

Management of mouldy core and core rot of apple causing pre-harvest fruit drop in Himachal Pradesh

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ABSTRACT

Different systemic and non-systemic fungicides were evaluated in the farmer's field in Shimla district of Himachal Pradesh for their efficacy to control mouldy core and core rot. EBI fungicides (difenoconazole, hexaconazole and myclobutanil) and protectants (mancozeb flowable, dodine and captan) gave better disease control of mouldy core and core rot of apple. Three sprays of difenoconazole sprayed at pink bud, full bloom and petal fall stages of apple provided 94 per cent control of mouldy core and core rot followed by sprays of mancozeb (at pink bud), difenoconazole (at full bloom) and hexaconazole (at petal fall) with 90 per cent disease control without hampering the fruit set.

Keywords: Mouldy core; core rot; pre-harvest fruit drop; apple; management

INTRODUCTION

Apple (*Malus x domestica* Borkh) a member of family Rosaceae is the most important fruit crop grown extensively in temperate regions all over the world. In India it is commercially grown in the Himalayan region including the states of Jammu and Kashmir, Himachal Pradesh and Uttarakhand and to a limited extent in north eastern states viz Arunachal Pradesh, Sikkim, Nagaland and Meghalaya with total annual production of 2001400 MT (Anon 2007a). Its cultivation has revolutionized the socio-economic condition of hilly farmers in

the state and it has become the number one commercial fruit crop which is being grown over an area of 94726 ha with an annual production of 592576 MT (Anon 2007b). With the intensive cultivation of this crop in the state some new disease problems have cropped up over a fairly large area. More recently a new problem of pre-harvest fruit drop associated with core rot has been encountered in major fruit growing areas of Shimla and Kullu districts of Himachal Pradesh (Gupta and Sharma 2008). However the natural occurrence of core rot in this state has already been reported and causal organism was identified as

Trichothecium roseum (Raina et al 1971). Preliminary studies have indicated the association of several fungi involved in mouldy core and core rot of dropped as well as fully mature apple fruit on the trees but *Alternaria alternata* is the predominant fungal pathogen responsible for mouldy core and core rot of apple in different regions of the world (Reuveni and Sheglov 2002). Spores infecting the open calyx of young fruits (presumably through the open calyx tube) and mycelia reaching the seed and carpel wall during growth and storage were reported by Miller (1959). The term mouldy core has been used to describe the situation where the fungal mycelium is evident within the core without causing penetration into the flesh or mesoderm of apple. If invasive penetration into the apple flesh is present the resultant rot is commonly described as a core rot (Ellis and Barrat 1983, Spotts 1990). Once inside the fruit the fungus is protected against contact fungicides and conditions for its growth are excellent. Fruit infection occurs either during flowering (Kennel 1983) or as a consequence of post-harvest infections primarily through dip tanks (Archer 2002). Some work has already been done on chemical control of mouldy

core and core rot of apple (Brown and Hendrix 1978). However there is still a wide gap in information regarding the management of the disease in the state. Hence the present investigations were undertaken to find out effective and practical control of the disease in the field.

MATERIAL and METHODS

Field efficacy of different fungicides:

Ten fungicides viz mancozeb flowable (0.35%), carbendazim (0.05%), dodine (0.075%), Shield (0.3%), captan (0.3%), hexaconazole (0.05%), myclobutanil (0.04%), difenoconazole (0.025%), iprodione + carbendazim (0.15%) and mancozeb + carbendazim (0.25%) were evaluated in field against mouldy core and core rot of apple. Adjacent untreated trees maintained side by the side served as control. Observations were recorded in two season trial on incidence of mouldy core and core rot on randomly selected dropped as well as intact fruits. Per cent disease incidence was calculated as given below and per cent disease control was calculated as follows:

$$\text{Disease incidence (\%)} = \frac{\text{Number of fruits with mouldy core and core rot}}{\text{Total number of fruits observed}} \times 100$$

$$\text{Disease control (\%)} = \frac{\text{Disease incidence in control (\%)} - \text{Disease incidence in treatment (\%)}}{\text{Disease incidence in control (\%)}} \times 100$$

Field efficacy of fungicidal spray schedules: Seven spray schedules involving different fungicides at different stages of apple were evaluated for their field efficacy in controlling mouldy core and core rot of apple at farmer's field at Kotkhai, district Shimla, Himachal Pradesh (Table 1). Observations were recorded on the incidence of the disease and per cent disease control was calculated.

Field efficacy of fungicides at bloom stages: Different fungicides viz mancozeb flowable (0.35%), difenoconazole (0.025%) and hexaconazole (0.05%) were evaluated in the field against mouldy core and core rot of apple by giving foliar sprays at bloom stage (Table 2).

Observations were recorded on the incidence of the disease and per cent disease control was calculated and data pertaining to fruit set in the treated trees was also recorded in this experiment and compared with the untreated trees. Fruit set was calculated by tagging and counting the flower clusters in a branch and was replicated four times. Number of fruit set in the tagged branch was counted and per cent fruit set was calculated.

RESULTS

Effect of different fungicides: The data presented in the Table 3 reveal that all the fungicides in general were effective in

controlling the disease in field and best control of mouldy core and core rot disease (93.69%) was provided by difenoconazole (0.025%) followed by hexaconazole (0.05%) providing 89.57 per cent disease control which were statistically at par with each other. Further mancozeb flowable (0.35%), dodine (0.075%), myclobutanil (0.04%) and iprodione + carbendazim (0.05%) also provided reasonably good disease control ranging from 83.70 to 74.51 per cent all of which were also statistically at par. Shield (0.30%) and carbendazim (0.35%) were however the least effective fungicides with only 37.83 and 29.69 per cent disease control respectively.

Effect of different fungicidal spray schedules: The data pertaining to disease incidence and per cent disease control are presented in Table 4. It is evident from the data that on an average spray schedule V provided maximum disease control (87.40%) which was followed by spray schedule I when fungicides were applied at pink bud, petal fall, pea size and successive stages at 21 day intervals. Spray schedule III provided on an average 83.92 and 77.75 per cent disease control respectively. Further spray schedule VI and VII (comprising repeated sprays of difenoconazole at walnut size stage to pre-harvest stage at 21 day intervals) were the least effective and provided on an average only 29.17 and 20.39 per cent disease control respectively.

Table 1. Spray schedules evaluated against mouldy core and core rot

Stages of apple	Spray schedule						
	I	II	III	IV	V	VI	VII
Pink bud	Mancozeb (0.35%)	Carbendazim (0.05%)	Difenoconazole (0.025%)	–	Difenoconazole (0.025%)	–	–
Petal fall	Difenoconazole (0.025%)	Difenoconazole (0.025%)	–	Difenoconazole (0.025%)	Difenoconazole (0.025%)	–	–
Pea size	Shield (0.3%)	Dodine (0.075%)	Difenoconazole (0.025%)	–	Difenoconazole (0.025%)	–	–
Walnut size	Iprodione + carbendazim (0.15%)	Iprodione + carbendazim (0.15%)	–	Difenoconazole (0.025%)	–	Difenoconazole (0.025%)	–
Fruit development-I	Zineb + hexaconazole (0.05%)	Mancozeb + carbendazim (0.25%)	Difenoconazole (0.025%)	–	Difenoconazole (0.025%)	Difenoconazole (0.025%)	–
Fruit development-II	Dodine (0.075%)	Hexaconazole (0.05%)	–	Difenoconazole (0.025%)	–	Difenoconazole (0.025%)	Difenoconazole (0.025%)
Pre-harvest	Mancozeb (0.35%)	Captan (0.3%)	Difenoconazole (0.025%)	–	–	Difenoconazole (0.025%)	Difenoconazole (0.025%)

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Table 2. Fungicides evaluated against mouldy core and core rot of apple by giving foliar sprays at bloom stage

Tree stage	Fungicide			
Pink bud	Difenoconazole (0.025%)	Mancozeb (0.35%)	Mancozeb (0.35%)	Mancozeb (0.35%)
Full bloom	Difenoconazole (0.025%)	Mancozeb (0.35%)	–	Difenoconazole (0.025%)
Petal Fall	Difenoconazole (0.025%)	Mancozeb (0.35%)	Difenoconazole (0.025%)	Hexaconazole (0.05%)

Table 3. Field efficacy of different fungicides against mouldy core and core rot of apple

Treatment	Conc (%)	Disease incidence (%)			Disease control (%)		
		2008	2009	Average	2008	2009	Average
Mancozeb flowable	0.35	6.80 (15.09)	5.76 (13.95)	6.28 (14.54)	83.00	84.39	83.70
Carbendazim	0.05	28.50 (33.48)	25.60 (30.40)	27.05 (31.37)	28.75	30.62	29.69
Dodine	0.075	7.65 (16.05)	6.30 (14.54)	6.98 (15.23)	80.80	82.90	81.85
Shield	0.30	26.65 (31.07)	21.30 (27.49)	23.98 (29.33)	33.38	42.27	37.83
Captan	0.30	11.65 (19.92)	9.19 (17.66)	10.42 (18.81)	70.87	75.18	73.03
Hexaconazole	0.05	3.30 (10.46)	4.65 (12.40)	3.98 (11.54)	91.75	87.39	89.57
Myclobutanil	0.04	10.33 (18.75)	9.00 (17.76)	9.67 (18.15)	74.25	75.60	74.93
Iprodione + carbendazim	0.15	10.15 (18.75)	9.45 (17.90)	9.80 (18.24)	74.62	74.39	74.51
Carbendazim + mancozeb	0.25	13.30 (21.39)	13.50 (21.26)	13.40 (21.47)	66.75	64.35	65.55
Difenoconazole	0.025	1.65 (7.38)	3.35 (10.50)	2.50	95.87 (9.40)	91.05	93.69
Control	-	40.00 (39.23)	36.90 (37.41)	38.45 (38.32)	-	-	-
Mean	-	14.55 (20.27)	13.18 (21.26)	13.87 (21.84)	70.00	70.81	70.41
CD _{0.05}	-	4.23 (11.83)	4.58 (12.38)	1.50 (7.03)	-	-	-

Table 4. Field efficacy of different fungicidal spray schedules against mouldy core and core rot of apple

Spray schedule	Disease incidence (%)			Disease control (%)		
	2008	2009	Average	2008	2009	Average
I	6.00 (17.17)	6.17 (9.30)	6.33 (14.54)	85.00	82.84	83.92
II	13.50 (21.54)	13.13 (21.25)	12.75 (20.90)	66.25	65.45	65.85
III	8.30 (17.33)	8.45 (16.90)	8.60 (17.05)	79.25	76.25	77.75
IV	18.30 (25.33)	18.05 (25.10)	17.80 (24.95)	54.25	51.75	53.00
V	4.30 (9.39)	4.82 (12.66)	5.33 (13.31)	89.25	85.55	87.40
VI	26.33 (30.87)	24.57 (29.70)	22.80 (27.80)	29.17	38.21	33.69
VII	33.30 (35.23)	30.67 (33.64)	28.03 (31.20)	16.75	24.03	20.39
Control	40.00 (39.23)	38.45 (38.29)	36.90 (37.41)	-	-	-
Mean	18.75 (25.65)	18.04 (25.40)	17.32 (24.58)	59.99	60.58	60.29
CD _{0.05}	2.11 (8.34)	2.08 (8.33)	2.80 (9.63)	-	-	-

Figure in parentheses denote arc sine transformed values

Field efficacy of bloom sprays of fungicides on mouldy core and core rot and fruit set of apple: Bloom sprays of the effective fungicides were evaluated against mouldy core and core rot of apple under field conditions during the cropping

seasons. The data pertaining to disease incidence and per cent disease control are presented in Table 5.

It is evident from the data that three sprays of difenoconazole applied at pink

Table 5. Field efficacy of different fungicidal sprays at bloom stage against mouldy core and core rot and fruit set of apple

Spray schedule	Disease incidence (%)			Disease control (%)			Fruit set (%)		
	2008	2009	Average	2008	2009	Average	2008	2009	Average
I	3.50 (10.78)	0.66 (4.93)	2.08 (8.33)	90.50	98.35	94.43	49.70	9.10	29.42
II	6.66 (14.72)	6.43 (14.70)	6.55 (14.77)	83.30	82.57	82.94	53.40	9.50	31.50
III	10.00 (17.93)	13.70 (21.72)	11.85 (20.12)	75.00	62.90	68.95	44.70	8.50	26.61
IV	4.33 (11.83)	3.33 (10.17)	3.83 (11.24)	89.18	90.98	90.08	46.70	8.30	27.50
Control	40.00 (39.23)	36.90 (37.41)	38.45 (38.29)	-	-	-	45.30	8.30	26.80
Mean	12.90 (20.59)	12.20 (20.44)	12.55 (20.70)	84.50	83.70	84.10	47.98	8.78	28.38
CD _{0.05}	4.85 (12.70)	3.95 (11.40)	4.08 (11.53)				3.7	1.3	2.5

Figure in parentheses denote arc sine transformed values

bud, full bloom and petal fall stages of apple provided maximum disease control in both the years with an average 94.43 per cent disease control followed by sprays of mancozeb, difenoconazole and hexaconazole applied at pink bud, full bloom and petal fall stages respectively also providing reasonably good disease control (90.08%) in both the seasons that was statistically at par with the first treatment ie difenoconazole spray at all the three stages of apple. Mancozeb sprays at all these three stages were comparatively less effective and provided 82.94 per cent disease control. A spray of difenoconazole at pink bud and that of mancozeb at petal fall provided minimum (68.95%) disease control in the

field. None of the treatments showed any deleterious or adverse effect on fruit set in any of the cropping seasons. In field best control of mouldy core and core rot of apple was provided by difenoconazole (0.025%), hexaconazole (0.05%), mancozeb flowable (0.35%) and dodine (0.075%) individually when sprayed at 21 day intervals right from pink bud to pre-harvest stage of the apple during 2008 and 2009 cropping seasons.

DISCUSSION

The effectiveness of various fungicides including iprodione, mancozeb, propineb, zineb, hexaconazole, dodine,

difenoconazole and trifloxystrobin has also been reported against *Alternaria alternata* causing different diseases on different hosts by earlier workers (Kim et al 1982, Tak et al 1985, Glaser and Kaiser 1986, Kock et al 1991, Yousuf and Ahmad 2001, Amenduni et al 2003, Reuveni et al 2002). Kumar (2004) also reported the best control of *Alternaria* leaf spot by difenoconazole (0.025%), iprodione + carbendazim (0.15%), hexaconazole (0.05%), propineb (0.3%), dodine (0.075%) and Shield (0.25%) individually when sprayed at 30 days interval during 2004 cropping season.

Among different spray schedules spray schedule V (in which difenoconazole was sprayed at pink bud, petal fall and pea size stages at 21 day intervals) was found the most effective providing on an average 87.40 per cent disease control under field conditions during 2008 and 2009. However repeated sprays of the same fungicide in this schedule may result fungicide resistance and control the apple diseases only up to pea size stage and therefore cannot be recommended to the farmers. It was followed by spray schedule I (which comprised sprays of systemic and non-systemic fungicides alternatively at pink bud, petal fall, pea size, walnut size, fruit development I and II and pre-harvest stages at 21 day intervals) provided equally good (83.92%) disease control of mouldy core and core rot and other major foliar diseases of apple during the year 2008 and 2009 cropping seasons and therefore

should be recommended to the apple growers for integrated control of apple diseases in the field. Rizzolli and Acler (2006) found that iprodione showed a good efficacy against *A. alternata* causing core rot of apple and Reuveni (2006) reported that three foliar applications of bromoconazole and Sygnum (pyraclostrobin + nicobifen) between the beginning of bloom and petal fall reduced the infected fruits by 55 to 70 and 45 to 80 per cent respectively. Similarly Reuveni and Prusky (2007) reported three foliar applications of bromoconazole or difenoconazole during the bloom period reducing the number of infected fruit with mouldy core by 40 to 60 per cent in Red Delicious apples compared with untreated control trees.

Bloom sprays of effective fungicides were comparatively more effective in controlling mouldy core and core rot in field. The results obtained during the 2008 and 2009 seasons revealed that three sprays of difenoconazole sprayed at pink bud, full bloom and petal fall stages of apple provided on an average maximum (94.43%) control of mouldy core and core rot of apple in the field. It was followed by the application of mancozeb (at pink bud), difenoconazole (at full bloom) and hexaconazole (at petal fall) providing 90.08 per cent disease control. However mancozeb application at all these above tree stages was comparatively less effective and resulted in 82.90 per cent disease control. There was no adverse effect of above

fungicides (sprayed at bloom stages) on fruit set besides giving excellent control of the disease in the field. Hence they can be recommended to the apple growers for controlling mouldy core and core rot disease of apple causing pre-harvest fruit drop. Brown and Hendrix (1978) also conducted similar study and reported that fungicide sprayed at bloom stage of apple reduced the fruit rot caused by *Alternaria* and *Phoma* species and did not significantly affect the fruit set. Reuveni et al (2002) also reported a control programme based on spray applications of difenoconazole and polyoxin B during bloom period to be effective against *A. alternata* causing mouldy core in Red Delicious apples.

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Received: 20.8.2014

Accepted: 21.11.2014