum* had numerically lesser disease index (14.33%). Mango fruits were observed at three different stages (Green, Colour-break and Ripe) for respiration rate during their post harvest life (Table 2). The fruits at green mature stage exhibited no statistical difference, where the mean values of respiration rate ranged from 84.57 ml CO_2/kg/h to 93.77 ml CO_2/kg/h. Nevertheless, notable variations were observed in respiration rate of fruits at colour break and ripe stages. Respiratory peak was observed in all the treatments at colour break stage. However, significantly lower peak was noticed in the fruits of trees treated with azoxyztrobin (504.75 ml CO_2/kg/h). Maximum respiratory peak was recorded in control fruits (870.19 ml CO_2/kg/h). Similar trend was observed at ripe stage with the lowest respiration rate in significance in the treatment azoxystrobin (319.95 ml CO_2/kg/h) and the highest in control (638.46 ml CO_2/kg/h). Amongst bioagents and botanicals, only *Eupatorium* managed to lower the respiration rate of fruits at ripe stage (502.17 ml CO_2/kg/h) than control and showed statistical similarities to few fungicides in this study.

Effect of pre-harvest treatments on physiological loss in weight (%), firmness (g), number of days taken for ripening and shelf life (days) of mango fruits
Lower physiological loss in weight (9.18%) and maximum firmness (339.38 g) with significance was noted in the fruits obtained from trees treated with azoxystrobin in comparison to control and other treatments. Control fruits suffered the most with higher physiological weight loss (21.44%) and were less firmer (200.65 g) (Table 3). Among the biological treatments, *Eupatorium* treated fruits had maximum firmness (254.15 g) and minimum physiological weight loss (16.12%) in significance to control. Significant differences were observed with respect to number of days taken for fruit ripening during post harvest observation (Table 3). The fruits under treatment azoxystrobin took significantly more number of days for ripening (14.78 days). On the other hand, significantly faster or early ripening was recorded by fruits of control (5.63 days). *Eupatorium odoratum* significantly delayed ripening (10. 20 days) compared to control, *Trichoderma spp* and *Nerium oleander*. Shelf life of mangoes recorded statistical difference among the treatments and showed almost a similar trend as the days taken for ripening (Table 3). Only, shelf life of the fruits of azoxystrobin was extended to four days (18.69) upon ripening while most of the fruits in other treatments and control lived for two to three days. The minimum shelf life of 7.59 days was found in control fruits.

Effect of pre-harvest treatments on total soluble solids (TSS) (^{0} B), total sugars (%) and titratable acidity (%) of mango fruits
The data pertaining to total soluble solids, total sugars and titratable acidity at optimum ripe stages of mangoes in this investigation revealed significant differences among the treatments (Table 4). Mango fruits of treatment azoxystrobin had significantly higher TSS of 20.49 ^{0}B over all other treatments while the control fruits recorded minimum TSS (13.51 ^{0}B). Similar trend was seen with respect to total sugars. Fruits under azoxystrobin treatment were sweeter at ripe stage with significantly higher sugar content (18.72%) compared to other treatments. Control fruits, on the other hand had minimum total sugar content of 11.55%. Significantly maximum titratable acidity was associated with the treatment azoxystrobin (0.40%). The least and same level of titratable acidity was noted in control, *Nerium oleander* and *Trichoderma harzianum* (0.27%) and they were non-significant with many treatments.

Effect of pre-harvest treatments on reducing sugars (%), non-reducing sugars (%) and sugar acid ratio of mango fruits

The data in table 5 shows the existence of significant differences in reducing and non-reducing sugars. Reducing sugar content of mango fruits was found to be significantly maximum and same both the years in the fruits of treatment azoxystrobin (6.25%). In this study, the fruits of control were found to contain minimum reducing sugars (1.85%). The non-reducing sugars were recorded to be highest in the fruits of treatment azoxystrobin (12.47%) and this treatment was on par with the treatments carbendazim (11.43%) and Thiophanate methyl (11.21%). Rest of the treatments though remained statistically on par; the minimum non-reducing sugars were associated with the treatment Tricyclazole (8.93%). Sugar acid ratio blend, a characteristic edible quality of Alphonso cultivar of mango was found maximum in the treatment carbendazin (50.32) (Table 5). But it exhibited statistical parity with the treatment azoxystrobin (47.64). Though the remaining treatments were statistically similar to each other throughout the investigation, the minimum sugar acid ratio was observed in *Trichoderma harzianum* (42.02).

Table 1: Influence of pre-harvest sprays of fungicides, botanicals and bioagents on anthracnose disease index of mango fruits cv. 'Alphonso'

Treatments	Disease index (%)		
	Year I	Year II	Mean
Control	22.67a	20.00a	21.33a
Carbendazim at 0.1%	8.00d	6.00c	7.00c
Tricyclazole at 0.1%	15.33bc	16.00ab	15.67b
Azoxystrobin at 01%	1.33e	0.67d	1.00d
Thiophanate methyl at 0.1%	10.00d	8.67c	9.33c
Zineb at 0.1%	14.00c	13.33b	13.67b
Eupatorium odoratum at 5%	14.67bc	14.00b	14.33b
Nerium oleander at 5%	18.00b	16.67ab	17.33b
Trichoderma viride at 0.%	16.00bc	15.33b	15.67b
Trichoderma harzianum at 0.1%	17.33bc	16.67ab	17.00b

Note: Values within the column without letter or with the same letter are not significantly different by Duncan Multiple Range Test at $P \leq 0.05$

Table 2: Influence of pre-harvest sprays of fungicides, botanicals and bioagents on respiration rate at green, colour- break and ripe stages of mango fruits cv. 'Alphonso'

Treatments	Respiration rate (ml CO_2/kg/h)								
	Green stage			Colour break			Ripe stage		
	Year I	Year II	Mean	Year I	Year II	Mean	Year I	Year II	Mean
Control	96.69	88.5	92.59	870.68a	869.70a	870.19a	645.80a	631.11a	638.46a
Carbendazim at 0.1%	91.84	88.66	90.25	655.08c	638.11d	646.6d	450.65c	444.72e	447.69c
Tricyclazole at 0.1%	91.07	95.28	93.18	849.14ab	809.25ab	829.20ab	582.69ab	571.64abcd	577.17ab
Azoxystrobin at 01%	83.06	86.2	84.64	503.41d	506.08e	504.75e	329.26d	310.63f	319.95d
Thiophanate methyl at 0.1%	85.8	86.63	86.22	688.92c	674.92cd	681.92cd	510.22bc	455.20de	482.71c
Zineb at 0.1%	94.23	91.99	93.12	734.19bc	723bcd	728.60bcd	512.13bc	501.70bcde	506.92bc
Eupatorium odoratum at 5%	84.34	93.97	89.16	770.51abc	768.11abc	769.31abc	515.23bc	489.10cde	502.17bc
Nerium oleander at 5%	93.27	94.25	93.77	840.64ab	844.29a	842.46a	644.71a	617.14ab	630.93a
Trichoderma viride at 0.%	92.65	85.16	88.91	823.47ab	830.66ab	827.07ab	601.90ab	596.25abc	599.08a
Trichoderma harzianum at 0.1%	81.38	87.75	84.57	831.04ab	826.36ab	828.70ab	638.06a	608.22abc	623.14a

Note: Values within the column without letter or with the same letter are not significantly different by Duncan Multiple Range Test at $P \leq 0.05$

Table 3: Influence of pre-harvest sprays of fungicides, botanicals and bioagents on physiological loss in weight, firmness, number of days taken for ripening and shelf life of mango fruits cv. 'Alphonso'

Treatments	Physiological loss in weight (%)			Firmness (g)			Number of days taken for ripening			Shelf life (Days)		
	Year I	Year II	Mean	Year I	Year II	Mean	Year I	Year II	Mean	Year I	Year II	Mean
Control	22.33a	20.49a	21.44a	195.52d	205.77e	200.65f	5.53e	5.71e	5.63e	7.52e	7.66e	7.59e
Carbendazim at 0.1%	13.47e	12.70e	13.08f	283.77b	295.21ab	289.49b	12.18b	12.47b	12.33b	15.16b	15.04b	15.10b
Tricyclazole at 0.1%	18.72c	17.52c	18.15c	237.93bcd	291.96b	264.95bc	7.41d	7.72d	7.57d	9.59d	9.69d	9.64d
Azoxystrobin at 01%	9.47f	8.84f	9.18g	332.05a	346.71a	339.38a	14.74a	14.82a	14.78a	18.76a	18.61a	18.69a
Thiophanate methyl at 0.1%	14.12e	14.21de	14.17e	264.47bc	275.15bc	269.82bc	11.75b	11.84b	11.80b	14.84b	14.88b	14.86b
Zineb at 0.1%	16.35d	15.51d	15.96d	236.27cd	263.20bcd	249.74cde	10.38c	10.26c	10.32c	12.45c	12.58c	12.52c
Eupatorium odoratum at 5%	16.66d	15.53d	16.12d	231.08cd	277.21bc	254.15bcd	10.12c	10.27c	10.20c	12.59c	12.73c	12.66c
Nerium oleander at 5%	20.65b	20.39a	20.53ab	209.31d	220.69de	215.00ef	5.78e	5.91e	5.85e	7.68e	7.85e	7.76e
Trichoderma viride at 0.%	19.53bc	18.52bc	19.04c	215.63d	235.78cde	225.70def	5.69e	5.72e	5.71e	7.64e	7.52e	7.58e
Trichoderma harzianum at 0.1%	20.51b	20.09ab	20.31b	222.86cd	212.61de	217.74ef	5.65e	5.66e	5.66e	7.56e	7.85e	7.71e

Note: Values within the column without letter or with the same letter are not significantly different by Duncan Multiple Range Test at $P \leq 0.05$

Table 4: Influence of pre-harvest sprays of fungicides, bioagents and botanicals on total soluble solids, total sugars and titratable acidity of mango fruits cv. 'Alphonso'

Treatments	Total soluble solids (^{0}B)			Total sugars (%)			Titratable Acidity (%)		
	Year I	Year II	Mean	Year I	Year II	Mean	Year I	Year II	Mean
Control	13.52e	13.51d	13.51d	11.38d	11.72d	11.55d	0.27c	0.26e	0.27e
Carbendazim at 0.1%	17.09b	18.13b	17.61b	16.40b	16.55b	16.48b	0.34b	0.32bc	0.33b
Tricyclazole at 0.1%	14.39cde	14.36cd	14.38cd	11.45d	12.11cd	11.78d	0.29c	0.27de	0.28cde
Azoxystrobin at 01%	20.58a	20.40a	20.49a	18.66a	18.77a	18.72a	0.40a	0.39a	0.40a
Thiophanate methyl at 0.1%	16.99b	17.06b	17.03b	15.81b	15.77b	15.80b	0.34b	0.32b	0.33b
Zineb at 0.1%	16.63bc	16.66b	16.65b	13.03c	13.21c	13.12c	0.29c	0.29cd	0.29c
Eupatorium odoratum at 5%	15.96bcd	16.29bc	16.13bc	12.88c	13.17c	13.02c	0.29c	0.27de	0.28cde
Nerium oleander at 5%	14.03de	14.09d	14.07cd	11.48d	11.88d	11.68d	0.27c	0.26e	0.27e
Trichoderma viride at 0.%	14.37cde	14.06d	14.22cd	11.52d	11.73d	11.63d	0.28c	0.27de	0.28cde

Note: Values within the column without letter or with the same letter are not significantly different by Duncan Multiple Range Test at $P \leq 0.05$

Table 5: Influence of pre-harvest sprays of fungicides, bioagents and botanicals on reducing sugars, non-reducing sugars and sugar acid ratio of mango fruits cv. 'Alphonso'

Treatments	Reducing sugars (%)			Non-reducing sugars (%)			Sugar acid ratio		
	Year I	Year II	Mean	Year I	Year II	Mean	Year I	Year II	Mean
Control	1.78f	1.92e	1.85e	9.60b	9.80bc	9.70bc	42.25bc	45.09bc	43.67cd
Carbendazim at 0.1%	5.07b	5.02b	5.05b	11.33a	11.53a	11.43a	48.28a	52.35a	50.32a
Tricyclazole at 0.1%	2.91de	2.80de	2.86de	8.54b	9.31c	8.93c	39.93c	44.35bc	42.14d
Azoxystrobin at 01%	6.25a	6.25a	6.25a	12.42a	12.52a	12.47a	46.70a	48.58ab	47.64ab
Thiophanate methyl at 0.1%	4.56b	4.62bc	4.59bc	11.25a	11.15ab	11.21ab	46.94a	48.82ab	47.88ab
Zineb at 0.1%	4.10bc	4.10bc	4.10bc	8.93b	9.11c	9.02c	44.97ab	45.56bc	45.27bcd
Eupatorium odoratum at 5%	3.52cd	3.71cd	3.61cd	9.36b	9.45c	9.41c	44.53ab	48.78ab	46.66abc
Nerium oleander at 5%	2.34ef	2.35e	2.35e	9.14b	9.53bc	9.34c	42.00bc	45.12bc	43.56cd
Trichoderma viride at 0.%	2.67def	2.66e	2.67de	8.86b	9.07c	8.96c	40.73bc	43.56c	42.14d
Trichoderma harzianum at 0.1%	2.26ef	2.32e	2.29e	9.13b	9.24c	9.19c	40.68bc	43.35c	42.02d

Note: Values within the column without letter or with the same letter are not significantly different by Duncan Multiple Range Test at $P \leq 0.05$

Discussion

In the present investigation, exogenous application of azoxystrobin had greater impact on anthracnose disease control. The disease index in this study was reduced to 1.00%. Our previous paper had shown a huge reduction in field inocula on leaves (24.54%) and postharvest anthracnose disease incidence (3.3%) of mango cv 'Alphonso' by azoxystrobin sprays (Manasa *et al.,* 2018) [17]. Hence, it is clearly evident that this fungicide not only suppressed foliage infection but also attended the manifestation of latent infection during storage. Many studies indicated the efficacy of this strobilurin fungicide in eradicating the anthracnose and other postharvest diseases *viz*., anthracnose fruit rot of grape berries and avocado (Wedge *et al.,* 2007; Miles *et al*., 2004) [32, 19], mold rot (*Alternaria alternata* (Fr.) Keissler) of apple, leather rot (*Phytophthora cactorum*) of strawberry (Rebollar-Alviter *et al.,* 2005) [23], black spot (*Guignardia citricarpa*) of citrus (Anesiadis *et al.,* 2003) [3] and gray mold (*Botrytis cinerea*) of many fruits and vegetables. Azoxystrobin has a unique mode of action of attacking on mitochondrial respiration of the pathogens, causing their death at cellular level (Harrison and Tedford, 2002) [12]. In this study, the respiration rate of fruits at green mature stage exhibited statistical non-significance among all the treatments. In unripe fruits, fungal pathogen remains in quiescent phase and the infection process is halted. Thus, the green fruits are resistant to fungal attack (Dennis, 1983) [7]. The disease development results in increased respiration rate of host tissue, heat production and enhanced ethylene evolution (Schiffmann-Nadel *et al*., 1985) [26]. This elucidates the reason behind elevated respiration rates of control fruits both at colour break and ripe stages that were severely infected with anthracnose disease in this study. In opposition, fruits of the azoxystrobin had lower respiration rate at both the stages. The process of ripening is accompanied by weakening of cell walls and a decline in ability to synthesize antifungal substances and the fruit thus no longer is able to resist the advancement of fungus (Schiffmann- Nadel *et al*., 1985) [26]. Probably the direct role of azoxystrobin in inhibiting the fungal growth following disease suppression as observed in this study might have guarded the fruits from respiratory damage. Fruits undergo some loss in their weights during storage and ripening due to the process of respiration and transpiration. Pathogens attack on cell wall during ripening making fruits more vulnerable to the disease. The diseased tissue hence tends to have higher respiration rates resulting in enhanced ethylene production leading to more weight loss (Schiffmann-Nadel *et al*., 1985) [26]. In this study, the effect of azoxystrobin in protecting the cell integrity might have maintained higher firmness, minimum physiological weight loss, diminished ethylene production and slowed down ripening process. The fruits of azoxystrobin treatment ripened late after 15 days of harvest and lived for 19 days as against 10-12 days of its normal shelf life at room temperature. Diedhiou *et al*. (2014) [8] stated that the azoxystrobin as pre-harvest spray is effective in improving the shelf life of mango by minimising post-harvest anthracnose disease. On contrary, the control mango fruits with highest disease index in the present experiment suffered from maximum loss of weight, early ripening, reduced firmness and shelf life. The performance of *Eupatorium odoratum* on disease control and shelf life was incomparable with azoxystrobin. However, the botanical had a beneficial effect on manipulating the postharvest behavior of the mango fruits in comparision to control. The total soluble solids, total sugars, reducing sugars and non-reducing sugars were higher in the fruits of trees of azoxystrobin in this experiment. This finding is in agreement with Smith (2013) [28] who noticed the highest sugars in grapes that received pre-harvest sprays of azoxystrobin. But the author reported no difference in the acidity of control fruits and those receiving azoxystrobin. Conversely, titratable acidity in the present study was detected higher in the fruits of trees sprayed with the same fungicide. Studies are needed to make conclusions for the role of azoxystrobin in boosting the sugars and maintenance of acidity in fruits. It can be speculated that the chemical did not harm the quality of fruits and might have warranted the fruits from respiratory impairment caused by the disease thereby impeding the utilization of sugars and acids in the process. Though higher sugar-acid ratio observed in carbendazim, fruits under the treatment azoxystrobin obtained high scores for taste and flavor during sensory evaluation (data not shown). This level of sugar to acid in the fruits treated with azoxystrobin appears to be optimum to impart characteristic sugar acid blend leading to maximum sensorial quality. It also indicates that higher sugar-acid ratio does not mean higher acceptability. Low sugars and acids in control fruits reveal lack of optimal blend of sugar-acid that could bring better taste to fruits. Bioagents and botanicals tested in the current research did not influence the physico-chemical properties of the mango fruits.

Conclusion

Azoxystrobin, a novel fungicide used as pre-harvest sprays in this study revealed a greater impact on minimizing the postharvest anthracnose disease of mango. Disease index as low as 1.00% achieved in the fruits proved this fungicide to be outstanding and promising alternative for mango anthracnose control in comparision to the earlier used fungicides. Extension of shelf life to 19 days in mango fruits with better physico-chemical attributes by azoxystrobin at

room storage was a notable achievement in this study. However, an advanced research and a deep understanding on its role on enzymatic levels are required. Considerable performance of *Eupatorium* on disease and shelf life of the fruits noticed in this study needs focus on its possible mechanism. Hence, integrated and multidisciplinary approach is essential for further exploration of this new chemical and introduced botanical on postharvest disease management as well as maintenance of ripening quality of mango fruits.

References

1. Adhikary NK, Dey S, Tarafdar J. Studies on morphology of mango anthracnose disease causing fungus *colletotrichum gloeosporioides* (penz.) penz. and sacc. and efficacy of azoxystrobin against the fungus under *in vitro* and *in vivo* condition. The Bioscan. 2013; 8(2):493-497.
2. Akem NC. Mango anthracnose disease: Present status and future research priorities. Plant Pathol. J. 2006; 5(3):266-273.
3. Anesiadis T, Karaoglanidis R, Klonari KT. Protective, curative and eradicant activity of the strobilurin fungicide azoxystrobin against *Cercospora beticola* and *Erysiphae betae*. J. Phytopathol. 2003; 151:647-651.
4. Arauz LF. Mango anthracnose: economic impact and current options for integrated management. Plant Dis. 2000; 84:600-611.
5. Blackarski RW, Bartz JA, Xiao CL, Legard DE. Control of post-harvest Botrytis fruit rot with pre-harvest fungicide applications in annual strawberry. Plant Dis. 2001; 85:597-602.
6. Chowdhury MNA, Rahim MA, Khalequzzaman KM, Alam MJ, Humauan MR. Effect of horticultural practices on incidence of anthracnose on yield and quality of mango. International J Sustain. Crop Prodn. 2008; 3:1-9.
7. Dennis C. Post-harvest pathology of fruits and vegetables. Academic press, London, 1983, 264.
8. Diedhiou PM, Mbaye N, Faye R, Samb PI. Field tests of fungicides against post-harvest rot of mangoes in Senegal. International J Sci. Environ. Technol. 2014; 3(2):597-606.
9. Dodd JC, Estrada AB, Matcham J, Jeffies P, Jerger MJ. The effect of climatic factors on *Colletotrichum gloeosporioides*, causal agent of mango anthracnose in the Philippines. Plant Pathol. 1991; 40:568-575.
10. Litz RE. The Mango: Botany, Production and uses. CABI publishing, Wallingford, 1997, 257-280.
11. Dubey RK, Kumar R, Jaya, Dubey NK. Evaluation of *Eupatorium cannabium* Linn oil in enhancement of shelf life of mango fruits from fungal rotting. World J Microbiol. Biotechnol. 2007; 23:467-473.
12. Harrison S, Tedford E. Quadris, a novel fungicide for disease control in rice. In: Proceeding of the temperate rice conference, B. IRRI, India, 2002, 289-294.
13. Hewitt HG, Strobilurins. Fungicides in Crop Protection. CAB International, NY, 1998, 128-129.
14. Kapse BM, Pawar VN, Sakhale BK. Post harvest disease management in mango (*Mangifera indica* L.) cv. Kesar. Acta Hort. 2009; 820:493-503.
15. Kumar MR, Reddy YN, Srihari D. Effect of calcium and plant growth regulators on flowering and yield of mango (*Mangifera indica* L.) cv. Baneshan. J Res. Angrau. 2006; 34:11-15.
16. Malhotra SS, Sarkar. Physiol. Plant. 1979; 47:223-228.
17. Manasa B, Jagadeesh SL, Thammaiah N, Jagadeesh RC, Gangadharappa PM, Nethravathi. Pre-harvest application of azoxystrobin minimised anthracnose of mango (cv. 'Alphonso') both at field and postharvest level enhancing yield and quality of fruits. J Pharmacognosy and Phytochemistry. 2018; 7(3):2962-2967.
18. Mandhare VK, Pawar BB, Kulkarni SR. Efficacy of fungicides against fruit spot of pomegranate. Pestology. 1996; 20:19-20.
19. Miles AK, Willingham SL, Cooke AW. Field evaluation of strobilurins and a plant activator for the control of citrus black spot. Australian Plant Pathol. 2004; 33:371-378.
20. Miller GL. Use of dinitrosalicylic acid reagent for determination of reducing sugars. Ann. Chem. 1972; 31:426-428.
21. Persley D. Diseases of fruit crops. Dept. Primary Industries, Queensland Govt, Brisbane, 1993.
22. Prakash OM, Srivastava KC. Mango diseases and their management. A world review. Today & tomorrow's printers and publishers, New Delhi. 1987; 175.
23. Rebollar-Alviter A, Madden LV, Ellis MA. Efficacy of azoxystrobin, pyraclostrobin, potassium phosphate, and mefenoxam for control of strawberry leather rot caused by *Phytophthora cactorum*. Plant Health Prog. 2005; doi:10.1094/PHP-2005-0107-01-RS.
24. Ridgway R. Mango pests and disorders. Dept. Primary Industries, Queensland Govt, Brisbane, 1989
25. Sangeetha CG, Rawal RD. Temperature requirement of different isolates at *Colletotrichum gloesporioides* isolated from mango. American-Euresian J Scientific Res. 2009; 4:20-25.
26. Schifman-Nadel M, Michaely H, Zauberman G, Chet I. Physiological changes occurring in picked climacteric fruit infected with different pathogenic fungi. Phytopathologische Zeitschrift. 1985; 13:277-284.
27. Sharma RR, Goswami AM, Singh CN, Chhonkar OP, Singh G. Catecholase and cresolase activities and phenolic concentration in mango (*Mangifera indica* L.) at panicle initiation. Scientia Hort. 2001; 87:147-151.
28. Smith BJ. Fruit quality, phyto chemical content and disease severity of Muscadine grapes affected by fungicide applications. Pharmaceutical crops. 2013; 4:21-37.
29. Sonkar RK, Ladaniya MS. Effect of pre-harvest sprays of ethephon, calcium acetate and carbendazim on rind colour, abscission and shelf-life of Nagpur mandarin (*Citrus reticulata*). Indian J Agric. Sci. 1999; 69:130-135.
30. Swart SH, Swart G, Labuschagne C. The effect of strategically timed pre-harvest fungicide applications on post-harvest decay of mango. Acta Hort. 2009; 820:511-520.
31. Vasanthaiah HKN, Ravishankar KV, Narayanaswamy P, Shivashankara KS. Influence of temperature on spongy tissue formation in 'Alphonso' Mango, International J Sci. 2008; 8(3):226-234.
32. Wedge DE, Smith BJ, Quebedeauxc JP, Constantin RJ. Fungicide management strategies for control of strawberry fruit rot diseases in Louisiana and Mississippi. Crop Protection. 2007; 26:1449-1458.
33. Wheeler BEJ. An Introduction to Plant Diseases, John Wiley and Sons Limited, London, 1969, 301.
34. William S. Official methods of analysis. Ed 14, Association of Official Analytical Virginia, 1984; 424- 462.
35. Zhang J, Timmer LW. Pre harvest application of fungicides for postharvest disease control on early season tangerine hybrids in Florida. Crop Prot. 2006; doi:10.1016/j.cropro.2006.08.007.