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Bio-efficacy evaluation of Chlorothalonil 40% w/w + Difenoconazole 4% w/w SC against apple diseases

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Abstract
Uttarakhand hills are best suited for production of a variety of fruit crops due to favorable agro-climatic conditions with apple being the most important temperate fruit grown in the region. Apple is the prime fruit of Uttarakhand and plays a major role in horticultural development and in improving economic status of the growers. The major diseases of apple crop in hill and mountain regions are scab [*Venturia inaequalis* (Cke.) Wint], premature leaf fall (*Marssonina coronaria* and *Alternaria mali*) and powdery mildew [*Podosphaera leucotricha* (Ellis and Everhart)] etc. These diseases have already plagued apple cultivation in Uttarakhand hills which happen to be the 3rd largest apple growing state of the country. Hence, to manage these diseases, Chlorothalonil 40% w/w + Difenoconazole 4% w/w SC at different dosages along with standard checks viz., Chlorothalonil 75% WP, Difenoconazole 25% EC, Propineb 70% WP, Sulphur 80 WG and Metiram 55% + Pyraclostrobin 5% WG at recommended doses were evaluated for bio-efficacy and phytotoxicity against apple scab, premature leaf fall and powdery mildew diseases at Harsil (District- Uttarkashi, Uttarakhand) during 2017 and 2018. The data analysis of two crop seasons (2017 & 2018) showed that all the treatments differed significantly with respect to per cent disease severity and per cent disease reduction over control for all the diseases studied. However, the treatment T_4 (Chlorothalonil 40% + Difenoconazle 4% w/w SC @ 900 ml/ha) was found most effective followed by treatment T_3 (Chlorothalonil 40% + Difenoconazole 4% w/w SC @ 800ml/ha) for all the diseases studied under present materials and conditions at Harshil location during 2017 and 2018. The data of two crop seasons indicated that maximum yield (98.83q/ha in 2017 and 95.20 q/ha in 2018) was recorded when the crop was sprayed with Chlorothalonil 40% + Difenoconazle 4% w/w SC @ 900 ml/ha followed by Chlorothalonil 40% + Difenoconazole 4% w/w SC @ 800ml/ha with 95.44 q/ha in 2017 and 94.55q/ha in 2018, respectively. For phytotoxicity studies, Chlorothalonil 40% + Difenoconazle 4% w/w SC @ 900 & 1800 ml/ha did not show any phytotoxic effects viz., yellowing, necrosis, chlorosis, epinasty, hyponasty and stunting on apple crop.

Keywords: Scab, premature, bio-efficacy, phytotoxicity, powdery mildew

Introduction
Apple cultivation in temperate fruit region of India has taken an important position in fruit production. It ranks 5th, first being mango followed by banana, citrus and guava. In fact, the economy of the entire temperate hill region of the country is overwhelmingly dependent upon apple alone than any other crop so far. Apple is the most important fruit crop in Uttarakhand hills as in other hilly states of the country, primarily Jammu & Kashmir and Himachal Pradesh. Its cultivation, therefore, has been receiving special attention in the region. In apple, the pest and disease problems are different and complex in nature. The production, quality and usage of the fruit are greatly influenced by the insect, pests and diseases. The diseases inflicting injury partly or wholly to an apple tree are several. Apple is attacked by a number of diseases viz., scab, premature leaf fall, cankers, powdery mildew, root rot, collar rot, seedling blight, fruit rots, sooty mould, fly speck, different leaf spots and blight including viral/viroid diseases namely; chlorotic leaf spot, apple mosaic dapple apple viroid and apple scar skin viroid (Singh *et al.*, 2012) [17]. Incidence of diseases is one of the most important factor in lowering the apple fruit production and they can cause as much as 30-50 percent loss under favourable conditions. Apart from the lowered fruit quality and yield, certain plant pathogens infecting roots and stems of the trees may cause premature decline of the orchards and death of

the bearing trees resulting in total loss. Fungicides can play an important role in ensuring crop health security by managing devastating diseases. They also provide substantial benefits on food quality and safety by indirectly reducing the levels of mycotoxins and phytotoxins in the infected plant products. The scenario of these diseases in apple is dynamic since their first appearance. It is mainly attributed to the availability of inoculum, susceptible host and prevalent environmental conditions. Further, availability of inoculum, initiation of a disease and its subsequent spread is largely determined by prevalent environmental conditions. In additions, pesticide use pattern and inappropriate adoption of package of practices have also contributed in changing disease pattern. Apple Scab caused by *Venturi ainaequalis* is one of the most destructive diseases of apple and leads to significant losses every season in India. In Uttarakhand, the disease was first detected in 1987 in Gangotri valley on about 35000 apple plants and soon after in the same year at Purola-Naugao fruit belt were also infected. It occurred in epidemic proportion in 1996 and again in 2008 in the Gangotri valley (District- Uttarkashi) of Uttarakhand (Singh and Kumar 1999, 2004, 2007, 2008, 2009; Singh, *et al.* 2010) [6, 12, 13, 14, 15, 16]. Chemical control forms an effective component of the disease management in apple scab as non-chemical alternatives do not exist. In Uttarakhand hills, the incidence of scab in Bhatwari fruit belt of District Uttarkashi over the past five years has ranged from 38.62 to 100 per cent. Pre-mature defoliation disease of apple caused by *Marssonina coronaria* and *Alternaria mali* appeared in large proportions areas of Uttarakhand. The disease is characterized by the appearance of dark green areas interspersed with lighter or yellow portions on the mature leaves sometimes giving a mosaic like appearance followed by the development of brown to dark brown spots of varying size ranging from 3 to 8 mm in diameter. The disease was first noticed to appear in the first week of July in most of the places of Uttarakhand and spread at a faster rate during the month of July, August and September with the occurrence of suitable temperature and frequent rains of moderate to high intensity. Powdery mildew of apple is caused by *Podosphaera leucotricha*. In Uttarakhand apple powdery mildew was an endemic problem in certain cultivars of apple but its incidence has increased in other cultivars also. The major economic loss to the grower is the reduction in fruit quality of mildew apples but the disease affects the crop in many ways. Severe infection may prevent the setting of fruits, defoliation of leaves, destruction of fruit buds, weakening and frequent killings of laterals and reduction in tree vigor (Singh *et al*., 2012) [18]. Therefore, keeping in view the importance of the crop and losses caused by these diseases, astudy was made to evaluate the bio-efficacy and phytotoxicity of Chlorothalonil 40% + Difenoconazole 4% w/w SCagainst apple disease complex (apple scab, apple blotch or premature leaf fall and powdery mildew) during 2017 and 2018.

Materials and Methods

A field trial was laid out at the worst affected orchard site (2600 m above msl) of Harsil (District Uttarakhasi), Uttarakhand, India in 2017 and 2018. Apple leaf & fruit scab, premature leaf fall and powdery mildew control experiments consisted of two spray schedule (June 11 and June 26) using systemic and non-systemic fungicides in the farmer's orchards. The farmer's orchards were selected such that they comprised of Royal delicious trees in the age group of 10-12 years. Fungicides were sprayed at different phenological stages of the trees using 2500 L water per hectare until run-off with a foot sprayer. The experiment was laid out in Randomized Block Design with nine treatments including untreated check (control) and each treatment was replicated thrice with three trees per replicate.The list of different bio-efficay and phtotocity treatments along with dosages are presented in Table 1 and Table 2. A total of three observations were taken throughout the season. Two observations were taken on apple leaves and fruits at 15 days interval after each spray schedule and the third observation was recorded at 30 days interval after second spray for each trait studied during both the years.

Table 1: List of different bio-efficacy treatments along with dosages

S. No.	Symbol	Treatment	Formulation dosage (g ai/ha)	Dose, Product (ml or gm/ha)
1.	T_1	Untreated check	-	-
2.	T_2	Chlorothalonil 40% + Difenoconazole 4% w/w SC	308 (280+28)	700
3.	T_3	Chlorothalonil 40% + Difenoconazole 4% w/w SC	352 (320+32)	800
4.	T_4	Chlorothalonil 40% + Difenoconazole 4% w/w SC	396 (360+36)	900
5.	T_5	Chlorothalonil 75% WP	1500	2000
6.	T_6	Difenoconazole 25% EC	40	160
7.	T_7	Propineb 70% WP	2100	3000
8.	T_8	Sulphur 80 WG	2500	3130
9.	T_9	Metiram 55% + Pyraclostrobin 5% WG	1050	1750

Table 2: List of different phytotoxicity treatments along with dosages

S. No.	Treatment	Formulation dosage (g ai/ha)	Dose, Product (ml or gm/ha)
1.	Chlorothalonil 40% + Difenoconazole 4% w/w SC	396 (360+36)	900
2.	Chlorothalonil 40% + Difenoconazole 4% w/w SC	792 (720+72)	1800

Spray Schedule

a. 2017 Apple season: June 11 and June 26 (Two applications).

b. 2018 Apple season: June 11 and June 26. (Two applications).

Observations

Disease incidence in terminals was calculated by determining the percentage of terminal with lesions on any of the terminal leaves. Per cent scabbed terminal leaves were also determined. Disease severity was visually recorded on a 0 to 5 scale (0 = No infection, 1=<5%, 2=5-10%, 3=10-25%, 4=25-30%, 5= > 50% leaf or fruit area infected).Disease severity on foliage was estimated by examining 10 terminals, 100 leaves and 30 fruits collected at random from all the four sides of the trees. Per cent scabbed terminal leaves were also determined. Additional data on disease severity data was collected on 10

terminals and 30 fruits and percent disease index was calculated as follows:-

$$\% \text{ Disease index} = \frac{\text{Class rating} \times \text{No. ofleaves or fruits in a particular class}}{\text{Total no. of leaves or fruits obsevation} \times \text{highest class rating}} \times 100$$

Per cent disease control was calculated by the following formula:-

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

Per cent yield increase was calculated by the following formula:-

$$\% \text{ Yield increase } = \frac{\% \text{ yield in treatment} - \% \text{ yield in control}}{\% \text{ yield in treatment}} \times 100$$

Phytotoxicity

Observations for phytotoxicity were taken at 0, 1, 3, 5, 7, and 10days after foliar application for different parameters *viz.*, yellowing, necrosis, chlorosis, epinasty, hyponasty and stunting as per phytotoxicity scale (0-10) given below:

Rating scale for Phytotoxicity

Crop injury score (%)	Rating scale
0	0
1-10	1
11-20	2
21-30	3
31-40	4
41-50	5
51-60	6
61-70	7
71-80	8
81-90	9
91-100	10

Results and Discussion

The results of the two season trial clearly indicated that all the fungicides were found to be significantly superior over control in the management of leaf scab, fruit scab, premature leaf fall and powdery mildew diseases of apple.

Bio-efficacy of fungicides against leaf scab and fruit scab diseases of apple under field conditions

Percent disease severity was recorded maximum in T_1 (untreated check) treatment in both the years as depicted in Table 3 and 4 followed by T_9 (Sulphur 80 WG @ 3130g/ha) treatment. With respect to leaf scab, among all the fungicidal treatments, maximum per cent reduction over control (ROC) was recorded in T_4 (Chlorothalonil 40% + Difenoconazole 4% w/w SC @ 900ml/ha) treatment with 75.13% ROC in 2017 and 64.54% ROC in 2018, respectively followed by T_3 (Chlorothalonil 40% + Difenoconazole 4% w/w SC @ 800ml/ha) treatment with 71.38% ROC in 2017 and 61.30% ROC in 2018 respectively. Both these treatments found to be statistically at par with each other and found superior over their solo components.

All the fungicidal treatments proved superior over untreated check with respect to disease control over fruit infection as depicted in Table 5 and 6. Among the fungicidal treatments, the treatment T_4 (Chlorothalonil 40% + Difenoconazole 4% w/w SC @ 900ml/ha) was found most effective and promising by registering minimum disease severity with 21.97% (2017) and 18.80% (2018) and maximum per cent disease control with 51.50% (2017) and 55.27% (2018) followed by T_3 (Chlorothalonil 40% + Difenoconazole 4% w/w SC @ 800ml/ha) treatment with 24.30% disease severity in 2017 and 21.03% disease severity in 2018 and at the same time 46.35% and 49.96% ROC in 2017 and 2018 respectively. Maximum disease severity was recorded under unsprayed trees (45.30% in 2017 & 42.03% in 2018, respectively). Different management strategies have been developed to prevent the disease efficiently through scheduled application of fungicides in a protective spray programme (Gupta, 1985, Singh and Kumar, 1997) [1, 9], besides, application of systemic and sterol-inhibiting (SBI) fungicides (Schwab, 1980, Schwabe and Jones, 1983; Thakur and Gupta, 1990, 1992) [2, 3, 19, 20]. Effective spray schedule for the control of apple scab disease was formulate/recommended on the basis of the fungicides evaluation for their various mode of action against the disease. Such spray strategies are in popular use in all the apple growing areas in India (Singh *et al.*, 1997; Singh and Kumar, 1999; Sharma, 1995) [10, 11, 4].

Bio-efficacy of fungicides against premature leaf fall disease of apple under field conditions

All the fungicidal treatments were significantly superior over untreated check by exhibiting lower disease severity and maximum per cent disease control in both the experimental years of 2017 and 2018 (Table 7 and 8). The data revealed that the maximum per cent disease controlwas recorded in the T_4 (Chlorothalonil 40% + Difenoconazole 4% w/w SC @ 900ml/ha) treatment with 72.59% in 2017 and 71.18% in 2018 followed by T_3 (Chlorothalonil 40% + Difenoconazole 4% w/w SC @ 800ml/ha) treatment with 70.97% (2017) and 67.68% (2018). Both these treatments were found to be statistically at par with each other. Maximum disease severity was recorded under unsprayed trees (24.08% in 2017 & 39.80% in 2018, respectively). Therefore, it is evident that all the sprays of different fungicidal treatments tested during the years 2017 and 2018 were effective in controlling premature leaf fall disease of apple over control (Untreated check) but the fungicide combination viz., Chlorothalonil 40% + Difenoconazole 4% w/w SC @ 900 ml/ha was found to be more effective in field against the complex pathogens. Earlier studies showed that protective sprays of mancozeb, carbendazim, dodine etc. were effective for the management of premature leaf fall/marssonina leaf blotch diseases of apple (Sharma and Gautam, 1997; Sharma *et al.*, 2004; Thakur and Sharma, 2010) [5, 8, 21]. Similarly, integrated sprays of contact and systemic fungicides at different fruit development stages have been found effective by Sharma and Bhardwaj (2003) [7] in management of premature leaf fall/marssonina leaf blotch.

Bio-efficacy of fungicides against powdery mildew disease in apple under field conditions

In general, the incidence of powdery mildew disease in apple was slightly higher during first year of experimentation (2017) when compared to the next year (2018) (Table 9 and 10). All the tested fungicides were found effective against control of powdery mildew disease and also found significant over untreated control. Of all the fungicidal treatments, T_4 (Chlorothalonil 40% + Difenoconazole 4% w/w SC @ 900ml/ha) and T_3 (Chlorothalonil 40% + Difenoconazole 4% w/w SC @ 800ml/ha) were statistically at par with each other and found most effective & promising by registering maximum per cent disease control as evident in Table 7 and 8. These treatments showed significant reduction on disease severity (74.71% in T_4&72.33% in T_3 during 2017 and 54.58% in T_4 &52.54% in T_3 during 2018 respectively) over

untreated check. Disease severity on unsprayed trees reached to 63.05% in 2017 and 46.83% in 2018, respectively. Effective control of powdery mildew in apple can be obtained by the sprays of carbendazim, hexaconazole, captan + hexaconazole, zineb, dodine, mancozeb etc. at different growth stages of apple trees in Uttarakhand (Singh *et al.*, 2012) [17].

Phyto-toxicity of fungicides after its application on apple under field condition

The tested fungicide combination, Chlorothalonil 40% + Difenoconazle 4% w/w SC @ 900 & 1800 ml/ha) did not show any phytotoxic effects like yellowing, necrosis, chlorosis, epinasty, hyponasty and stunting etc. when sprayed at III fruit development stage.The trees were evaluated on whole plot basis on 0-100% scale for phyto-toxicity (yellowing, necrosis, chlorosis, epinasty, hyponasty and stunting) at 0, 1, 3, 5, 7 &10 days after each spray applications. All the tested doses of Chlorothalonil 40% + Difenoconazle 4% w/w SC @ 900 & 1800ml/ha were found non-phytotoxic to any part of apple tree (Table 11).

Fruit yield after application of fungicides against diseases of apple under field condition

Data recorded on royal delicious fruit yield indicated that all the treatments were significantly superior over untreated check. The data of two crop seasons presented on Table 12 and Table 13 indicated that highest fruit yield (98.83 q/ha in 2017 and 95.20 q/ha in 2018) was recorded when the crop was sprayed with Chlorothalonil 40% + Difenoconazle 4% w/w SC @ 900 ml/ha followed by Chlorothalonil 40% + Difenoconazole 4% w/w SC @ 800ml/ha with 95.44 q/ha in 2017 and 94.55 q/ha in 2018, respectively. Data on yield losses indicated that maximum yield losses occurred when crop was left unsprayed.

Table 3: Bio-efficacy evaluation of different fungicides against leaf scab of apple under field conditions during 2017

S. No.	Symbol	Treatment	Dose, Product (ml or gm/ha)	Harsil location				
				Disease severity (%)			Mean	% Reduction over control
				1st observation (June 26)	2nd observation (July 12)	3rd observation (July 28)		
1	T_1	Untreated check	-	38.55	43.88	50.77	42.11	-
2	T_2	Chlorothalonil 40% + Difenoconazole 4% w/w SC	700	13.77	15.77	18.22	15.47	63.26
3	T_3	Chlorothalonil 40% + Difenoconazole 4% w/w SC	800	10.66	12.77	15.77	12.05	71.38
4	T_4	Chlorothalonil 40% + Difenoconazole 4% w/w SC	900	9.44	11.11	13.22	10.47	75.13
5	T_5	Chlorothalonil 75% WP	2000	17.88	18.77	22.11	19.47	53.76
6	T_6	Difenoconazole 25% EC	160	14.33	15.88	19.22	16.13	61.69
7	T_7	Propineb 70% WP	3000	19.55	21.44	24.77	20.91	50.34
8	T_8	Sulphur 80 WG	3130	23.44	25.11	27.77	24.55	41.70
9	T_9	Metiram 55% + Pyraclostrobin 5% WG	1750	15.33	15.88	21.44	17.47	58.51
		Grand mean	-	18.11	20.07	23.70	-	-
		S.Em (±)	-	1.10	0.59	1.00	-	-
		CD at 1% level	-	4.54	2.45	4.13	-	-
		CD at 5% level	-	3.29	1.78	3.00	-	-
		CV	-	10.53	5.14	7.32	-	-

Table 4: Bio-efficacy evaluation of different fungicides against leaf scab of apple under field conditions during 2018

S. No.	Symbol	Treatment	Dose, Product (ml or gm/ha)	Harsil location				
				Disease severity (%)			Mean	% Reduction over control
				1st observation (June 26)	2nd observation (July 12)	3rd observation (July 28)		
1	T_1	Untreated check	-	38.85	43.44	47.77	41.04	-
2	T_2	Chlorothalonil 40% + Difenoconazole 4% w/w SC	700	18.77	21.11	22.22	19.22	53.16
3	T_3	Chlorothalonil 40% + Difenoconazole 4% w/w SC	800	15.11	17.44	19.77	15.88	61.30
4	T_4	Chlorothalonil 40% + Difenoconazole 4% w/w SC	900	13.22	15.77	18.44	14.55	64.54
5	T_5	Chlorothalonil 75% WP	2000	23.88	26.44	30.00	25.30	38.35
6	T_6	Difenoconazole 25% EC	160	20.44	23.44	25.44	21.22	48.29
7	T_7	Propineb 70% WP	3000	26.11	29.44	32.77	27.97	31.84
8	T_8	Sulphur 80 WG	3130	28.77	31.11	33.77	29.69	27.65
9	T_9	Metiram 55% + Pyraclostrobin 5% WG	1750	22.44	25.77	27.44	23.44	42.88
		Grand mean	-	23.07	26.00	28.63	-	-
		S.Em (±)	-	1.13	1.14	1.00	-	-
		CD at 1% level	-	4.68	4.71	4.13	-	-
		CD at 5% level	-	3.40	3.41	3.00	-	-
		CV	-	8.51	7.59	6.05	-	-

Table 5: Bio-efficacy evaluation of different fungicides against fruit scab of apple under field conditions during 2017

S. N0.	Symbol	Treatment	Dose, Product (ml or gm/ha)	Harsil location				
				Disease severity (%)			Mean	% Reduction over control
				1st observation (June 26)	2nd observation (July 12)	3rd observation (July 28)		
1	T_1	Untreated check	-	39.44	52.33	60.55	45.30	-
2	T_2	Chlorothalonil 40% + Difenoconazole 4% w/w SC	700	24.00	27.44	31.00	25.89	42.84
3	T_3	Chlorothalonil 40% + Difenoconazole 4% w/w SC	800	22.88	25.11	29.77	24.30	46.35
4	T_4	Chlorothalonil 40% + Difenoconazole 4% w/w SC	900	20.33	23.11	26.33	21.97	51.50
5	T_5	Chlorothalonil 75% WP	2000	26.44	31.11	34.11	28.75	36.53
6	T_6	Difenoconazole 25% EC	160	25.11	27.44	32.33	26.50	41.50
7	T_7	Propineb 70% WP	3000	28.33	31.00	35.77	29.64	34.56
8	T_8	Sulphur 80 WG	3130	29.77	33.66	37.11	31.41	30.66
9	T_9	Metiram 55% + Pyraclostrobin 5% WG	1750	25.44	29.11	34.00	27.47	39.35
		Grand mean	-	26.86	31.15	35.66	-	-
		S.Em (±)	-	1.19	1.33	1.47	-	-
		CD at 1% level	-	4.93	5.50	6.08	-	-
		CD at 5% level	-	3.58	3.99	4.41	-	-
		CV	-	7.71	7.41	7.14	-	-

Table 6: Bio-efficacy evaluation of different fungicides against fruit scab of apple under field conditions during 2018

S. No.	Symbol	Treatment	Dose, Product (ml or gm/ha)	Harsil location				
				Disease severity (%)			Mean	% Reduction over control
				1st observation (June 26)	2nd observation (July 12)	3rd observation (July 28)		
1	T_1	Untreated check	-	37.44	49.22	56.11	42.03	-
2	T_2	Chlorothalonil 40% + Difenoconazole 4% w/w SC	700	21.33	25.66	28.77	23.55	43.96
3	T_3	Chlorothalonil 40% + Difenoconazole 4% w/w SC	800	19.44	23.44	25.00	21.03	49.96
4	T_4	Chlorothalonil 40% + Difenoconazole 4% w/w SC	900	17.77	20.22	22.11	18.80	55.27
5	T_5	Chlorothalonil 75% WP	2000	25.44	29.77	32.00	27.33	34.97
6	T_6	Difenoconazole 25% EC	160	24.11	27.77	30.44	25.64	38.99
7	T_7	Propineb 70% WP	3000	27.66	30.33	32.11	28.47	32.26
8	T_8	Sulphur 80 WG	3130	28.11	31.11	34.11	29.61	29.55
9	T_9	Metiram 55% + Pyraclostrobin 5% WG	1750	24.77	28.22	31.11	26.55	36.83
		Grand mean	-	25.12	29.53	32.42	-	-
		S.Em (±)	-	1.25	1.03	1.67	-	-
		CD at 1% level	-	5.16	4.26	6.88	-	-
		CD at 5% level	-	3.75	3.09	5.00	-	-
		CV	-	8.62	6.05	8.90	-	-

Table 7: Bio-efficacy evaluation of different fungicides against pre-mature leaf fall disease under field conditions during 2017

S. No.	Symbol	Treatment	Dose, Product (ml or gm/ha)	Harsil location				
				Disease severity (%)			Mean	% Reduction over control
				1st observation (June 26)	2nd observation (July 12)	3rd observation (July 28)		
1	T_1	Untreated check	-	21.44	23.55	30.55	24.08	-
2	T_2	Chlorothalonil 40% + Difenoconazole 4% w/w SC	700	8.21	8.55	11.44	8.68	63.95
3	T_3	Chlorothalonil 40% + Difenoconazole 4% w/w SC	800	6.44	6.55	9.88	6.99	70.97
4	T_4	Chlorothalonil 40% + Difenoconazole 4% w/w SC	900	5.88	6.21	9.77	6.60	72.59
5	T_5	Chlorothalonil 75% WP	2000	11.22	12.88	15.88	12.44	48.33
6	T_6	Difenoconazole 25% EC	160	8.88	9.21	12.22	9.35	61.17
7	T_7	Propineb 70% WP	3000	13.22	14.44	18.11	14.58	39.45
8	T_8	Sulphur 80 WG	3130	15.88	16.22	21.11	17.00	29.40
9	T_9	Metiram 55% + Pyraclostrobin 5% WG	1750	9.10	9.88	14.44	10.27	57.35
		Grand mean	-	11.14	11.95	15.93	-	-
		S.Em (±)	-	0.63	0.75	0.51	-	-
		CD at 1% level	-	2.61	3.09	2.14	-	-
		CD at 5% level	-	1.89	2.24	1.55	-	-
		CV	-	9.83	10.87	5.63	-	-

Table 8: Bio-efficacy evaluation of different fungicides against pre-mature leaf fall disease under field conditions during 2018

S. No.	Symbol	Treatment	Dose, Product (ml or gm/ha)	Harsil location				
				Disease severity (%)			Mean	% Reduction over control
				1st observation (June 26)	2nd observation (July 12)	3rd observation (July 28)		
1	T_1	Untreated check	-	36.88	43.77	47.44	39.80	-
2	T_2	Chlorothalonil 40% + Difenoconazole 4% w/w SC	700	14.22	16.77	19.77	15.80	60.30
3	T_3	Chlorothalonil 40% + Difenoconazole 4% w/w SC	800	11.44	14.77	16.11	12.86	67.68
4	T_4	Chlorothalonil 40% + Difenoconazole 4% w/w SC	900	10.44	12.11	15.88	11.47	71.18
5	T_5	Chlorothalonil 75% WP	2000	21.11	25.77	27.44	23.19	41.73
6	T_6	Difenoconazole 25% EC	160	17.11	20.77	21.55	18.30	54.70
7	T_7	Propineb 70% WP	3000	23.77	27.77	31.11	25.88	34.97
8	T_8	Sulphur 80 WG	3130	26.44	30.77	34.11	28.77	27.71
9	T_9	Metiram 55% + Pyraclostrobin 5% WG	1750	19.55	23.77	25.77	21.22	46.68
		Grand mean	-	20.11	24.03	26.58	-	-
		S.Em (±)	-	1.29	1.15	0.74	-	-
		CD at 1% level	-	5.33	4.78	3.08	-	-
		CD at 5% level	-	3.87	3.47	2.23	-	-
		CV	-	11.13	8.34	4.86	-	-

Table 9: Bio-efficacy evaluation of different fungicides against powdery mildew disease under field conditions during 2017

S. No.	Symbol	Treatment	Dose, Product (ml or gm/ha)	Harsil location				
				Disease severity (%)			Mean	% Reduction over control
				1st observation (June 26)	2nd observation (July 12)	3rd observation (July 28)		
1	T_1	Untreated check	-	60.55	63.55	70.21	63.05	-
2	T_2	Chlorothalonil 40% + Difenoconazole 4% w/w SC	700	17.22	19.77	23.10	19.13	69.65
3	T_3	Chlorothalonil 40% + Difenoconazole 4% w/w SC	800	16.11	17.55	21.44	17.44	72.33
4	T_4	Chlorothalonil 40% + Difenoconazole 4% w/w SC	900	14.66	16.22	19.44	15.94	74.71
5	T_5	Chlorothalonil 75% WP	2000	24.44	25.11	29.10	25.02	60.31
6	T_6	Difenoconazole 25% EC	160	18.33	20.33	24.88	20.05	68.19
7	T_7	Propineb 70% WP	3000	26.77	28.44	31.66	28.16	55.33
8	T_8	Sulphur 80 WG	3130	31.55	33.00	35.77	32.58	48.32
9	T_9	Metiram 55% + Pyraclostrobin 5% WG	1750	19.33	20.55	26.88	21.13	66.48
		Grand mean	-	25.44	27.17	31.39	-	-
		S.Em (±)	-	1.13	0.75	1.05	-	-
		CD at 1% level	-	4.69	3.09	4.35	-	-
		CD at 5% level	-	3.40	2.24	3.16	-	-
		CV	-	7.74	4.77	5.81	-	-

Table 10: Bio-efficacy evaluation of different fungicides against powdery mildew disease under field conditions during 2018

S. No.	Symbol	Treatment	Dose, Product (ml or gm/ha)	Harsil location				
				Disease severity (%)			Mean	% Reduction over control
				1st observation (June 26)	2nd observation (July 12)	3rd observation (July 28)		
1	T_1	Untreated check	-	45.11	49.88	53.21	46.83	-
2	T_2	Chlorothalonil 40% + Difenoconazole 4% w/w SC	700	23.44	25.44	28.55	24.55	47.57
3	T_3	Chlorothalonil 40% + Difenoconazole 4% w/w SC	800	21.44	22.77	26.44	22.27	52.44
4	T_4	Chlorothalonil 40% + Difenoconazole 4% w/w SC	900	20.44	22.44	25.10	21.27	54.58
5	T_5	Chlorothalonil 75% WP	2000	29.44	32.22	35.55	30.91	33.99
6	T_6	Difenoconazole 25% EC	160	24.77	27.55	29.21	26.08	44.30
7	T_7	Propineb 70% WP	3000	30.66	34.22	37.55	32.72	30.10
8	T_8	Sulphur 80 WG	3130	33.77	35.55	40.88	35.19	24.85
9	T_9	Metiram 55% + Pyraclostrobin 5% WG	1750	27.44	30.55	33.44	29.05	37.96
		Grand mean	-	28.50	31.18	34.43	-	-
		S.Em (±)	-	1.03	0.65	1.11	-	-

		CD at 1% level	-	4.29	2.69	4.59	-	-
		CD at 5% level	-	3.11	1.95	3.33	-	-
		CV	-	6.31	3.62	5.59	-	-

Table 11: Phyto-toxicity evaluation of Chlorothalonil 40% + Difenoconazole 4% w/w SC after its application on apple under field conditions during 2017 and 2018

S. No.	Treatment	Dose, Product (ml or gm/ha)	Days	Harsil location											
				2017						2018					
				Y	N	C	E	H	S	Y	N	C	E	H	S
1	Chlorothalonil 40% + Difenoconazole 4% w/w SC	900	0	0	0	0	0	0	0	0	0	0	0	0	0
			1	0	0	0	0	0	0	0	0	0	0	0	0
			3	0	0	0	0	0	0	0	0	0	0	0	0
			5	0	0	0	0	0	0	0	0	0	0	0	0
			7	0	0	0	0	0	0	0	0	0	0	0	0
			10	0	0	0	0	0	0	0	0	0	0	0	0
2	Chlorothalonil 40% + Difenoconazole 4% w/w SC	1800	0	0	0	0	0	0	0	0	0	0	0	0	0
			1	0	0	0	0	0	0	0	0	0	0	0	0
			3	0	0	0	0	0	0	0	0	0	0	0	0
			5	0	0	0	0	0	0	0	0	0	0	0	0
			7	0	0	0	0	0	0	0	0	0	0	0	0
			10	0	0	0	0	0	0	0	0	0	0	0	0

Y= Yellowing**, N=** Necrosis**, C=** Chlorosis**, E=** Epinasty**, H=** Hyponasty**, S=** Stunting

Table 12: Effect of different fungicides on fruit yield of apple during 2017

S. No.	Symbol	Treatment	Dose, Product (ml or gm/ha)	Harsil location	
				Yield (Qtl./ha)	% Increase over Control
1	T_1	Untreated check	-	61.39	-
2	T_2	Chlorothalonil 40% + Difenoconazole 4% w/w SC	700	89.64	31.51
3	T_3	Chlorothalonil 40% + Difenoconazole 4% w/w SC	800	95.20	35.51
4	T_4	Chlorothalonil 40% + Difenoconazole 4% w/w SC	900	98.83	37.88
5	T_5	Chlorothalonil 75% WP	2000	79.60	22.87
6	T_6	Difenoconazole 25% EC	160	87.74	30.03
7	T_7	Propineb 70% WP	3000	74.33	17.40
8	T_8	Sulphur 80 WG	3130	70.67	13.13
9	T_9	Metiram 55% + Pyraclostrobin 5% WG	1750	85.04	27.81
		Grand mean	-	82.49	-
		S.Em (±)	-	1.46	-
		CD at 1% level	-	6.06	-
		CD at 5% level	-	4.40	-
		CV	-	3.08	-

Table 13: Effect of different fungicides on fruit yield of apple during 2018

S. No.	Symbol	Treatment	Dose, Product (ml or gm/ha)	Harsil location	
				Yield (Qtl./ha)	% Increase over Control
1	T_1	Untreated check	-	62.88	-
2	T_2	Chlorothalonil 40% + Difenoconazole 4% w/w SC	700	91.44	31.23
3	T_3	Chlorothalonil 40% + Difenoconazole 4% w/w SC	800	94.55	33.49
4	T_4	Chlorothalonil 40% + Difenoconazole 4% w/w SC	900	95.44	34.11
5	T_5	Chlorothalonil 75% WP	2000	83.77	24.93
6	T_6	Difenoconazole 25% EC	160	90.11	30.21
7	T_7	Propineb 70% WP	3000	77.11	18.45
8	T_8	Sulphur 80 WG	3130	71.22	11.71
9	T_9	Metiram 55% + Pyraclostrobin 5% WG	1750	86.44	27.25
		Grand mean	-	83.66	-
		S.Em (±)	-	0.996	-
		CD at 1% level	-	4.113	-
		CD at 5% level	-	2.985	-
		CV	-	**2.062**	-

Conclusion

The treatment T_4 (Chlorothalonil 40% + Difenoconazole 4% w/w SC @ 900 ml/ha) was found most effective and at the same time statistically at par with treatment T_3 (Chlorothalonil 40% + Difenoconazole 4% w/w SC @ 800ml/ha) for suppressing disease complex severity and improving yield in apple crop under present environment and conditions. Therefore, Chlorothalonil 40% + Difenoconazole 4% w/w SC @ 800 ml/ha could be utilized as the optimum dose for management of scab, premature leaf fall & powdery mildew diseases in apple crop. The Chlorothalonil 40% + Difenoconazole 4% w/w SC at different dosages viz., 900 & 1800 ml/ha did not show any phytotoxic effect on apple crop. Chlorothalonil is a contact protective fungicide that inhibits production of compounds that have $–NH_2$ and –SH groups, namely amino acids and enzymes. Whereas, Difenoconazole

is a broad spectrum systemic fungicide. The mode of action is that it is a sterol demethylation inhibitor that prevents the development of the fungus by inhibiting cell membrane ergosterol biosynthesis. This combination of Chlorothalonil 40% + Difenoconazole 4% w/w SC @ 900 ml/ha has protective as well as systemic activity that can delay or prevent the buildup of resistance in the pathogen and can be effectively utilized as a promising fungicide for the control of disease complex in apple crop.

References

1. Gupta GK. Recent trends in forecasting and control of apple scab [*Venturia inaequalis* (Cke.) Wint.]. Pesticides. 1985; 19:19-13.
2. Schwabe WFS. Curative activity of fungicide against apple leaf infection by *Venturia inaequalis*. Phytophylactica. 1980; 12:199-207.
3. Schwabe WFS, Jones AL. Apple scab control with bitertanol as influenced by adjuvant addition. Plant disease. 1983; 67:1371-1373.
4. Sharma JN. Efficacy of fungicidal spray schedules for the control of apple scab. Indian J. Mycol. Plant Pathology. 1995; 25:250-253.
5. Sharma JN, Gautam DR. Studies on premature leaf fall of apple –a new problem. Plant Protection. 1997; 25:8-12.
6. Singh KP, Kumar J. Severe Incidence of Apple Scab in Bhatwari Fruit belt of Uttar Pradesh Himalayas. (Abstr.). National Symposium on Challenges and Prospects of Plant Pathology in the Coming Millennium, NBRI, 1999, 24p.
7. Sharma IM, Bhardwaj SS. Eficacy and economics of different fungicide spray schedule in controlling premature leaf fall of apple. Plant Disease Res. 2003; 18:21-24.
8. Sharma JN, Sharma Anita, Sharma Pankaj. Outbreak of Marssonina blotch in warmer climates causing premature leaf fall problem of apple and its management. Acta Horticulturae. 2004; 662:405-409.
9. Singh KP, Kumar J. Maturation and discharge of ascospores of *Venturia inaequalis* in Central Himalayas of India (Abstr.). International Conference on Integrated Plant Disease Management for Sustainable Agriculture, organized by Indian Phytopathological Society, ICAR and IARI, held at IARI, New Delhi from November 10-15, 1997.
10. Singh KP, Kumar J, Pal Ramesh. Efficacy of fungicides for apple scab control in Garhwal Himalayas. (Abstr.) Society of Mycology and Plant Pathology annual conference, Jan. 11-13, held at Department of Botany, Dr. Babasaheb Ambedkar Marathwada University, Augangabad, Maharashtra, 1997.
11. Singh KP, Kumar J. Efficacy of different fungicidal spray schedules in combating apple scab severity in Uttar Pradesh Himalayas. Indian Phytopathology. 1999; 52:142-147.
12. Singh KP, Kumar J. Incorporation of Weather Forecasting in integrated, Biological- Chemical Management of *Venturia inaequalis* in Hills of Uttaranchal. International Plant Protection Congress on "Plant Pretection towards the 21st Century" Organized by The International Association for the Plant Protection Sciences, held from May 11-16, 204 at Beijing, China, 2004.
13. Singh KP, Kumar J. Prediction of Ascospore Maturation of *Venturia inaequalis*in Central Himalayas. 3rd Asian Conference on Plant Pathology on "The Role of Plant Pathology in Rapidly globalizing Economies of Asia" Organized by The Indonesian Phytopathological Society and GadjahMada University from August 20-24, 2007 at Yogyakarta, Indonesia, 2007.
14. Singh KP, Kumar J. Disease Warning System for Scab of Apple: A Field Study. GBPUAT, CFHA. 2008; 22:1-18.
15. Singh KP, Kumar J. Forewarning Scab caused by *Venturia inaequalis* in Commercial Apple Orchards. 5th International Conference on Plant Pathology in the Globalized Era Organized by Indian Phytopathological Society and IARI, New Delhi form November 10-13, 2009 at IARI, New Delhi, 2009.
16. Singh KP, Kumar J, Kumar B. GBPUAT and Apple Disease Research in the Gangotri Valley region of India. In: Microbial diversity and plant disease management, 625 p., Singh, K.P. and Shahi, D.K. (eds). VDM Verlag Dr. Muller GmbH & Co. KG, Germany/USA/U.K., 2010, 276-301p.
17. Singh KP, Kumar J, Pandey AK. Integrated Pest Management Strategies in Apple.1st Edition, Uttarakhand University of Horticulture and Forestry, Ranichauri Campus, Ranichauri- 249199, Tehri Garhwal, Uttarakand, 2012, 130.
18. Singh KP, Kumar B, Kumar J. Development of Computer-based Weather Monitoring and Disease Warning System for Integrated Management of Apple Scab in Uttarakhand Hills. In: Eco-friendly Innovative Approaches in Plant Disease Management, 682 p., Singh, V. K., Singh, Y. and Singh, A. (eds). International Book Distributors, Dehradun, 2012, 113-146p.
19. Thakur VS, Gupta GK. Evaluation of pre symptom expression conidia production and viability of *Venturia inaequalis*. Indian Phytopath. 1990; 43:520-526.
20. Thakur VS, Gupta GK. Post-infection fungicidal inhibition of apple scab (*Venturia inaequalis*) sporulation. Indian J. Agric. Sci., 1992, 152-156.
21. Thakur VS, Sharma Nirupma. Epidemic outbreak of apple blotch disease: epidemiology and management in Himachal Pradesh. Indian Phytopath. 2010; 63(2):141-144.