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Sustainable management of post harvest disease fruit rot in papaya caused by *Colletotrichum rioidesgloeospo*

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ABSTRACT

Papaya (*Carica papaya* L.) fruits are highly perishable commodity suffer from heavy post harvest losses and cause about 8 to 18 per cent losses during storage to marketing. Post harvest losses in papaya are caused by biotic and abiotic factors. Among different biotic factors, anthracnose is an important post harvest disease which causes heavy loose in quality and economic of papaya. This investigations were carried out in 2018 to 2020 on sustainable management fruit rot of papaya through wrapping materials, botanicals and oil coating of fruit by pre inoculation of pathogens in papaya fruits. The significantly minimum disease intensity after 15 days of the incubation was observed in wrapping papaya fruits with polythene bag 37.78 per cent with 57.50 per cent disease control followed by news paper 46.67 per cent. Among Nine botanical extracts at 10 per cent concentration the minimum disease intensity was observed in garlic extract (28.89%) with 68.29 per cent disease control followed by neem extracts (35.56%) with 60.97 per cent disease control as well as taken 2.83 days for initiation of symptoms. Among eight different oil coatings significantly minimum fruit rot intensity was observed in fruits treated with lemon grass oil (31.11%) and it was at par with mustard oil (33.33%) with 67.44 and 65.12 per cent disease control, respectively.

***Key words**: Botanicals, Pathogens, Wrapping materials, Lemongrass oil*

Introduction

The papaya (*Carica papaya* L.) is a popular fruit of the Caricaceae family. With 48 species, Carica is the largest of the four genera, with *Carica papaya* L. being the most important and widely cultivated (Badillo, 1971; Waller, 1992). The papaya fruit is widely available worldwide in tropical and subtropical regions due to its popularity. Since the middle of the 19th century, papaya cultivation has become increasingly popular due to its high nutritive value and wide range of climate tolerance. Papaya leaves, in addition to the fruit, have some medicinal properties. The roots can be used to treat

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piles and yams, and the stem and bark can be used to make ropes. As a result, papaya has earned the moniker "common man's fruit." Postharvest losses are significant because fruits are living entities and highly perishable commodities that are affected by a variety of factors that result in postharvest spoilage. PHLs can result from a variety of factors, including biodegradation by microorganisms, insects, rodents, or birds or improper handling.

The decline in both quantity and quality of a food production from harvest to consumption is known as postharvest loss. Quality losses include those that have an effect on a product's acceptability, edibility, and nutrient/calorie composition. In general, developed nations experience a higher rate of these losses (Kader, 2002).

Several sustainable strategies, including wrapping materials, botanicals, and oil coatings available to prevent papaya postharvest diseases. Wrapping technique that utilizes a variety of packaging materials, such as paper as the lining material, bagging, individual paper wrapping, polyethylene sheet lining, individual polyethylene shrink wrapping or seal packing, cardboard boxes covered with high and low density polyethylene, and so on, to increase fruit shelf life through modified atmosphere techniques (Bhattarai and Shah, 2017).

Plant extracts are being used to make natural or bio-pesticides, which are good for the environment and don't harm plants or soil. They also had insecticidal and fungicidal properties. As a result, these can be utilized in place of synthetic or chemical products. In this context, the neem tree (*Azadirachta indica*), chinaberry (*Melia azadrach*), and marigold (*Tagetes* spp.) are the widely studied plants. Biopesticides are being made with them (Malik *et al.,* 2016). Post-reap medicines utilizing rejuvenating balms might have somewhat high acknowledgment, buyer inclination for the utilization of regular plant items instead of engineered fungicides to control rot (Abd-Alla *et al.,* 2014). According to Goubran and Holmes (1993), essential oils are complex, volatile compounds produced in various plant parts that are known to have a variety of plant functions, including conferring resistance to pests and diseases. Terpene hydrocarbons and their oxygenated derivatives, such as alcohols, aldehydes, ketones, acids, and esters, contribute to the complexity of essential oils (Wijesekara *et al*., 1997).

Materials and Methods

Present investigation was carried out in the Department of Plant Pathology, Chimanbhai Patel College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, Gujarat during the year 2018 to 2020

Effect of different wrapping materials for the management of fruit rot of papaya

Surface of maturing fruit of papaya is more susceptible to the fungal infection and is tender to penetrate the saprophytes to cause rotting. So it is necessary to keep hindrance in the surface for the surrounding spores of the several contaminating saprophytes. Keeping this view in mind various wrapping materials were tested for the packaging of fruits to improve its shelf-life.

With a view to improve the shelf-life of the fruit after harvest, five fruits from each treatment were washed, surface sterilized with sodium hypochlorite 1 per cent solution for 1 minutes and dried. Six different wrapping materials *viz.,* news paper, brown paper bag, tissue paper, butter paper, polythene bag and aluminium foil were sterilized under UV light for 15 minutes under laminar air flow. These sterilized materials were wrapped on the fruits so that whole fruit was covered and no portion left open with one control (unwrapped open fruit) was kept.

Each treatment was repeated thrice. Different types of infection and development of symptoms was recorded at regular interval at 5, 10 and 15 days of inoculations and per cent disease intensity in different treatments were scored using 0 to 5 scale (Kumar, 2001).

Grade		Per cent disease on the fruit surface
0	=	No disease
1	=	0.1-5 %
2	=	5.1-10 %
3	=	10.1- 25 %
4	=	25.1- 50 %
5	=	> 50 %

Per cent disease index (PDI) of postharvest disease was calculated by using the formula (Wheeler 1969) as under.

Effect of botanicals against fruit rot of papaya

Preparation of extracts of botanicals

Fresh healthy plant material was collected and

washed first in tap water and then in distilled water. Fresh sample (100 g) was chopped and crushed in a surface sterilized pestle and mortar by adding 100 ml sterile water (1:1 w/v). The extracts were filtered through double layer of muslin cloth. Finally, filtrate thus obtained was used as stock solution.

Half matured, healthy fruits of uniform size were surface sterilized by dipping in the sodium hypochlorite one per cent solution for one minute and was inoculated with test fungus (1×10^8cfu/ml) by pin prick injury method and was incubated for 24 hours at room temperature. The inoculated fruits were then dipped in respective 10 per cent solution of botanicals for five minutes in three repetitions. In control treatment fruits were dipped in the sterilized distilled water after inoculation and incubated at room temperature.

Number of days taken for initiation of symptoms was recorded and per cent disease intensity in different treatments were calculated using 0 to 5 scale (Kumar, 2001).

Effect of different oil coatings against fruit rot of papaya

Preparation of the oil emulsions

Oil emulsions were prepared by using various six types of oils *viz.*, groundnut oil, sunflower oil, mustard seed oil, castor oil, soybean oil, neem oil, lemongrass oil and eucalyptus oil. Two hundred and fifty milliliter each oil was separately mixed with 750 ml of one per cent soap solution (surf excel) and mixed well in conical flask on mechanical shaker at 150 rpm for 30 minutes.

Five healthy equally matured papaya fruits of uniform size for each treatment were brought to the laboratory, washed, surface sterilized with sodium hypochlorite (1%) solution for one minutes and inoculated with pathogen (1×10^8cfu/ml) and incubated for 24 hours. Then fruits were dipped for five minutes in each of the respective oil emulsions prepared earlier with a control treatment (dipping fruits in soap solution only) was mentioned. Each treatment was repeated thrice and then incubated at room temperature.

Number of days taken for initiation of symptoms was recorded and per cent disease intensity in different treatments were calculated by scoring in 0 to 5 scale (Kumar, 2001).

Results and Discussion

Effect of different wrapping material for the management of fruit rot of papaya

The effect of different wrapping material *viz.*,news paper, brown paper bag, tissue paper, butter paper, polythene bag and aluminum foil along with one unwrapped fruits (control) on fruit rot of papaya caused by *Colletotrichum gloeosporioides*. The papaya fruits were pre-inoculated with *Colletotrichum gloeosporioides* by pin prick injury as mentioned material and methods. The results are presented in Table 1.

Among all the wrapping material, polythene bag wrapping was taken highest days for symptoms initiation (3.33 days). The next best in order were news paper and butter paper wrapping were taken 3.00 and 2.67 days for symptoms initiation, respectively. Brown paper bag wrapping was taken 2.33 days for symptoms initiation. The aluminum foil and tissue paper wrapping were taken 1.67 and 1.33 days for symptoms initiation respectively. In unwrapped open fruit was taken 1.33 days to initiate symptoms.

All the wrapping materials were found superior in reducing fruit rot disease. The significantly lowest disease intensity (17.78%) was found in polythene bag with maximum per cent disease control (68.00%) after five days of the incubation. The next best in order were news paper and butter paper wrapping showed 24.44 and 31.11 per cent disease intensity with 56.01 and 44.01 per cent disease control, respectively after five days of incubation, followed by brown paper bag wrapping was showed 33.33 per cent disease intensity with 40.01 per cent disease control. The aluminum foil and tissue paper wrapping were at par with each other, showed 42.22 per cent disease intensity with 24.01 per cent disease control. In unwrapped open fruit was showed 55.56 per cent disease intensity after five days of incubation with *Colletotrichum gloeosporioides* fruit rot causing fungus.

At ten days after incubation of papaya fruits, the significantly lowest per cent disease intensity(28.89%) was found in polythene bag with maximum per cent disease control (56.67%) as compared to control. The next best in order were news paper and butter paper wrapping were showed 35.56 and 40.00 per cent disease intensity with 46.66 and 40.00 per cent disease control respectively, after ten daysof incubation, followed by brown paper bag

Table 1. Effect of different wrapping material on fruit rot of papaya caused by *C. gloeosporioides* after different incubation period

Sr. No.	Wrapping material	Incubation period for symptoms initiation	Disease Intensity (%) after			Disease Control (%) after		
			5 days	10 days	15 days	5 days	10 days	15 days
1.	News paper	3.00	29.91 (24.44)^{de}	36.87 (35.56)^{cd}	43.36 (46.67)^{c}	56.01	46.66	47.50
2.	Brown paper bag	2.33	35.49 (33.33)^{c}	40.76 (42.22)^{bc}	45.91 (51.11)^{c}	40.01	36.67	42.50
3.	Tissue paper	1.33	40.79 (42.22)^{b}	44.63 (48.89)^{b}	47.18 (53.33)^{c}	24.01	26.67	40.00
4.	Butter paper	2.67	34.17 (31.11)^{cd}	39.47 (40.00)^{c}	44.63 (48.89)^{c}	44.01	40.00	45.00
5.	Polythene bag	3.33	25.21 (17.78)e	32.79 (28.89)^{d}	38.19 (37.78)^{d}	68.00	56.67	57.50
6.	Aluminium foil	1.67	40.79 (42.22)^{b}	44.63 (48.89)^{b}	52.38 (62.22)^{b}	24.01	26.67	30.00
7.	Control (unwrapped fruits)	1.33	48.47 (55.56)^{a}	55.02 (66.67)^{a}	71.18 (88.89)^{a}	-	-	-
	S.Em. ±	-	1.58	1.64	1.29	-	-	-
	C.D. at 5%	-	4.82	4.98	3.86	-	-	-
	C.V. %	-	7.51	6.74	4.55	-	-	-

Figures in parentheses are retransformed value of arc sin transformed values.
Means followed by different letter(s) in each row are significantly different by DNMRT test (P≤0.05).

wrapping was showed 42.22 per cent disease intensity with 36.67 per cent disease control over control. The aluminum foil and tissue paper wrapping were at par with each other, showed 48.89 per cent disease intensity with 26.67 per cent disease control. In unwrapped open fruit wasshowed 66.67 per cent disease intensity after ten days of inoculation with *Colletotrichum gloeosporioides* fruit rot causing fungus.

At 15 days after incubation, the significantly minimum per cent disease intensity was found in polythene bag *i.e.,* 37.78 with maximum per cent disease control *i.e.,* 57.50. The next best in order were news paper and butter paper wrapping were showed 46.67 and 48.89 per cent disease intensity with 47.50 and 45.00 per cent disease control, respectively followed by brown paper bag wrapping was showed 51.11 per cent disease intensity with 42.50 per cent disease control. The tissue paper and aluminum foil wrapping were showed 53.33 and 62.22 per cent disease intensity with 40.00 and 30.00 per cent disease control. In unwrapped open fruit was showed 88.89 per cent disease intensity after 15 days of incubation.

Effect of botanicals against fruit rot of papaya

Different nine botanicals *viz.,* neem, marigold, melia, dhatura, tulsi, ginger, papaya, garlic and lantana extracts at 10 per cent concentration with dipping fruit in sterilized water as a control were studied.The fruits were pre-inoculated by pin prick injury as mention in point material and methods. The results are presented in Table 2.

Among the different botanical extracts, garlic and neem extracts at 10 per cent concentration were taken 2.83 days for initiation of symptoms. Tulsi (2.67 days), marigold (2.67 days), melia and dhatura (2.33 days), ginger and lantana (2.00 days) and papaya (1.33 days) taken for initiation of symptoms in papaya fruits pre-inoculated with *Colletotrichum gloeosporioides* fungus.

The significantly lowest fruit rot intensity was found in garlic bulb extracts (15.56%) with 70.82 per cent disease control after three days of incubation. The next best treatment in order of merits were neem (22.22%), marigold (24.44%), melia and tulsi (26.67%), dhatura and ginger (31.11%), papaya (33.33%) and lantana (35.56%) fruit rot intensity with 58.33, 54.17, 49.99, 49.99, 41.67, 41.67, 37.50 and 33.32 per cent disease control, respectively after

three days of incubation as compared to control (53.33%) disease intensity.

After seven days of incubation, lowest fruit rot intensity was observed in garlic extract (28.89%) with 68.29 per cent disease over control and it was significantly superior over other treatments. The next best treatment in order was neem extracts (35.56%), melia extracts (37.78%) and marigold (40.00%) fruit rot intensity with 60.97, 58.53 and 56.10 per cent disease control. Datura and tulsi (42.22%), papaya (46.67%), ginger (48.89%) and lantana (51.11%) with 53.66, 53.66, 48.78, 46.34 and 43.90 per cent disease control, respectively as compared to control (91.11%) disease intensity.

Among the different botanical extracts, garlic showed lowest disease intensity and highest reduction of fruit rot disease over control due to the fungicidal activity which retarded the fungal growth and sporulation. Lantana showed highest disease intensity and lowest reduction of fruit rot disease over control.

Effect of different oil coatings against fruit rot of papaya

The effect of different oils coated to pre-inoculated *Colletotrichum gloeosporioides* in healthy papaya fruits was observed for initiation of symptoms. Lemongrass oil and castor oil coated fruits were taken 2.67 days for initiation of symptoms followed by mustard oil and neem oil (2.33 days), groundnut oil (1.67 days). Sunflower oil, Eucalyptus oil and soybean oil were taken 1.33 days for initiation of symptoms.The results are presented in Table 3.

Significantly minimum fruit rot intensity was observed in fruits coated with lemon grass oil (17.78 %) and it was at par with mustard oil (20.00 %) and neem oil (22.22%) with 66.66, 62.50 and 58.33 per cent disease control after three days of incubation followed by castor oil (24.44%), groundnut oil (28.89%), sunflower oil (31.11%), soybean oil (33.33%) and eucalyptus oil (35.56%) with 54.17, 45.83, 41.67, 37.50 and 33.32 per cent disease control, respectively after three daysof incubation.

After seven days of incubation, significantly minimum fruit rot intensity was observed in fruits coated with lemongrass oil (31.11%) and it was at par with mustard oil (33.33%) and neem oil (35.56%) with 67.44, 65.12 and 62.79 per cent disease control, respectively. The next best treatment in order of merits were castor oil (42.22%) and groundnut oil (48.89%) with 55.82 and 48.84 per cent disease control respectively after seven days of incubation followed by sunflower oil (53.33%), soybean oil (53.33%) and eucalyptus oil (57.78%) with 44.19, 44.19 and 39.54 per cent disease control respectively, after seven days of incubation.

Table 2. Effect of different botanicals against *C. gloeosporioides* causing fruit rot of papaya after different incubation period

Sr. No.	Botanicals	Incubation period for symptoms initiation	Disease intensity (%) after		Disease control (%) after	
			3 days	7 days	3 days	7 days
1.	Neem	2.83	28.41 (22.22)^{ef}	36.87 (35.56)^{ef}	58.33	60.97
2.	Marigold	2.67	29.91 (24.44)^{de}	39.47 (40.00)^{cde}	54.17	56.10
3.	Melia	2.33	31.29 (26.67)^{cde}	38.15 (37.78)^{de}	49.99	58.53
4.	Datura	2.33	34.17 (31.11)^{bcd}	40.76 (42.22)^{bcde}	41.67	53.66
5.	Tulsi	2.67	31.29 (26.67)^{cde}	40.79 (42.22)^{bcde}	49.99	53.66
6.	Ginger	2.00	34.17 (31.11)^{bcd}	44.63 (48.89)^{bc}	41.67	46.34
7.	Papaya	1.33	35.49 (33.33)^{bc}	43.36 (46.67)^{bcd}	37.50	48.78
8.	Garlic	2.83	23.52 (15.56)^{f}	32.79 (28.89)^{f}	70.82	68.29
9.	Lantana	2.00	36.87 (35.56)^{b}	45.91 (51.11)^{b}	33.32	43.90
10.	Control(Dipping in sterilized water)	1.00	47.18 (53.33)^{a}	73.39 (91.11)^{a}	-	-
	S.Em.±	-	1.76	1.79	-	-
	C.D. at 5 %	-	5.22	5.27	-	-
	C.V. %	-	9.16	7.11	-	-

Figures in parentheses are retransformed value of arc sin transformed values.
Means followed by different letter(s) in each row are significantly different by DNMRT test (P<0.05).

Among the all essential oil coating, lemongrass oil was found effective to control the fruit rot of papaya. The lemon grass oil contains monoterpene hydrocarbons such as limonene and camphene. These compounds exert their fungitoxicity by diffusing into cell membrane and caused membrane deformation. The fungitoxic activity of lemongrass was mainly contributed to presence of high level of citral aldehyde which attributed has the ability to cause irreversible cell membrane disruption through cross linkage reaction (Ali *et al.*, 2015).

The present findings are similar with results of the earlier researchers; according to Padmanaban *et al*. (2014), papaya fruits packed without any pretreatment in polyethylene bags maintained the quality of papaya with minimum changes. Bhattarai and Shah (2017) the plastic with five holes was effective in improving shelf-life, minimizing weight loss, slow change in colour index, lower pathological disorder and higher marketabilityof Mandarin.

Shinde *et al.* (2016) reported effectiveness of garlic extract (1%) against *C. gloeosporioides* and *Alternaria alternate* of papaya and mango fruit rot.Patel *et al*. (2008) recorded that extract of *Allium sativum* significantly effective followed by *Jatropha curcas* and *Aloe barbadensis* extracts against fruit rot of aonla. Meena *et al*. (2009) reported *Allium sativum* bulb for their efficacy in reducing these verity of post-harvest fruit rot of guava caused by *Pestalotiopsisp almarum*. Leaf extracts of *Ocimum sanctum* and *Azadirachta indica* were proved to be equally effective as pre and post inoculation treatments against fruit rot disease of guava.

Ali *et al*. (2015) tested lemon grass oil against anthracnose of papaya fruits caused by *Colletotrichum gloeosporioides in vivo* at room temperature for nine days. Lemon grass oil was most effective against anthracnose of artificially inoculated papaya fruit without affecting the natural ripening process. The potential of castor oil for the control of anthracnose of papaya caused by *Colletotrichum gloeosporioides* has been reported by Cesar *et al.* (2012). Patel *et al*. (2008) achieved most effective control of fruit rot of aonla (*Aspergillus niger*) using neem, cotton, castor, mustard, sesamum, soybean and groundnut as pre- and post-inoculation treatment. All the oil coating treatments significantly reduced the fruit rot severity. Among all essential oils, mustard oil was the most effective in controlling the fruit rot, followed by neem oil and cotton oil.

Conflicts of Interest Statement

The authors whose names are listed immediately below certify that they have NO affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the sub-

Table 3. Effect of different oil coatings on *C. gloeosporioides* caused fruit rot of papaya after different incubation period

Sr. No.	Types of oils	Incubation period for symptoms initiation	Disease intensity (%) after 3 days	Disease intensity (%) after 7 days	Disease control (%) after 3 days	Disease control (%) after 7 days
1.	Ground nut	1.67	32.79 (28.89)^{bcd}	44.62 (48.89)^{bc}	45.83	48.84
2.	Sunflower	1.33	34.10 (31.11)^{bc}	47.19 (53.33)^{b}	41.67	44.19
3.	Mustard	2.33	26.91 (20.00)^{e}	35.55 (33.33)^{de}	62.50	65.12
4.	Castor	2.67	29.91 (24.44)^{cde}	40.49 (42.22)^{cd}	54.17	55.82
5.	Soybean	1.33	35.49 (33.33)b	47.19 (53.33)b	37.50	44.19
6.	Neem	2.33	28.41 (22.22)^{de}	36.87 (35.56)^{de}	58.33	62.79
7.	Lemon grass	2.67	24.21 (17.78)^{e}	34.17 (31.11)^{e}	66.66	67.44
8.	Eucalyptus	1.33	36.87 (35.56)^{b}	49.75 (57.78)^{b}	33.32	39.54
9.	Control(Dip in soap solution)	1.00	47.19 (53.33)^{a}	80.19 (95.22)^{a}	-	-
	S.Em.±	-	1.79	2.22	-	-
	C.D. at 5 %	-	5.33	5.67	-	-
	C.V. %	-	9.38	8.33	-	-

Figures in parentheses are arc sin transformed values.
Means followed by different letter(s) in each row are significantly different by DNMRT test ($P < 0.05$).

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