

**Validation of fungicide spray schedule for management of
fungal foliar diseases of apple (*Malus x domestica* Borkh.)
under high density orchard system**

Urfy Jan
(MSH/2018/219)



Division of Plant Pathology
Faculty of Horticulture

**Sher-e-Kashmir University of Agricultural Sciences &
Technology of Kashmir**

2021

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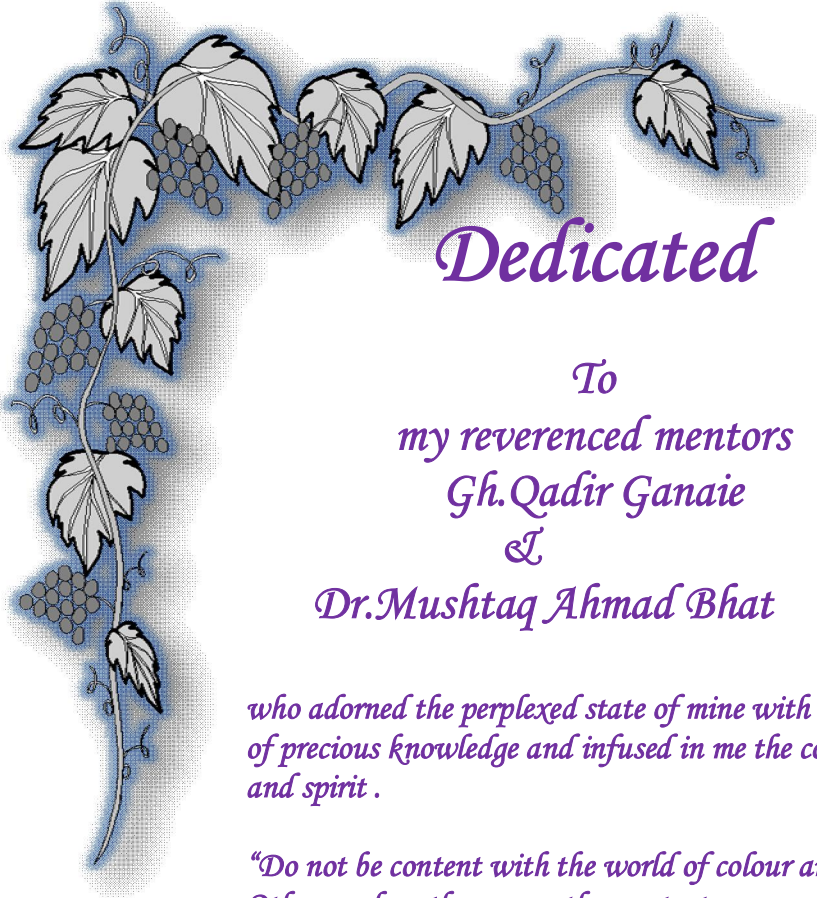
Thesis

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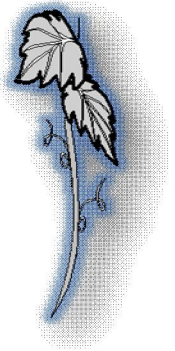
Dedicated

*To
my revered mentors
Gh. Qadir Ganaie
&
Dr. Mushtaq Ahmad Bhat*

*who adorned the perplexed state of mine with the seeds
of precious knowledge and infused in me the courage
and spirit .*

*“Do not be content with the world of colour and smell,
Other gardens there are, other nests, too.
What is the worry if one nest is lost?
There are other places to sigh and cry for!
You are an eagle, flight is your vocation,
you have other skies stretching out before you.
Do not let mere day and night ensnare you,
Other times and places belong to you”*

(Alama Iqbal^{RA})



Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
Faculty of Horticulture, Division of Plant Pathology

Certificate – I

This is to certify that the thesis entitled “**Validation of fungicide spray schedule for management of fungal foliar diseases of apple (*Malus x domestica* Borkh.) under high density orchard system**” submitted in partial fulfilment of the requirements for the award of the degree of **Master of Science in Horticulture (Plant Pathology)**, to the **Faculty of Horticulture, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir** is a record of bonafide research work carried out by **Ms. Urfy Jan (Regd. No. MSH/2018/219)** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

It is further certified that any help or information received during the course of investigation has duly been acknowledged.

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This is to certify that the thesis entitled, “**Validation of fungicide spray schedule for management of fungal foliar diseases of apple (*Malus x domestica* Borkh.) under high density orchard system**” submitted by **Ms. Urfy Jan (Regd. No. MSH/2018/219)** to the **Faculty of Horticulture, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir** in partial fulfilment of the requirements for the award of the degree of **Master of Science in Horticulture (Plant Pathology)** was examined and approved by the Advisory Committee and External Examiner on

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Title of the Thesis : **“Validation of fungicide spray schedule for management of fungal foliar diseases of apple (*Malus x domestica* Borkh.) under high density orchard system”**

ABSTRACT

The present research programme entitled “Validation of fungicide spray schedule for management of fungal foliar diseases of apple (*Malus x domestica* Borkh.) under high density orchard system” was conducted under high density apple orchard block of Division of Fruit Science and Fruit Pathology laboratory of the Division of Plant Pathology, SKUAST-K, Shalimar during March-September, 2019 season. The aim of the study was to explore the four phenological stage based fungicide spray modules and were compared with conventional schedule and control (water sprays only) against two major fungal foliar diseases (apple scab and Alternaria leaf blotch) on four exotic commercial cultivars of apple viz., Super Chief Sandidge, Red Velox, Fuji Aztec Zehn and Gala Redlum. In each module, crucial phenological stages were targeted to find out the efficacy of complimentary sprays in addition to conventional schedule. The conventional schedule recommended for 2019 season was adopted which include sprays at green tip (mancozeb 75WP @ 0.3%), pink bud (captan 70%+hexaconazole 5% 75WP @ 0.05%), 60-70 per cent petal-fall (difenaconazole 25EC @ 0.03%), fruit-let (dodine 65 WP @ 0.06%), Fruit Development-I (FD)-I (zineb 68%+hexaconazole 4% 72WP @ 0.1%), FD-II (captan 70%+hexaconazole 5% 75WP @ 0.05%) and FD-III (propineb 70 WP @ 0.3%). The plants in each selected cultivars were sprayed with water only at their respective phenological

stages serves as control (water sprays only). In addition to conventional schedule, module-I consists of phenological based complimentary stage i.e. 40 per cent petal fall was sprayed with flusilazole 40EC (0.02 per cent) and in module-II complementary stage i.e. 40 per cent petal-fall and cherry size were sprayed with flusilazole 40EC (0.02%) and metiram 55%+pyraclostrobin 5% 60 WG (0.1%), respectively. Whereas, module-III consisted of complimentary stages including 40 per cent petal-fall, cherry size and FD-IV were sprayed with flusilazole 40EC (0.02%), metiram 55% + pyraclostrobin 5% 60 WG (0.1%) and zineb 75WP (0.30%) respectively.

Amongst the tested modules, module-III proved significantly superior as compared to Conventional schedule and control in controlling scab and Alternaria leaf blotch. The module-III recorded significantly minimum leaf scab incidence and intensity on cultivar Gala Redlum (03.09% & 01.37 %) followed by Super Chief Sandidge (03.80 & 02.38%), Fuji Aztec Zehn (04.09 & 01.77 %) and Red Velox (05.14 & 02.08%), respectively. The module-III again registered significantly lowest fruit scab incidence and intensity (01.17 & 00.50%), (02.50 & 00.88%), (03.16 & 01.03%) and (03.83 & 02.51%) on cultivars viz., Gala Redlum, Super Chief Sandidge, Red Velox and Fuji Aztec Zehn, respectively. Again, module-III was more effective in controlling Alternaria leaf blotch with least incidence and intensity in cultivar Gala Redlum (02.00 & 00.84%) followed by Fuji Aztec Zehn (05.07 & 02.29%), Red Velox (05.67 & 02.51%) and Super Chief Sandidge (06.13 & 02.68%), respectively. The phytotoxicity analysis of different fungicide molecules at double the recommended concentrations were carried out at FD-I stage on different cultivars of apple viz., Silver Super, Fuji Zehn Aztec, Gala Redlum, Jona Gold, Granny Smith, Jeromine and Red Velox. Phytotoxic effects in the form of leaf brittleness was observed in case of Red Velox, Gala Redlum, Fuji Zehn Aztec and Granny Smith when sprayed with tebuconazole 8% + captan 32% 40SC (0.025%), zineb 68% + hexaconazole 4% 72WP (0.2%) and difenaconazole 25EC (0.06%), respectively. However, russetting was apparent on fruits of cv. Red Velox, Granny Smith and Jeromine when sprayed with Tebuconazole 8% + Captan 32% 40SC (0.05%). Further, curling of the leaves of cultivar Granny Smith was observed when sprayed with metiram 55% + pyraclostrobin 5% 60WG (0.2%) and zineb 68% + hexaconazole 4% 72WP (0.2%).

Key words: Alternaria leaf blotch, Apple, fungicides schedule, scab

Signature of Student
Dated : _____

Signature of Major Advisor
Dated: _____

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Place: Shalimar, Srinagar

Dated:

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Chapter 1

INTRODUCTION

Apple (*Malus x domestica* Borkh.) belongs to genus *Malus* of family Rosaceae and order Rosales. Apple, pear, quince, medlar and a few other species have been classified into the subfamily, Pomoideae, the pome fruits having fruits with two to five carpels enclosed in a fleshy covering. It is fourth among the most widely produced fruits in the world after banana, orange and grape. Ancestry of *Malus domestica* was unknown until recent gene studies supported the hypothesis that *M. domestica* was derived from *M. sieversii* (Velasco *et al.*, 2010). There are currently about 35 *Malus* species out of which only four: *M. domestica* (worldwide), *M. melliana* (China), *M. prattii* (China) and *M. sylvestris* (Europe) are used for commercial fruit plantations, while other *Malus* species are used as ornamentals or rootstocks (Forsline *et al.*, 2003).

Presently, apple throughout the world is grown over an area of 4,933.841 thousand hectares with an annual production of 83,139.326 thousand metric tonnes (Anonymous, 2019). The major apple producing countries of the world are China, United States, Poland, Turkey and India. In India, apple is cultivated over an area of 307.0 thousand hectares with an annual production of 2371.0 thousand metric tonnes (Anonymous, 2018). In India, it is predominantly grown in Jammu and Kashmir (J&K), Himachal Pradesh (H.P), Uttarakhand (U.K), Arunachal Pradesh (A.P) and Nagaland. In J&K, it is grown over an area of 164.742 thousand hectares with a production of 1882.319 metric tonnes (Anonymous, 2018a).

Apple is host to a wide range of diseases and pests, many of which are ubiquitous in all apple producing regions of the world (Way *et al.*, 1990). Fungal diseases significantly affected apple production and deteriorated its quality which dented the economy to a greater extent. In Kashmir valley, the most predominant and devastating diseases are apple scab (*Venturia inaequalis*),

Alternaria leaf blotch (*Alternaria mali*), powdery mildew (*Podosphaera leucotricha*), Marssonina leaf blotch (*Marssonina coronaria*), root rot (*Dematophora necatrix*), canker (*Botryosphaeria obtusa*) and collar rot (*Phytophthora cactorum*).

Amongst the fungal diseases, scab and Alternaria leaf blotch appears constantly causing enormous economic losses to growers. Scab being the main disease, involves an average of 70 per cent of plant protection treatments (MacHardy, 1996). Scab is endemic to almost all apple producing countries, causes 70 per cent losses to production (Biggs, 1990; MacHardy, 1996). It leads to weakening and unproductiveness of tree due to mid-summer defoliation and reduces the market value of fruit due to devaluation in fruit grade. Apple scab is especially severe in temperate regions that have cool and wet weather in spring. Apple scab was first reported from Sweden in 1819 (Fries, 1819). The disease in India was first reported from Kashmir in 1930 in its asexual stage (Nath, 1935) and in its perfect stage by Koul in 1960. Its epiphytotic have been a regular feature since 1973 (Joshi *et al.*, 1973; Qazi, 1991) in valley. Scab in apple remained confined to Ambri cultivar growing regions of Kashmir upto 1972 and appeared in epiphytotic form in 1973 involving other commercially important apple cultivars. The disease was reported to have shifted from Ambri to delicious in 1972 (Malik *et al.*, 1976) and caused major havoc throughout the valley. In 1974, apple scab was declared as national disease and continues to be ranked as number one national plant disease of India.

The second most important disease of apple in Kashmir is Alternaria leaf blotch. The disease was first reported by Roberts (1924) from USA and is now ubiquitous in occurrence, causing huge economic losses due to premature defoliation. Alternaria leaf blotch has been observed to cause 95 per cent defoliation ultimately reducing tree vigour, fruit quality and yield in the subsequent seasons (Filajdic and Sutton, 1991, 1995; Hartevelde *et al.*, 2014). The disease is reported to cause pre-mature defoliation to the extent of 60-80 per cent

in North Carolina (Filajdic and Sutton, 1991). The disease caused severe outbreak in South Korea, China and Yugoslavia which resulted in 50 per cent defoliation (Filajdic and Sutton, 1992). In India, the disease was first reported from Himachal Pradesh (Gupta and Agarwal, 1968). The disease, previously considered of minor significance, has now attained the status of major disease in Jammu and Kashmir, during past few years (Shahzad *et al.*, 2002). In China, the annual loss of apple production due to *Alternaria* leaf blotch has been reported to the tune of 15.9 to 30.1 per cent (Shou *et al.*, 2009; Zhao *et al.*, 2011). The disease primarily occurs in Asian countries and seriously affects their apple production (Lee *et al.*, 2011).

In Jammu and Kashmir, the traditional orchard system (seedling rootstock) is entirely adopted by which many problems like stagnant production, less colour development, irregular bearing habits and high disease incidence touched the peak in the valley. Recently, the initiative of government interventions from several years has generated a model shift in introducing high density plantation with growers showing interest in adopting the approach. The use of intensive orchards has been proposed to improve profitability and yield in apple orchards (Lauri *et al.*, 2004). Moreover, the demand of fruit market have encouraged widespread planting of new cultivars such as Gala, Fuji, Granny Smith, Silver Spur, Vance Delicious, Red Velox, Super Chief Sandidge and Red Chief which are very susceptible to scab and *Alternaria* leaf blotch (Yousuf, 2017).

Throughout the world apple disease management is accomplished by use of fungicides applied at different phenological stages/intervals of time. Chemical control forms an effective component of the disease management in apple scab as non-chemical alternatives do not exist (Jones, 1995). In valley, the management of diseases under conventional orchard system is furnished by the usage of apple plant protection schedule developed and recommended by SKUAST-K. Recent introduction of the high density apple orchard system in Kashmir valley, demands proper management programme to enshrine the hope of farmers. Recommended spray schedule for conventional apple orchards under Kashmir conditions has not

given satisfactory results under high density orchard system (Yousuf, 2017). The disease aspect of this plantation cannot be ignored as it may dwindle down its economic benefit ratio.

The recurrent epiphytotics of scab and alternaria diseases during the past few years has necessitated to generate basic information pertaining to phenological stages prone to infection and subsequently development of spray schedule under HD orchard system is needed. Therefore, development of a suitable fungicide spray schedule for the management of major fungal foliar disease of apple under HD system in Kashmir valley is the need of the hour. Therefore, the study is proposed with the following objectives:

1. To validate the fungicide spray schedule for effective management of fungal foliar diseases under HD apple orchard system.
2. To assess the phytotoxicity of fungicides on exotic cultivars of apple.

Chapter-2

REVIEW OF LITERATURE

The high density plantation of apple has been introduced in bulk to India in recent times. Therefore, the literature pertaining to the present investigation with regard to fungicide scheduling and phytotoxic assessment under apple high density orchard system is not available. The perusal of literature revealed that most of the work on disease management under high density apple orchard system has been done in abroad. Hence, relevant literature available on the efficacy of fungicides on apple diseases under high density as well as conventional orchard system and phytotoxic studies has been reviewed as under.

2.1 Apple scab

Apple is host to a wide range of diseases and pests, many of which are present in all apple producing regions of the world (Way *et al.*, 1990). Among them, scab and Alternaria leaf blotch diseases are considered to be the major constraints in the successful production of apple throughout the world. Scab caused by *Venturia inaequalis* (Cooke) Winter (anamorph *Spilocia pomi* Fr.) is one of the most destructive disease of apple (*Malus x domestica* Borkh.) worldwide (MacHardy, 1996) and leads to significant losses every season in India (Anonymous, 1998). The first botanical description of apple scab was given by Fries in 1819 from Sweden as *Spilocaea pomi* on the basis of its imperfect stage. Since then, it occurs very likely in every country where the cultivated apple (*Malus x domestica* Borkh.) is grown (Anonymous, 1985). In India, Nath (1935) first time reported this disease from Kulgam village of Kashmir valley on Ambri cultivar in its conidial stage on leaves. Later on, its perfect stage was also observed from overwintered fallen diseased leaves by Koul (1960). A number of scab epidemics have been reported from world over (Anonymous, 1985). The first epidemic touched Jammu and Kashmir in the year 1973 lead to the loss of Rs.

0.54 crore and in 1983, Himachal Pradesh was also hit by an epidemic which causes loss of Rs. 1.50 crore (Gupta, 1985).

2.1.1 Chemical management of scab

Apple production is hampered by a number of factors which includes insects, fungi, bacteria, viruses, viroids and phytoplasmas, frequently causing havoc to crops (Sharma, 2000; Abrol, 2015). Fungal diseases are of utmost economic importance among the production hindrances and are responsible for widespread economy drop for the growers (Verma and Khosla, 2018). In order to manage pest complex and produce a marketable crop, growers have relied on 10 to 18 applications of crop protection chemicals (MacHardy *et al.*, 2001) at an annual cost of US\$202 to \$506/ha (Reganold *et al.*, 2001; Zhang *et al.*, 2009; Slattery *et al.*, 2011). Apple growers usually adopt a zero tolerance policy towards pathogens and major insect pests (Percival and Boyle, 2005). Consequently, the economics of fruit production requires frequent application of synthetic pesticides throughout the growing season (Eccel *et al.*, 2009).

The fungicide schedule developed under Kashmir conditions by the host university under conventional apple orchard system (seedling rootstock) as a control program for scab are integrated with control measures for powdery mildew and various summer diseases such as *Alternaria* leaf blotch, *Marssonina* blotch, sooty blotch and flyspeck. For control of primary infections, sprays are often applied according to host phenology, with the first spray at green tip and additional spray at pink bud, 60-70 per cent petal and fruit let. The number of sprays prior to petal fall varies with many factors, including weather conditions, the cultivar, the rate of tissue development and the fungicide used. Sprays applied after fruit let are fruit development-I, II, III and need based sprays at fruit development IV and pre-harvest for long term storage are applied at 25 days before harvest (Anonymous, 2019a). Furthermore, the efficacy of conventional apple orchard based spray schedule was evaluated under high density orchard system and was found ineffective (Adeeba *et al.*, 2019).

Scab management may require 5 to 18 fungicide treatments per season depending on cultivar susceptibility, weather conditions and disease pressure (MacHardy 1996; MacHardy *et al.*, 2001). Most commercial apple cultivars are very susceptible to scab and in commercial apple orchards 15 to 22 fungicides are applied to control apple scab, depending on weather conditions, disease pressure and cultivar susceptibility (Holb *et al.*, 2005).

In general, control measures are based largely on protective fungicide sprays timed according to the developmental stage of the trees and ascospore maturity and release from overwintering leaves (MacHardy and Jeger, 1982). These treatments are supplemented by curative sprays applied after weather conditions for infection have occurred (MacHardy and Gadoury, 1989; Penrose, 1989). Chemical control forms an effective component in the disease management of apple scab as non-chemical alternatives do not exist (Jones, 1995). Different management strategies have been developed to prevent the disease efficiently through scheduled application of fungicides in a protective spray programme under conventional orchard system (Gupta, 1985), besides, application of systemic and sterol-inhibiting (SBI) fungicides (Schwabe, 1980; Szkolnik, 1981; Schwabe and Jones, 1983; Schwabe *et al.*, 1984;; Thakur and Gupta, 1990, 1992).

Yousuf (2017) carried out experimental studies on the evaluation of SKUAST-K recommended fungicidal spray schedule for the management of apple diseases of conventional apple orchard under high density orchard system. The spray schedule provided 70.07 to 74.27 per cent and 63.96 to 79.97 per cent control of leaf scab incidence and intensity under high density orchard system as against 93.89 and 95.17 per cent, respectively, in conventional system. Similarly, the spray schedule offered 63.96 to 70.31 and 63.21 to 68.21 per cent control of fruit scab incidence and intensity in high density orchard system as against 92.31 to 90.04 per cent, respectively in conventional system.

Burchill and Williamson (1971) reported that the benomyl spraying at 14 or 28 day intervals curbed the scab efficiently. Comparison of triarimol and

benomyl indicated that the triarimol at 14-day intervals was even more effective and also surpassed benomyl in controlling apple mildew.

Nowacka (1991) noticed the inefficacy of systemic fungicides or their mixtures when applied alone prior to flowering, become increasingly inefficient with decreasing temperature. Moreover, post-flowering application of these fungicides improved the efficiency of the scab control programme.

Thakur *et al.* (1992) studied the effect of post-infection treatments with different triazole fungicides recorded abnormal growth and changes in hyphal morphology in mycelia of *Venturia inaequalis*, causal agent of apple scab.

Sharma (1995) observed the application of difolatan at green tip, benlate at petal fall, hexacap at walnut size, mancozeb at 15-20 days before harvest and urea at pre-leaf fall efficacious stages to dwindle down the number of viable conidia of scab.

Singh (2019) reported that carbendazim and thiophanate methyl at petal fall stage were more effective than mancozeb, bitertanol, dodine, myclobutanil, fenarimol, captan in managing primary scab.

Shafi (2019) reported 10-15 sprays at different phenological stages are sufficient for effective scab management.

Singh *et al.* (2001) reported the efficacy of penconazole (0.05%), difenoconazole (0.015%) and myclobutanil (0.04%) in reducing the conidial production up to the extent of 83.46, 82.36 and 80.25 per cent and conidial germination up to the extent of 91.24, 93.74 and 90.28 per cent, respectively. Efficacy of thiophanate-methyl, biteranol, dodine, chlorothalonil and captan against scab was observed and confirmed by several workers (Singh and Kumar 1999; Gonzalez *et al.*, 2017; Belete and Boyraz 2017, Mir *et al.*, 2018).

Meszka *et al.* (2002) studied the effectiveness of fenarimol, difenaconazole and dodine on apple cultivar McIntosh and observed fenarimol application significantly poor in curbing of apple scab than difenoconazole.

Fungicidal spray schedule comprising of three consecutive sprays of mancozeb + carbendazim, zineb and ziram at earlier stages of apple tree effectively managed the scab (Sharma and Bhardwaj, 2003).

Sharma *et al.* (2005) has revealed that protective sprays of copper oxychloride (0.3%), zineb (0.3%), dodine (0.075%), carbendazim (0.05%), dithianon (0.05%), mancozeb flowable (0.35%), companion (0.25%) and ziram (0.3%) exhibited complete protection of apple trees in the field. Benzimidazole fungicides were also found to have an excellent pre-symptom activity when applied 2 days prior to symptom expression (Gupta, 1979).

Rather *et al.* (2019) reported three sprays of proquinazid 20EC @ 0.025 concentration prior to scab initiation at an interval of 15 days completely controlled the disease and recorded 0.0 per cent disease incidence.

Byarugaba *et al.* (2013) noticed fungicides *viz.*, propineb, metalaxyl + mancozeb and bupirimate productive in combating the apple scab with disease severity reduced by 61.11, 61.11 and 58.33 percent, respectively.

Many scab control programs in the United States, Canada and Australia are aiming to protect trees against primary infections through repeated application of fungicides (MacHardy *et al.*, 2001; Beresford *et al.*, 1994).

Chatzidimopoulos (2020) evaluated three different fungicide spray programs against apple scab at critical phenological stages of the apple crop and recorded disease severity ratings on leaves and fruits below 1.88 per cent.

2.2 Alternaria leaf blotch

The second most destructive disease in apple caused by *Alternaria mali* was first reported in United States in 1924 (Roberts, 1924). The disease gained the attention of the scientific community after its outbreak in Japan in 1956 (Sawamura, 1972). Sawamura (1972) proposed the name Alternaria blotch to the disease caused by a pathogenic strain of *Alternaria mali*. Alternaria leaf blotch left its footprints worldwide especially in Japan, South Korea, China, Zimbabwe,

Yugoslavia and other Asian countries (Biggs, 1990). In India, the disease was first reported from Himachal Pradesh in 1968 (Gupta and Agarwala, 1968). Shahzad *et al.* (2002) reported the occurrence of *Alternaria* leaf blotch in Jammu and Kashmir. However, the occurrence of leaf blight disease on apple caused by *A. tenuissima* dates back as early as 1987 (Puttoo, 1987). Filajdic and Sutton (1991) recorded that disease incidence varied from zero to 95 per cent in 60 apple orchards of Western North Carolina (USA) during 1989 and 1990, with about 30.00 per cent orchards having at least 10 per cent disease incidence. In Kashmir average disease incidence and intensity of 41.32 and 20.47 per cent, respectively, has been recorded by Shahzad (2002).

2.2.1 Chemical management of *Alternaria* leaf blotch

Survilienè and Dambrauskienè (2006) reported the inhibitory activity of boscalid + pyraclostrobin (Signum 334 WG) and tebuconazole (Folicur 250 EW) on the growth of *Alternaria* spp.

Hu *et al.* (2006) observed that the tebuconazole, flusilazole, difenoconazole, propineb, mancozeb and diniconazole were effective in curbing of *Alternaria mali* Roberts and further reported that propineb, mancozeb and diniconazole controlled *Alternaria mali* upto 88.41, 85.99 and 85.24 per cent, respectively. The fungicide Mancozeb was significantly superior in inhibiting mycelial growth of *Alternaria* spp. as reported by Prasad and Naik (2003) and Ganie *et al.* (2013).

Shahzad (2009) carried out field evaluation of different fungicidal treatments at three different concentrations for two years concluded that all the fungicides at different levels of concentration in each year significantly reduced the *Alternaria* leaf blotch of apple as compared to check. The fungicide, hexaconazole 5 EC @ 0.05 per cent was significantly superior in reducing the disease. Similarly, among non-systemic fungicides copper oxychloride and ziram

both at 0.4 per cent proved significantly superior in controlling the disease compared to check.

Thakur and Nirupma (2010) reported that preventive fungicidal sprays with Indofil M-45 (0.3%), Antracol (0.3%), Indofil Z-78 (0.3%), Bavistin (0.05%), Kocide (0.3%), Tohfa (0.075%) and Copter (0.3%) against premature leaf fall of apple provided hundred per cent control with very good to excellent fruit finish.

Harteveld *et al.* (2014) reported that the timing of the spore production dynamics from dormancy to bloom in leaf residue and from fruit growth to dormancy in canopy leaves and twigs is the most crucial timing for control of spore production to prevent development of *Alternaria* in orchards

Aulam *et al.* (2016) studied the effect of fungicides on hyphal and mycelial growth and observed that carbendazim + mancozeb at 2.0 g/l completely inhibited the sporulation, colony growth of *Alternaria* leaf spot. While as, fungicide ziram, mancozeb, dodine and myclobutanil demonstrated only a temporary inhibition of fungal growth and sporulation.

Verma and Khosla (2018) found fluopyram 200+tebuconazole 200 SC at 0.0625 & 0.05 per cent concentrations effective against *Alternaria* leaf blotch.

The chemical control of *Alternaria* leaf blotch of apple has been achieved through use of fungicides by various workers such as iprodione, mancozeb, captan (Asari and Takahashi, 1988), polyoxin, captafol (Filajdac and Sutton, 1992), dodine, zineb, mancozeb + hexaconazole (Sharma *et al.*, 2005); hexaconazole, copper oxychloride, ziram (Shahzad, 2009) and penconazole (Sofi *et al.*, 2013).

Ergosterol biosynthesis inhibiting fungicides, viz, flusilazole, difenoconazole and penconazole provided efficient disease management against *Alternaria* leaf spots resulted better protective activities as compared to the conventional protectants (Singh *et al.* 2001; Mir *et al.*, 2018)

2.3 Phytotoxic effect of fungicides

Rosenberger (2013) reported that captan should be omitted from sprays applied to apples between full bloom and 1st cover. The rationale for this recommendation comes from the fact that captan has been involved in most of the phytotoxicity-related losses.

Lalancette (2014) studied the effect of azoxystrobin (Abound), kresoxim-methyl (Sovran) and trifloxystrobin (Flint) on certain apple cultivars. The cultivar McIntosh have been found to be particularly sensitive to azoxystrobin with respect to tree fruit crops and is recommended/ available for use on stone fruits, while both Sovran and Flint are labeled for pome fruits.

Rosenberger (2014) reported that combining numerous products in a single application increases the probability of incompatibility among the various adjuvants included in the formulations. Also reported accidental carryover of azoxystrobin (e.g., Abound/Quadris) in a sprayer that was previously used to spray stone fruits, grapes, or vegetable crops can make McIntosh and Gala fruit unmarketable.

However, several studies showed that the repeated application of sulfur compounds had ecotoxicological side effects (Palmer *et al.*, 2003) and could also lead to leaf phytotoxicity or reduced fruit quality (Holb *et al.* 2003; Jamar *et al.*, 2008).

Hobl *et al.* (2016) conducted an experimental trial to analyze the impact of Potassium mono and bicarbonate treatment in combination with wettable sulphur against apple scab and powdery mildew of apple and recorded low phytotoxicity values with all bicarbonates than lime sulphur

Rather *et al.*(2019) carried out phytotoxicity studies with Proquinazid 20EC and concluded no phytotoxicity symptoms are manifested even at higher doses (0.04 and 0.08%).

Butt *et al.* (1973) sprayed various fungicides on seven apple cultivars

including Cox's Orange Pippin, Golden Delicious and Jonathan and found binapacryl or dinocap compounds were more phytotoxic without substantially or consistently improving the control of *Podosphaera leucotricha*.

During 2014-15, the fungicide azoxystrobin 11%+tebuconazole 18.3% was evaluated and subsequently recommended at petal fall stage in the spray schedule during 2016 cropping season. However, in the same year the fungicide causes phytotoxicity to leaves and fruit in the form of burning when sprayed to cultivar Mollies Delicious and Gala (Anonymous, 2016). Similarly, during the year 2016-17, the fungicide azoxystrobin+difenaconazole 32.5 SC found phytotoxic to cultivar Mollies Delicious and Gala varieties. However, the fungicide did not show any sign of phytotoxicity on the cultivar Oregon Spur and Red Delicious (Anonymous, 2018b).

Chapter 3

MATERIAL AND METHODS

The present research programme was carried out under high density orchard block of Division of Fruit Science and in the Fruit Pathology Laboratory, Division of Plant Pathology, Faculty of Horticulture, Sher-e- Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar during the year 2019. The materials used and the methodology adopted in achieving the objectives of the study are described as under:

3.1 Experimental site

The experiment was carried out on a eight year old high density apple orchard block with uniform vigour (Plate 1) having four cultivars *viz.*, Super Chief Sandidge, Gala Redlum, Fuji Aztec Zehn and Red Velox, each planted line wise at a spacing of 1.5 x 3m, installed with 4-wire trellis system. All the cultivars are grafted on M9 rootstocks with tall spindle training system and free standing spur spindle.

The experimental site is located at an elevation of 1685 m MSL with 34° 9'22" N latitude, 74° 52' 55" E longitude. The site is characterized by very cold temperature during December to March, minimum temperature of about 7°C occurs in January and maximum temperature of around 35°C in July. The month of April and May remain cold and mild, while, June to August comparatively warm and mild in September. Besides, the month of October and November are cold and generally dry.

3.2 Evaluation of fungicide spray modules and conventional schedule

The fungicide spray modules and conventional schedule were evaluated during cropping season 2019 season under HD orchard system on selected cultivars against major fungal foliar diseases *viz.*, scab and Alternaria leaf blotch of apple to validate the spray schedule. The validation of fungicide modules were



Plate 1: Experimental High Density Orchard Block at SKUAST-K, Shalimar

carried out at various phenological stages and observation on incidence and intensity of the target diseases were recorded one day before each fungicide spray at their respective stages (Plate 2). The fine mists of fungicide suspension were sprayed at various phenological stages with the help of 2HP Honda power sprayer. The experiment was laid out in randomized complete block design (RCBD) with three replications. A single plant represented as unit of replication per treatment. Moreover, the plants in each selected cultivar (three replications) were sprayed with water only at their respective phenological stages serves as control (water sprays only) for comparison with rest of the modules and conventional schedule. The detailed study of the conventional schedule and other evaluated modules is as under:

3.2.1 Conventional schedule

The conventional fungicide spray schedule recommended for 2019 season by SKUAST-K, Shalimar was adopted for evaluation under HD orchard system. The schedule is applicable to conventional orchard system (cultivars grafted on seedling rootstocks) for the orchardists of Kashmir valley. The recommended fungicides along with their concentration at various phenological stages were evaluated on each selected cultivar. The conventional schedule was used as comparison with the modules. The detail of the conventional schedule is as under:

Phenological Stages	Fungicide	Trade name	Conc. (%)
Green Tip	mancozeb 75WP	Indofil M-45 75WP	0.30
Pink Bud	captan70%+hexaconazole 5% 75WP	Rely 75WP	0.05
Petal Fall	difenaconazole 25EC	Score 25EC	0.03
Fruit let (Pea Size)	dodine 65 WP	Superstar 65WP	0.06
Fruit Development – I	zineb 68%+hexaconazole 4% 72WP	Avtar 72WP	0.10
Fruit Development –II	captan 70%+hexaconazole 5% 75WP	Rely 75WP	0.05
Fruit Development – III	propineb 70 WP	Antracol 70WP	0.30



Green Tip



Pink Bud



40 % Petal Fall



Petal Fall



Fruit Let (Pea Size)



Cherry size

Plate 2: Phenological stages under high density orchard system

Contd...

Plate 2: contd.....



Fruit development-I



Fruit development-II



Fruit development-III



Fruit development-IV

3.2.2 Module-I

In addition to conventional schedule, module-I was evaluated in the experiment carrying same fungicides as that of conventional along with an additional spray at 40 per cent petal-fall to ascertain the influence against the targeted disease(s) on selected cultivars. The fungicide evaluated at 40 per cent petal-fall was flusilazole 40EC @ 0.02 per cent concentration with rest of the phenological stages same as that of conventional schedule. The detail of the module-I is as under:

Phenological Stages	Fungicide	Trade name	Conc. (%)
Green Tip	mancozeb 75WP	Indofil M-45	0.30
Pink Bud	captan 70%+hexaconazole 5% 75WP	Rely 75 WP	0.05
Petal Fall 40%	flusilazole 40EC	Governor 40 EC	0.02
Petal Fall	difenaconazole 25EC	Score 25 EC	0.03
Fruit let (Pea Size)	dodine 65 WP	Superstar 65 WP	0.06
Fruit Development – I	zineb 68% + hexaconazole 4% 72WP	Avtar 72 WP	0.10
Fruit Development –II	captan 70% + hexaconazole 5% 75WP	Rely 75WP	0.05
Fruit Development – III	propineb 70 WP	Antracol 70WP	0.30

3.2.3 Module-II

Two supplementary sprays were evaluated in this module at 40 per cent petal-fall and cherry size in addition to other sprays as that of conventional schedule. Flusilazole 40 EC (0.02%) and metiram 55% + pyraclostrobin 5% 60 WG (0.1%) were evaluated at 40 per cent petal-fall and cherry size, respectively. The details of phenological stages, fungicides, their trade names along with concentrations are as under:

Phenological Stages	Fungicide	Trade name	Conc. (%)
Green Tip	mancozeb 75WP	Indofil M-45	0.30
Pink Bud	captan 70% + hexaconazole 5% 75WP	Rely 75 WP	0.05
Petal Fall 40%	flusilazole 40EC	Governor 40 EC	0.02
Petal Fall	difenaconazole 25EC	Score 25 EC	0.03
Fruit let (Pea Size)	dodine 65 WP	Superstar 65 WP	0.06
Fruit let (cherry Size)	metiram 55% + pyraclostrobin 5% 60 WG	Cabrio Top 60 WG	0.10
Fruit Development – I	zineb 68%+ hexaconazole 4% 72WP	Avtar 72 WP	0.10
Fruit Development –II	captan 70% +hexaconazole 5% 75WP	Rely 75WP	0.05
Fruit Development – III	propineb 70 WP	Antracol 70WP	0.30

3.2.4 Module-III

Module third consisted of three phenological based supplementary sprays viz., 40 per cent petal-fall, cherry size and FD-IV including other sprays as that of conventional schedule. The complimentary fungicides sprayed at 40 per cent petal-fall, cherry size and FD-IV were flusilazole 40EC @ 0.02 per cent, metiram 55% + pyraclostrobin 5% 60 WG @ 0.1 per cent and zineb 75WP @ 0.3 per cent concentration, respectively. The details of phenological stages, fungicides and concentrations are as under:

Phenological Stages	Fungicide	Trade name	Conc. (%)
Green Tip	mancozeb 75WP	Indofil M-45	0.30
Pink Bud	captan 70%+hexaconazole 5% 75WP	Rely 75 WP	0.05
Petal Fall 40%	flusilazole 40EC	Governor 40 EC	0.02
Petal Fall	difenaconazole 25EC	Score 25 EC	0.03
Fruit let (Pea Size)	dodine 65 WP	Superstar 65 WP	0.06
Fruit let (cherry Size)	metiram 55% + pyraclostrobin 5% 60 WG	Cabrio Top 60 WG	0.10
Fruit Development- I	zineb 68%+hexaconazole 4% 72WP	Avtar 72 WP	0.10
Fruit Development –II	captan 70%+hexaconazole 5% 75WP	Rely 75WP	0.05
Fruit Development – III	propineb 70 WP	Antracol 70WP	0.30
Fruit Development –IV	zineb 75 WP	Indofil Z-78 75 WP	0.30

3.2.5 Module -IV

Module-IV was conducted to analyze the efficiency of only protectant fungicides recommended in the schedule of SKUAST-K on the selected cultivars against the targeted fungal diseases. In addition to conventional schedule based phenological stages, the other stages targeted were 40 per cent petal fall, cherry size and FD-IV with dodine 65 WP (0.06%), dodine 65 WP (0.06%) and zineb 75 WP (0.3%), respectively. The details of module-IV are as under.

Phenological Stages	Fungicide	Trade name	Conc. (%)
Green Tip	mancozeb 75 WP	Indofil M-45	0.30
Pink Bud	captan 50 WP	Kohicap 50WP	0.30
Petal Fall 40%	dodine 65 WP	Superstar 65 WP	0.06
Petal Fall	propineb 70 WP	Antracol 70WP	0.30
Fruit let (Pea Size)	mancozeb 75 WP	Indofil M 45	0.30
Fruit let (cherry Size)	dodine 65 WP	Superstar 65 WP	0.06
Fruit Development- I	captan 50 WP	Kohicap 50WP	0.30
Fruit Development –II	propineb 70 WP	Antracol 70WP	0.30
Fruit Development – III	ziram 80 WP	Zed -78 80WP	0.20
Fruit Development –IV	zineb 75 WP	Indofil Z-78 75WP	0.30

3.3 Disease incidence and intensity

3.3.1 Leaf and fruit scab

In order to calculate the leaf and fruit scab incidence and intensity, hundred leaves and fifty fruits selected from four randomly selected branches from four sides of the tree canopy were assessed. The observations were recorded one day before spraying of fungicides at their respective phenological stages.

i). Per cent disease incidence:

Per cent leaf and fruit scab disease incidence was calculated by using the following formula:

$$\text{Per cent Disease Incidence (PDI)} = \frac{\text{Number of leaves Infected}}{\text{Total no. of leaves observed}} \times 100$$

ii) Per cent disease severity

Leaf and fruit scab severity was determined by using 0-5 scale given by (Croxall *et al.*, 1953) with slight modification (Plate 3 & 4).

Category	Grade	Leaf scab %	Fruit scab %
0	0	Free	Free
1	I	>1 ≤ 5	> 0 ≤ 1.0
2	II	>5 ≤ 10	>1 ≤ 5.0
3	III	>10 ≤ 25	>5 ≤ 20.0
4	IV	>25 ≤ 50	>20 ≤ 50.0
5	V	>50	>50

Per cent disease severity (PDS) was calculated as per the formula:

$$PDS = \frac{\sum(n \times v)}{N \times G} \times 100$$

Where,

\sum = Summation

n = No. of diseased leaves.

v = Numerical value of the category.

N = Total no. of leaves examined.

G= Highest grade value

3.3.2 Alternaria leaf blotch (ALB)

In order to calculate the Alternaria leaf blotch incidence and intensity, hundred leaves selected from four randomly selected branches from four sides of the tree canopy were assessed. The observations were recorded one day before spraying of fungicides at respective phenological stages.

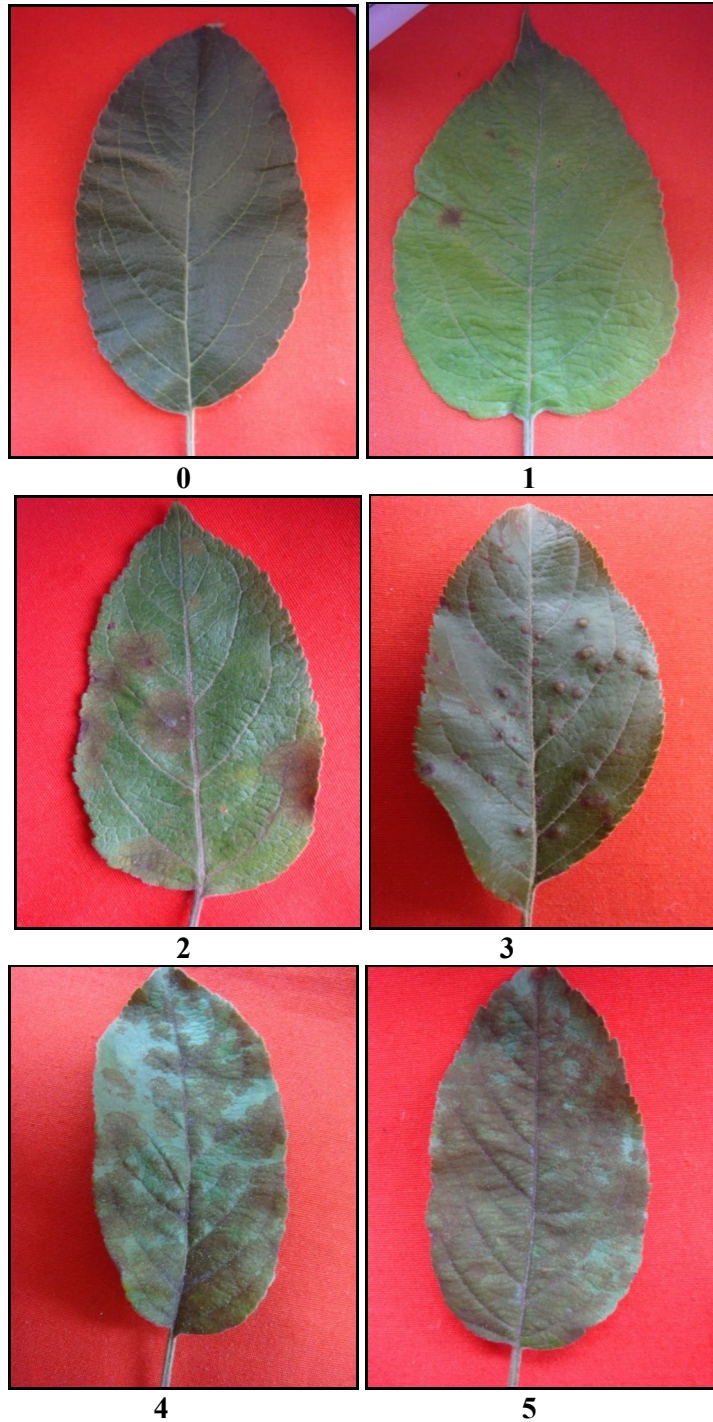


Plate 3: 0-5 visual assessment scale of leaf scab



0



1



2



3



4



5

Plate 4: 0-5 visual assessment scale of fruit scab

i). Per cent disease incidence

Per cent disease incidence was calculated as per this formula.

$$\text{Per cent Disease Incidence (PDI)} = \frac{\text{Number of leaves Infected}}{\text{Total no. of leaves observed}} \times 100$$

ii). Per cent disease severity

The per cent disease severity (Plate 5) was calculated by using modified scale (0-5) adopted by Filajdic and Sutton (1991).

Category	Numerical value	% Area infected
0	0	Free
I	1	>0 ≤ 3.0
II	2	>3 ≤ 6.0
III	3	>6 ≤ 12.0
IV	4	>12 ≤ 25.0
V	5	>25

Per cent disease severity was calculated as per formula:

$$\text{PDS} = \frac{\sum(n \times v)}{N \times G} \times 100$$

Where,

\sum = Summation

n = No. of diseased leaves

v = Numerical value of the category

N = Total no. of leaves examined

G= Highest grade value

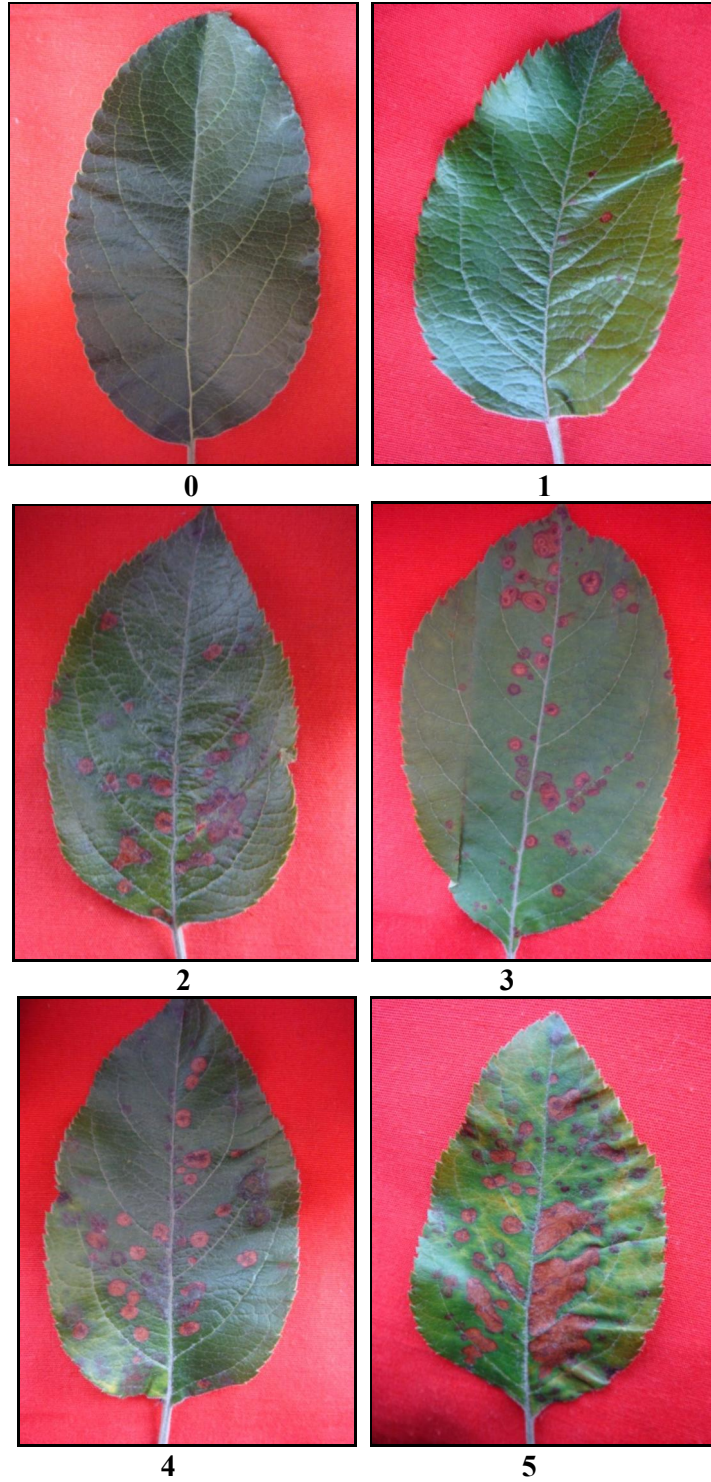


Plate 5: 0-5 visual assessment scale of Alternaria leaf blotch

3.4 Date of sprays and observations

Phenological Stage	Date of Spray	Date of Observation
Green tip	01/04/2019	31/03/2019
Pink Bud	10/04/2019	09/04/2019
40%Petal Fall	21/04/2019	20/04/2019
Petall Fall	30/04/2019	29/04/2019
Fruit let (Pea size stage)	10/05/2019	09/05/2019
Cherry Size	16/05/2019	15/05/2019
Fruit Development-I	27/05/2019	26/06/2019
Fruit Development-II	18/06/2019	17/06/2019
Fruit Development-III	08/07/2019	07/07/2019
Fruit Development-IV	02/08/2019	01/08/2019
Pre-harvest	-	18/08/2019

3.5 Phytotoxic effects

The phytotoxic tests of different fungicides were carried out under high density orchard block of Division of Fruit Science, SKUAST-K, Shalimar during 2019 cropping season. The phytotoxicity analysis of different fungicide molecules were analyzed for phytotoxic effects on the tested cultivars *viz.*, Super Chief Sandidge, Fuji Aztec Zehn, Gala Redlum, Jona Gold, Granny Smith, Jeromine and Red Velox at FD-I stage. The fungicides were tested at double the recommended concentrations for their toxic effects. The details of fungicides along with concentrations for assessment of phytotoxic effect are as under:

Chemical Name	Commercial Name	Conc. (%)
zineb 68%+hexaconazole 4% 72WP	Avtar 72WP	0.20
metiram 55% + pyraclostrobin 5% 60 WG	Cabrio Top 60WP	0.20
captan 70%+hexaconazole 5% 75WP	Rely 75WP	0.10
dodine 65 WP	Super Star 65WP	0.12
ziram 80WP	Zed-78 80WP	0.40
propineb 70 WP	Antracol 70WP	0.60
difenaconazole 25EC	Score 25EC	0.06
mancozeb 75WP	Dithane M-45 5WP	0.60
captan 50WP	Captan 50WP	0.60
flusilazole 40EC	Governor 40EC	0.04
carbendazim 12% + mancozeb 63% 75 WP	Saathi 75WP	0.50
trifloxystrobin 25% + tebuconazole 50% 75WG	Nativo 75WG	0.08
tebuconazole 8% + captan 32% 40 SC	Shamir 40 SC	0.50

3.5.1 Observations

The phytotoxic effects such as leaf necrosis, leaf tip injury, wilting, vein clearing, russeting, epinasty and hyponasty were recorded at 1st, 3rd, 5th, 7th and 10th days after application (DAA) of fungicide at fruit development stage 1st. The level of phytotoxicity was estimated by visual assessment using 0-10 scale (Anonymous, 2018). However, the phytotoxicity in the form of leaf brittleness and curling were recorded as present (+) or absent (-).

Scale of rating for phytotoxicity symptoms

Per cent injury	Rating Injury
0	No Phytotoxicity
$>1 \leq 10$	1
$>11 \leq 20$	2
$>21 \leq 30$	3
$>31 \leq 40$	4
$>41 \leq 50$	5
$>50 \leq 60$	6
$>60 \leq 70$	7
$>70 \leq 80$	8
$>80 \leq 90$	9
$>90 \leq 100$	10

3.6 Statistical analysis:

The data of the various experiments were subjected to appropriate transformation wherever needed and statistically analyzed as per standard statistical procedures given by Gomez and Gomez (1984).

Chapter 4

EXPERIMENTAL FINDINGS

The results of the present study on validation of fungicide spray schedules for management of fungal foliar diseases of apple (*Malus x domestica* Borkh.) under high density orchard system, carried out in the orchard block of Division of Fruit Science and in the laboratory of Fruit Pathology, Division of Plant Pathology, SKUAST-K, Faculty of Horticulture, Shalimar are as under:

4.1 Leaf scab incidence and intensity

Perusal of the data presented in Table 1-8 and Fig. 1, 2, 3 & 4 clearly depicts that the leaf scab was first visually observed at fruit-let stage under HD orchard system of apple during 2019 season. The results pertaining to leaf scab on selected cultivars are as under:-

4.1.1 Super Chief Sandidge

The impact of modules, conventional schedule and control on cultivar Super Chief Sandidge pertaining to leaf scab (LS) incidence is presented in Table 1 and Fig.1a. Analysis of the data revealed that the modules were *significantly* superior in controlling the leaf scab as compared to control. Among the modules, module III was significantly superior with lowest LS incidence of 03.80 and highest per cent disease control (PDC) of 86.41 per cent followed by module-II (06.90 & 82.93%), module-IV (08.66 & 78.86%) and module-I (17.23 & 63.20%), respectively. The control experienced highest incidence of 45.04 per cent followed by conventional schedule having incidence and PDC (20.04 & 51.41%), respectively. The overall mean of incidence of the modules differ statistically among each other.

It was also observed that the phenological stages maintained significance among each other. Irrespective of the number of sprays, an increasing trend in the LS incidence was evident across phenological stages. The significantly lowest LS

incidence of 04.94 per cent was recorded at fruit-let stage & highest 35.55 per cent was observed at pre-harvest, respectively.

The interactive effect of modules x phenological stages clearly depicts the impact of targeting crucial stages *viz.*, 40 per cent petal fall, cherry size and FD-IV stage. Analysis of the data at fruit-let stage revealed that the module-III recorded lowest LS incidence of 02.33 per cent with highest PDC of 78.16 per cent followed by module-II (03.00 & 71.88%), module-I and module-IV each recorded (03.33 & 68.79%), respectively. Whereas, conventional schedule recorded LS incidence and PDC of 07.00 & 34.39 per cent however, highest LS incidence of 10.67 per cent was recorded in control. All the modules were statistically at par with each other and differ significantly with conventional schedule and control. The complementary spray at cherry size stage clearly revealed the impact at FD-I stage with lowest LS incidence and highest PDC of 04.33 and 84.71 per cent recorded in module-III followed by module-II (04.67 & 83.51%), module-IV (05.00 & 82.35%) and module-I (12.33 & 56.47%), respectively with no statistical difference between module II, III & IV. However, the highest LS incidence of 28.33 per cent was observed in control followed by conventional schedule recorded 14.00 per cent having PDC of 50.58 per cent, respectively. Similarly at pre-harvest stage, module-III recorded 07.33 per cent with PDC of 92.00 followed by module-IV (16.33 & 82.25%), module-II (19.00 & 79.34%) and module-I (38.67 & 57.96%), respectively. All the modules differ statistically with conventional schedule and control except module-I. The highest LS incidence of 92.00 per cent was recorded in control followed by conventional schedule with LS incidence and PDC of 40.00 & 56.52 per cent, respectively.

Analysis of the data (Table 2 & Fig. 3a) revealed that all the spray modules were effective in reducing the leaf scab intensity as compared to control. Among the modules, module-III proved significantly effective than other modules, conventional schedule and control. The significantly lowest LS intensity & highest PDC of 02.38 & 87.50 per cent was registered in module III followed

Table 1: Evaluation of phenological based modules on leaf scab incidence of apple cv. Super Chief Sandidge under HD orchard system

Stages	Fruit let		Cherry Size		*FD-I		*FD-II		*FD-III		*FD-IV		Pre-harvest		Mean	
Modules	Incidence	PDC	Incidence	PDC	Incidence	PDC	Incidence	PDC	Incidence	PDC	Incidence	PDC	Incidence	PDC	Incidence	PDC
Module-I	03.33 (10.39)	68.79	05.67 (13.68)	70.15	12.33 (20.48)	56.47	15.67 (23.30)	61.14	20.00 (26.55)	63.63	25.00 (29.98)	64.28	38.67 (38.43)	57.96	17.23 (23.26)	63.20
Module-II	03.00 (09.54)	71.88	04.00 (11.27)	78.94	04.67 (12.35)	83.51	05.33 (13.26)	86.74	05.67 (13.68)	89.69	06.67 (14.89)	90.47	19.00 (25.79)	79.34	06.90 (14.40)	82.93
Module-III	02.33 (08.46)	78.16	03.67 (10.85)	80.68	04.33 (11.73)	84.71	05.00 (12.87)	87.60	05.33 (13.26)	90.30	06.00 (14.14)	91.42	07.33 (15.65)	92.03	03.80 (12.42)	86.41
Module-IV	03.33 (10.49)	68.79	04.67 (12.27)	75.42	05.00 (12.87)	82.35	07.67 (16.01)	80.98	10.00 (18.41)	81.81	13.67 (21.66)	80.47	16.33 (23.79)	82.25	08.66 (16.50)	78.86
Conventional Schedule	07.00 (15.31)	34.39	10.00 (18.33)	47.36	14.00 (21.90)	50.58	19.00 (25.77)	52.88	23.00 (28.62)	58.18	28.00 (31.89)	60.00	40.00 (39.20)	56.52	20.04 (25.86)	51.41
Control (Water sprays)	10.67 (19.03)		19.00 (25.82)		28.33 (32.13)	-	40.33 (39.40)	-	55.00 (47.85)	-	70.00 (56.77)	-	92.00 (74.04)	-	45.04 (42.15)	
Mean	04.94 (12.20)		07.83 (15.37)		11.44 (18.58)		15.50 (21.77)		19.83 (24.73)		24.89 (28.22)		35.55 (36.15)			

CD (p≤0.05)

Modules	=	1.18
Phenological Stages	=	1.27
Modules x Phenological Stages	=	3.12

Figures within the parenthesis are arc sine angular transformed values
FD= Fruit Development, PDC= per cent disease control

by module-II (03.47 & 84.37%), module-IV (04.56 & 77.88%) and module-I (08.73 & 64.70%), respectively. The overall mean of intensity of the modules statistically differ among each other. The significantly highest LS intensity of 25.56 per cent was registered in control followed by conventional schedule with LS intensity and PDC (10.19 & 51.62%), respectively.

The overall mean of phenological stages indicated that there is significant difference among phenological stages. An increasing trend in the LS intensity was found across phenological stages irrespective of the number of sprays. The lowest LS intensity of 01.76 per cent was recorded at fruit-let stage & highest LS intensity of 20.67 per cent was observed at pre-harvest, respectively.

The influence of different modules on *cv.* Super Chief Sandidge studied in the experiment clearly depicted the impact of complementary spray at respective phenological stages. At fruit-let stage, lowest LS intensity of 00.80 per cent with PDC of 80.95 per cent was recorded in module-III followed by module-II (01.00 & 76.19%), module-IV (01.67 & 60.23%) and module-I (01.60 & 61.90%), respectively. However, highest LS intensity of 04.20 per cent was recorded in control and is significantly different from the modules and conventional schedule. At FD-I, lowest LS intensity of 02.20 per cent with PDC of 85.45 were recorded in module-III followed by module-II having 02.27 & 84.96 per cent and module-IV having 02.73 & 81.95 per cent, respectively. It is evident from the data at pre-harvest stage, that the LS intensity of 03.87 per cent was recorded in module-III which gave PDC of 93.68 per cent followed by module-IV (08.53 & 86.09%), module-II (10.13 & 83.48%), module-I (19.73 & 67.82%) and conventional schedule (20.47 and 66.62%), respectively. However, significantly highest LS intensity of 61.33 per cent was recorded in control.

Table 2: Evaluation of phenological based modules on leaf scab intensity of apple cv. Super Chief Sandidge under HD orchard system

Stages	Fruit let		Cherry Size		*FD-I		*FD-II		*FD-III		*FD-IV		Pre-harvest		Mean	
Modules	Intensity	PDC	Intensity	PDC	Intensity	PDC	Intensity	PDC	Intensity	PDC	Intensity	PDC	Intensity	PDC	Intensity	PDC
Module-I	01.60 (08.20)	61.90	02.73 (10.72)	67.72	06.20 (14.12)	59.02	07.70 (16.33)	64.56	10.07 (18.10)	65.19	13.07 (20.48)	66.71	19.73 (25.86)	67.82	08.73 (16.26)	64.70
Module-II	01.00 (06.37)	76.19	01.93 (08.43)	76.83	02.27 (09.13)	84.96	02.60 (09.94)	88.03	03.00 (10.43)	89.63	3.33 (11.11)	91.52	10.13 (18.89)	83.48	03.47 (10.61)	84.37
Module-III	00.80 (04.39)	80.95	01.60 (05.96)	80.79	02.20 (07.48)	85.45	02.40 (08.01)	88.95	02.73 (09.24)	90.56	03.07 (09.85)	92.18	03.87 (10.46)	93.68	02.38 (07.91)	87.50
Module-IV	01.67 (07.25)	60.23	02.27 (09.32)	72.74	02.73 (11.11)	81.95	04.07 (13.05)	81.27	05.27 (14.43)	81.78	07.40 (15.47)	81.15	08.53 (18.28)	86.09	04.56 (12.69)	77.88
Conventional Schedule	03.07 (09.72)	26.90	05.40 (13.06)	35.17	07.07 (15.10)	53.27	09.80 (17.87)	54.90	11.53 (19.60)	60.14	14.00 (21.62)	64.34	20.47 (27.53)	66.62	10.19 (17.78)	51.62
Control (Water sprays)	04.20 (11.02)	-	08.33 (16.75)	-	15.13 (21.00)	-	21.73 (27.79)	-	28.93 (33.92)	-	39.27 (41.72)	-	61.33 (50.63)	-	25.56 (28.97)	
Mean	01.76 (07.82)		03.71 (10.69)		05.93 (12.99)		08.05 (15.50)		10.25 (17.62)		11.92 (20.04)		20.67 (22.28)			

CD (p≤0.05)

Modules	=	0.78
Phenological Stages	=	0.84
Modules x Phenological Stages	=	2.07

Figures within the parenthesis are arc sine angular transformed values

FD= Fruit Development, PDC= per cent disease control

4.1.2 Red Velox

Perusal of the data (Table 3 & Fig.1b) indicated that the modules significantly controlled leaf scab (LS) as compared to control. The significantly least LS incidence of 05.14 with PDC of 84.56 per cent was registered in module-III followed by module-II (07.57 & 80.23%) and module-IV (09.85 & 74.75%), respectively. The control recorded LS incidence of 45.71 per cent followed by conventional schedule with LS incidence & PDC (18.61 & 54.34%), respectively. All the modules and conventional schedule differ statistically with each other.

All the phenological stages maintained significance among each other. The lowest LS incidence of 05.22 per cent was recorded at fruit-let stage & highest 36.22 per cent was observed at pre-harvest, respectively.

The interactive effect of modules x phenological stages on cultivar Red Velox clearly depicts that the lowest LS incidence of 03.00 and PDC of 70.00 per cent was recorded at fruit-let stage in module-III followed by module-II and IV each recorded LSI & PDC of 4.00 & 60.00 per cent while, in case of module-I recorded 04.33 & 56.70 per cent, respectively. All the modules were statistically at par with each other and differ with conventional schedule and control. But, significantly highest LS incidence of 10.00 per cent was recorded in control and conventional schedule having LS incidence & PDC 06.00 & 40.00 percent, respectively. Subsequently, the complimentary spray at cherry size stage, reduced the LS incidence and enhanced PDC at FD-I stage in module-III (04.67 & 84.26%) followed by module-II (05.00 & 83.14%), module-IV (07.00 & 76.40%), module-I (11.33 & 61.18%) and in conventional schedule (13.33 & 55.07%), respectively. Significantly highest LSI was recorded 29.67 per cent in control in which only water sprays was applied. Subsequently, the influence of complimentary spray at FD-IV clearly reveals the impact at pre-harvest stage in which highest LSI of 93.33 per cent was recorded in control and was significantly different from rest of the modules and conventional schedule. However, the lowest LSI of 06.67 per cent with PDC of 92.85 per cent was recorded in module-

Table 3: Evaluation of phenological based modules on leaf scab incidence of apple cv. Red Velox under HD orchard system

Stages	Fruit let		Cherry Size		*FD-I		*FD-II		*FD-III		*FD-IV		Pre-harvest		Mean	
Modules	Incidence	PDC	Incidence	PDC	Incidence	PDC	Incidence	PDC	Incidence	PDC	Incidence	PDC	Incidence	PDC	Incidence	PDC
Module-I	04.33 (11.89)	56.70	07.67 (16.06)	58.15	11.33 (19.63)	61.18	15.00 (22.77)	61.53	19.67 (26.31)	62.17	24.00 (29.31)	69.10	38.33 (38.23)	58.93	17.19 (23.46)	61.10
Module-II	04.00 (11.47)	60.00	04.33 (11.89)	76.37	05.00 (12.87)	83.14	05.67 (13.68)	85.46	06.33 (14.50)	87.82	07.00 (15.31)	90.98	20.67 (27.00)	77.85	07.57 (15.24)	80.23
Module-III	03.00 (09.87)	70.00	04.00 (11.47)	78.17	04.67 (12.27)	84.26	05.33 (13.26)	86.33	06.00 (14.14)	88.46	06.33 (14.43)	91.85	06.67 (14.77)	92.85	05.14 (12.89)	84.56
Module-IV	04.00 (11.47)	60.00	05.33 (13.26)	70.92	07.00 (15.31)	76.40	09.67 (18.07)	75.20	12.00 (20.21)	76.92	13.67 (21.66)	82.39	17.33 (24.58)	81.43	09.85 (17.79)	74.75
Conventional Schedule	06.00 (14.14)	40.00	08.67 (17.04)	52.70	13.33 (21.38)	55.07	17.67 (24.84)	54.69	22.33 (28.18)	57.05	27.33 (31.49)	64.81	41.00 (39.79)	56.06	18.61 (25.27)	54.34
Control (Water sprays)	10.00 (18.41)	-	18.33 (25.34)	-	29.67 (32.97)	-	39.00 (38.62)	-	52.00 (46.12)	-	77.67 (61.79)	-	93.33 (75.16)	-	45.71 (42.62)	
Mean	05.22 (12.87)		08.05 (15.84)		11.83 (19.07)		15.39 (21.87)		19.72 (24.91)		26.00 (29.00)		36.22 (36.58)			

CD (p≤0.05)

Modules	=	0.98
Phenological Stages	=	1.05
Modules x Phenological Stages	=	2.59

Figures within the parenthesis are arc sine angular transformed values

*FD= Fruit Development, PDC= per cent disease control

III followed by module-IV (17.33 & 81.43%) and module-II (20.67 & 77.85%), respectively. All the modules at pre-harvest were statistically different with each other, except module-I and conventional schedule.

It is evident from the data (Table 4 & Fig. 3b), that the modules were more effective in controlling the leaf scab (LS) intensity as compared to control. Among the modules, module-III was more effective in terms of exhibiting highest intensity of LS control of 88.48 per cent against lowest LS intensity of 02.08 per cent followed by module-II with LS intensity and PDC of (03.80 & 78.70%), module-IV (05.19 & 74.18%), respectively. The corresponding highest LS intensity of 26.01 per cent was registered in control followed by conventional schedule with LS intensity and PDC (10.07 & 50.07%), respectively. All the modules, conventional schedule and control significantly differ with each other.

The overall mean of the phenological stages indicated that all the key stages were significantly different with each other. The lowest LS intensity of 02.01 per cent was recorded at fruit-let & highest 20.67 per cent was observed at pre-harvest.

The interactive effect of modules x phenological stages on cultivar Red Velox clearly depicts that the highest LS intensity was recorded in control 03.67 per cent at fruit-let stage. The significantly lowest leaf scab intensity of 00.60 per cent was recorded in module-III with highest PDC of 83.65 per cent followed by module-II, module-IV and module-I having leaf scab intensity and PDC of 01.27 & 65.37 per cent, 01.60 & 56.40 per cent and 02.07 & 43.59 per cent, respectively. At FD-I stage, significantly least LS intensity and highest PDC was recorded in module-III (01.80 & 86.07%) followed by module-II (02.53 & 80.43%), module-IV (3.73 & 71.15%) and module-I (06.00 & 53.59%), respectively. However, the statistically highest LS intensity of 12.93 per cent was registered in control followed by conventional schedule having LS intensity and PDC (06.80 & 47.40%), respectively. Similarly at pre-harvest stage, the significantly lowest leaf scab intensity and PDC of 03.40 & 94.31 per cent was

Table 4: Evaluation of phenological based modules on leaf scab intensity of apple cv. Red Velox under HD orchard system

Stages	Fruit let		Cherry Size		*FD-I		*FD-II		*FD-III		*FD-IV		Pre-harvest		Mean	
Modules	Intensity	PDC	Intensity	PDC	Intensity	PDC	Intensity	PDC	Intensity	PDC	Intensity	PDC	Intensity	PDC	Intensity	PDC
Module-I	02.07 (08.20)	43.59	03.47 (10.72)	58.34	06.00 (14.12)	53.59	07.93 (16.33)	63.62	09.67 (18.10)	69.00	12.27 (20.48)	72.32	19.07 (25.86)	68.11	08.64 (16.26)	59.22
Module-II	01.27 (06.37)	65.39	02.20 (08.43)	73.58	02.53 (09.13)	80.43	03.00 (09.94)	86.23	03.33 (10.43)	89.32	03.73 (11.11)	91.58	10.53 (18.89)	82.39	03.80 (10.61)	78.70
Module-III	00.60 (04.39)	83.65	01.13 (05.96)	86.43	01.80 (07.48)	86.07	02.00 (08.01)	90.82	02.60 (09.24)	91.66	03.00 (09.85)	93.23	03.40 (10.46)	94.31	02.08 (07.91)	88.48
Module-IV	01.60 (07.25)	56.40	02.60 (09.23)	68.78	03.73 (11.11)	71.15	05.13 (13.05)	90.82	06.27 (14.43)	79.90	07.13 (15.47)	83.91	09.87 (18.28)	83.49	05.19 (12.69)	74.18
Conventional Schedule	02.87 (09.72)	21.79	05.13 (13.06)	38.41	06.80 (15.10)	47.40	09.43 (17.87)	76.46	11.27 (19.60)	63.87	13.60 (21.62)	69.32	21.40 (27.53)	64.21	10.07 (17.78)	50.07
Control (Water sprays)	03.67 (11.02)		08.33 (16.75)		12.93 (21.00)		21.80 (27.79)	-	31.20 (33.92)	-	44.33 (41.72)	-	59.80 (50.63)		26.01 (28.97)	
Mean	02.01 (07.82)		03.81 (10.69)		05.63 (12.99)		08.21 (15.50)		10.72 (17.62)		14.01 (20.04)		20.67 (25.28)			

CD (p≤0.05)

Modules	=	0.78
Phenological Stages	=	0.84
Modules x Phenological Stages	=	2.07

Figures within the parenthesis are arc sine angular transformed values

*FD= Fruit Development, PDC= per cent disease control

observed in module-III followed by module-IV 09.87 & 83.49 per cent, module-II 10.53 & 82.39 per cent, module-I 19.07 & 68.11 per cent and in conventional schedule 21.40 & 64.21 per cent, respectively. The statistically highest LS intensity of 59.80 per cent was recorded in control.

4.1.3 Fuji Zehn Aztec

Perusal of the data (Table 5 & Fig. 1c) reflected that the modules were significantly superior in controlling leaf scab incidence as compared to control. Among the modules, module-III significantly reduced LS incidence of 04.09 per cent with PDC of 90.37 per cent followed by module-II (07.14 & 86.09%), module-IV (11.14 & 78.14%) and module-I (18.28 & 67.34%), respectively. Statistically highest LS incidence of 52.95 per cent recorded in control followed by conventional schedule (20.95 & 58.01%), respectively. All the modules, conventional schedule and control differ statistically.

Each phenological stage maintained significant difference between each other. The least LS incidence of 06.11 per cent was recorded at fruit-let & significantly highest LS incidence of 37.11 per cent was observed at pre-harvest, respectively.

The interactive effect of modules x phenological stages on *cv.* Fuji Aztec Zehn clearly depicts that the modules were significantly superior in controlling LS incidence as compared to control. Among the modules at fruit-let, significantly lowest LS incidence & highest PDC of 2.67 & 82.96 per cent was recorded in module-III followed by module-II (03.33 & 78.74%), module-IV (03.33 & 78.74%) and module-I (04.00 & 74.47%), respectively. However, in case of conventional schedule recorded LS incidence and PDC of 07.67 and 51.05 per cent with significantly highest LS incidence of 15.67 per cent was recorded in control. At FD-I stage, significantly lowest LS incidence & highest PDC was recorded in module-III (03.67 & 89.80%) statistically at par with module-II having 04.00 & 88.88 per cent but differ significantly with module-IV (08.00 &

Table 5: Evaluation of phenological based modules on leaf scab incidence of apple cv. Fuji Aztec Zehn under HD orchard system

Stages	Fruit let		Cherry Size		*FD-I		*FD-II		*FD-III		*FD-IV		Pre-harvest		Mean	
Modules	Incidence	PDC	Incidence	PDC	Incidence	PDC	Incidence	PDC	Incidence	PDC	Incidence	PDC	Incidence	PDC	Incidence	PDC
Module-I	04.00 (09.31)	74.47	06.00 (13.75)	73.13	13.33 (21.29)	62.97	17.00 (24.24)	65.53	21.67 (27.61)	68.59	26.00 (30.60)	68.41	40.00 (39.20)	58.33	18.28 (23.70)	67.34
Module-II	03.33 (10.33)	78.74	03.67 (10.85)	83.56	04.00 (11.47)	88.88	04.67 (12.35)	90.53	05.00 (12.87)	92.75	07.33 (15.59)	91.09	22.00 (27.93)	77.08	07.14 (14.48)	86.09
Module-III	02.67 (09.80)	82.96	03.00 (09.87)	86.56	03.67 (10.85)	89.80	04.00 (11.27)	91.89	04.33 (11.66)	93.72	05.00 (12.74)	93.92	06.00 (14.14)	93.75	04.09 (11.37)	90.37
Module-IV	03.33 (10.33)	78.74	06.00 (14.14)	73.13	08.00 (16.40)	77.77	11.00 (19.31)	77.70	14.33 (22.21)	79.23	16.00 (23.52)	80.56	19.33 (26.04)	79.86	11.14 (18.85)	78.14
Conventional Schedule	07.67 (15.61)	51.05	11.33 (19.52)	49.26	15.33 (23.02)	57.41	20.00 (26.48)	59.45	24.33 (29.50)	64.73	28.67 (32.33)	65.17	39.33 (38.82)	59.03	20.95 (26.47)	58.01
Control (Water sprays)	15.67 (21.67)	-	22.33 (28.16)	-	36.00 (36.85)	-	49.33 (44.60)	-	69.00 (56.16)	-	82.33 (65.17)	-	96.00 (78.59)	-	52.95 (47.31)	
Mean	06.11 (12.72)		08.72 (16.02)		13.38 (19.98)		17.66 (23.04)		23.11 (26.68)		27.55 (29.99)		37.11 (37.45)			

CD (p≤0.05)
 Modules = 1.63
 Phenological Stages = 1.77
 Modules x Phenological Stages = 4.33
 Figures within the parenthesis are arc sine angular transformed values
 *FD= Fruit Development, PDC= per cent disease control

77.77%) and module-I (13.33 & 62.97%), respectively. Conventional schedule recorded (15.33 & 57.41%) as against control in which statistically highest LS incidence of 36.00 per cent was recorded. Similarly, at pre-harvest stage module-III recorded significantly lowest LS incidence and highest PDC of (06.00 & 93.75%) followed by module-IV (19.33 & 79.86%) statistically at par with module-II recorded (22.00 & 77.08%) and differ significantly with module-I (40.00 & 58.33%), respectively. The conventional schedule having LS incidence & PDC of (39.33 & 59.03%) and were statistically at par with module-I. The significantly highest LS incidence of 96.00 per cent was recorded in control and was statistically different with rest of the modules and conventional schedule.

It is evident from the data (Table 6 & Fig. 3c), that the modules were more effective in controlling the LS intensity as compared to control. Among the modules, module-III exhibited significantly highest LS intensity control of 93.50 per cent against least LS intensity of 01.77 per cent followed by module-II with LS intensity and PDC of (03.60 & 87.24%), module-IV (05.85 & 78.11%), respectively. The corresponding highest LS intensity of 31.86 per cent was registered in control followed by conventional schedule 10.81 with PDC of 57.32 per cent, respectively. All the modules, conventional schedule and control differ statistically with each other.

The overall mean of the phenological stages indicated that all the stages were significantly different with each other. The least LS intensity of 02.38 per cent was recorded at fruit-let stage & highest 21.76 per cent was observed at pre-harvest.

The interactive effect of modules x phenological stages on *cv.* Fuji Aztec Zehn clearly depicts that the modules were significantly superior in controlling LS intensity as compared to control. At fruit-let stage among the modules, module-III provided significantly least LS intensity of 00.53 per cent with PDC of 89.40 per cent statistically at par with module-II (01.20 & 76.00%) and differs significantly with module IV (01.73 & 65.40%), respectively. The significantly highest LS

Table 6: Evaluation of phenological based modules on leaf scab intensity of apple *cv.* Fuji Aztec Zehn under HD orchard system

Stages	Fruit let		Cherry Size		*FD-I		*FD-II		*FD-III		*FD-IV		Pre-harvest		Mean	
Modules	Intensity	PDC	Intensity	PDC	Intensity	PDC	Intensity	PDC	Intensity	PDC	Intensity	PDC	Intensity	PDC	Intensity	PDC
Module-I	01.93 (06.41)	61.14	03.13 (09.81)	70.82	06.93 (15.20)	65.00	08.87 (17.30)	70.69	11.00 (19.32)	73.03	13.40 (21.43)	73.72	20.27 (26.70)	69.00	09.36 (16.60)	69.05
Module-II	01.20 (06.01)	76.00	01.67 (07.32)	84.43	02.07 (08.23)	89.54	02.27 (08.54)	92.50	02.67 (09.36)	93.45	04.00 (11.43)	92.15	11.33 (19.64)	82.67	03.60 (10.07)	87.24
Module-III	00.53 (04.04)	89.40	00.73 (04.83)	93.19	01.27 (06.37)	93.58	01.93 (07.74)	93.62	02.20 (08.26)	94.60	02.60 (09.15)	94.90	03.13 (10.17)	95.21	01.77 (07.22)	93.50
Module-IV	01.73 (07.46)	65.40	03.07 (10.03)	71.38	03.93 (13.79)	80.15	05.73 (13.79)	81.07	07.67 (16.06)	81.20	08.40 (16.79)	83.52	10.40 (18.73)	84.09	05.85 (13.46)	78.11
Conventional Schedule	03.93 (11.10)	21.40	06.00 (14.06)	44.08	07.67 (18.76)	61.26	10.42 (18.76)	65.57	12.73 (20.87)	68.79	14.87 (22.65)	70.84	20.07 (26.59)	69.31	10.81 (18.58)	57.32
Control (Water sprays)	05.00 (12.82)	-	10.73 (19.10)	-	19.80 (26.39)	-	30.27 (33.35)	-	40.80 (39.67)	-	51.00 (45.55)	-	65.40 (53.98)	-	31.86 (32.98)	
Mean	02.38 (07.97)		04.22 (10.86)		06.94 (16.58)		09.91 (13.94)		12.85 (18.92)		15.71 (21.17)		21.76 (25.97)			

CD (p≤0.05)

Modules	=	1.19
Phenological Stages	=	.29
Modules x Phenological Stages	=	3.17

Figures within the parenthesis are arc sine angular transformed values

*FD= Fruit Development, PDC= per cent disease control

intensity was recorded in control (05.00%) followed by conventional schedule with LS intensity of 03.93 & PDC 21.40 per cent, respectively. The control and conventional schedule were statistically different from rest of the modules. At FD-I stage, significantly least LS intensity of 01.27 per cent in module-III with PDC of 93.58 per cent at par with module-II recorded 02.07 & 89.54 per cent and differs statistically with module-IV & module-I recorded 03.93 & 80.15 per cent and 06.93 & 65.00 per cent, respectively. Further, significantly highest LS intensity of 19.80 per cent was recorded in control and conventional schedule recorded LS intensity & PDC of (07.67 & 61.26%), respectively. At pre-harvest stage, significantly least LS intensity and highest PDC of 03.13 & 95.21 per cent was recorded in module-III followed by module-IV 10.40 & 84.09 per cent, module-II 11.33 & 82.67 per cent and 20.27 & 69.00 per cent in module-I, respectively. Module-III, conventional schedule and control were highly significant with each.

4.1.4 Gala Redlum

Perusal of the data (Table 7 & Fig.1d) indicated that all the spray modules significantly controlled leaf scab as compared to control. Among the modules, module-III provided significantly least LS incidence of 03.09 per cent with PDC of 92.09 per cent followed by module-II (04.85 & 89.26%), module-IV (05.71 & 86.92%) and module-I (09.52 & 79.45%), respectively. The control recorded significantly highest LS incidence of 37.42 per cent followed by conventional schedule (10.85 & 74.52%), respectively. However, module I, II, III, conventional schedule and control differ significantly with each other.

All the phenological stages maintained statistical significance among each other. An increasing trend in the LS incidence was observed across phenological stages irrespective of the number of sprays. The least LS incidence of 01.60 per cent was recorded at fruit-let & highest 29.33 per cent was registered at pre-harvest, respectively.

Table 7: Evaluation of phenological based modules on leaf scab incidence of apple cv. Gala Redlum under HD orchard system

Stages	Fruit let		Cherry Size		*FD-I		*FD-II		*FD-III		*FD-IV		Pre-harvest		Mean	
Modules	Incidence	PDC	Incidence	PDC	Incidence	PDC	Incidence	PDC	Incidence	PDC	Incidence	PDC	Incidence	PDC	Incidence	PDC
Module-I	00.33 (01.91)	96.53	02.00 (06.55)	85.71	05.33 (13.33)	74.21	07.00 (15.31)	78.12	08.67 (17.09)	80.73	13.33 (21.38)	78.26	30.00 (33.19)	62.65	09.52 (15.54)	79.45
Module-II	00.00 (00.60)	100	01.67 (06.03)	88.07	03.00 (09.87)	85.48	03.33 (10.33)	89.59	03.67 (10.75)	91.84	06.00 (14.14)	90.21	16.33 (23.79)	79.67	04.85 (10.70)	89.26
Module-III	00.00 (00.60)	100	01.33 (06.53)	90.50	02.33 (08.74)	88.72	03.00 (09.87)	90.62	04.67 (12.27)	89.62	05.00 (12.74)	91.84	05.33 (13.26)	93.36	03.09 (09.06)	92.09
Module-IV	00.00 (00.60)	100	01.33 (05.41)	90.50	03.33 (10.33)	73.88	06.00 (14.06)	81.25	07.33 (15.67)	83.71	09.00 (17.39)	85.32	13.00 (21.36)	93.81	05.71 (12.03)	86.92
Conventional Schedule	00.67 (03.82)	92.27	03.33 (10.49)	76.21	06.67 (14.94)	67.73	09.00 (17.43)	71.87	11.00 (19.37)	75.55	14.33 (22.21)	76.63	31.00 (33.80)	61.40	10.85 (17.43)	74.52
Control (Water sprays)	08.67 (17.07)	-	14.00 (21.93)	-	20.67 (27.00)	-	32.00 (34.42)	-	45.00 (42.11)	-	61.33 (51.54)	-	80.33 (63.66)	-	37.42 (36.81)	-
Mean	01.60 (03.80)		03.94 (09.49)		06.88 (14.04)		10.05 (16.90)		13.39 (19.54)		18.16 (23.23)		29.33 (31.51)			

CD ($p \leq 0.05$)

Modules	=	1.37
Phenological Stages	=	1.49
Modules x Phenological Stages	=	3.64

Figures within the parenthesis are arc sine angular transformed values

*FD= Fruit Development, PDC= per cent disease control

The interactive effect of modules x phenological stages on *cv. Gala Redlum* clearly depicts that the modules were significantly superior in controlling LS incidence as compared to control recorded 08.67 per cent was recorded at fruit-let stage. The modules and conventional schedule were at par with each other except control. At FD-I stage, module-III significantly exhibited lowest LS incidence and highest PDC (02.33 & 88.72%) followed by module-II (03.00 & 85.48%), module-IV (03.33 & 73.88%), module-I (05.33 & 74.21%) and control registered highest leaf scab incidence of 20.67%, respectively. At pre-harvest stage, significantly lowest LS incidence and PDC were recorded in module-III (05.33 & 93.36%) followed by module-IV (13.00 & 83.81%), module-II (16.33 & 79.67%), module-I (30.00 & 62.65%), respectively. The significantly highest LS incidence of 80.33 per cent was registered in control followed by conventional schedule with LS incidence 31.00 & PDC of 61.40 per cent, respectively. The modules-III, conventional schedule and control differ significantly with each.

Analysis of the data (Table 8 & Fig. 3d), reflected that all the modules were effective in controlling the leaf scab (LS) intensity as compared to control. Among the modules, module-III significantly exhibited lowest LS intensity of 01.37 per cent against highest PDC of 93.83 per cent followed by module-II (02.49 & 89.36%), module-IV (03.00 & 87.04%) and module-I (04.79 & 79.93%), respectively. The significantly highest LS intensity of 19.30 per cent was registered in control followed by conventional schedule with LS incidence & PDC (05.29 & 75.89%), respectively. The conventional schedule and control were statistically different with rest of the modules.

The overall mean of the phenological stages indicated that the stages were significantly different with each other. The least LS intensity of 00.27 per cent was recorded at fruit-let stage & highest 15.42 per cent was observed at pre-harvest.

The interactive effect of spray modules and phenological stages at fruit-let stage recorded 100 per cent disease control in module-II, III and IV followed by

Table 8: Evaluation of phenological based modules on leaf scab intensity of apple cv. Gala Redlum under HD orchard system

Stages	Fruit let		Cherry Size		*FD-I		*FD-II		*FD-III		*FD-IV		Pre-harvest		Mean	
Modules	Intensity	PDC	Intensity	PDC	Intensity	PDC	Intensity	PDC	Intensity	PDC	Intensity	PDC	Intensity	PDC	Intensity	PDC
Module-I	00.07 (00.85)	95.23	00.93 (04.51)	82.99	02.47 (09.02)	76.54	03.73 (11.13)	77.96	04.57 (12.32)	80.52	06.60 (14.85)	80.58	14.80 (22.59)	65.74	04.74 (10.75)	79.93
Module-II	00.00 (00.60)	100	00.87 (04.33)	84.09	01.27 (06.37)	87.93	01.47 (06.93)	91.31	02.00 (07.95)	91.47	03.07 (10.06)	90.97	08.73 (17.16)	79.79	02.49 (07.54)	89.36
Module-III	00.00 (00.60)	100	00.27 (02.91)	95.06	00.87 (05.33)	91.73	01.33 (06.57)	92.14	02.07 (08.12)	91.18	02.47 (08.89)	92.73	02.60 (09.25)	93.98	01.37 (05.87)	93.83
Module-IV	00.00 (00.60)	100	00.60 (03.62)	89.03	01.60 (07.19)	84.80	02.93 (09.79)	82.69	03.87 (11.31)	83.51	04.67 (12.41)	86.26	07.33 (15.67)	83.03	03.00 (08.57)	87.04
Conventional Schedule	00.13 (01.70)	91.15	01.67 (07.41)	69.46	02.53 (09.14)	75.97	03.93 (11.41)	76.78	05.67 (13.75)	75.84	07.20 (15.55)	78.82	15.87 (23.45)	63.26	05.29 (11.77)	75.89
Control (Water sprays)	01.47 (06.92)	-	05.47 (13.51)	-	10.53 (18.92)	-	16.93 (24.26)	-	23.47 (28.88)	-	34.00 (35.65)	-	43.20 (41.07)	-	19.30 (24.17)	
Mean	00.27 (01.58)		01.63 (06.05)		03.21 (09.33)		05.05 (11.68)		06.94 (02.31)		09.66 (16.23)		15.42 (21.53)			

CD (p≤0.05)

Modules = 0.93

Phenological Stages = 1.00

Modules x Phenological Stages = 2.46

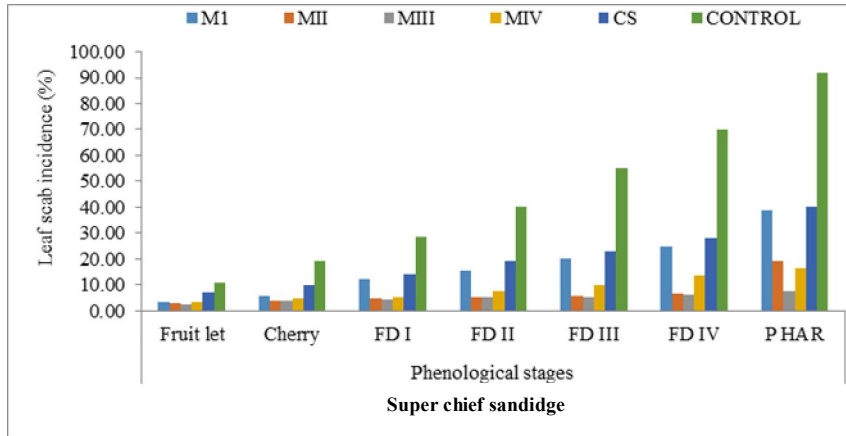
Figures within the parenthesis are arc sine angular transformed values

*FD= Fruit Development, PDC= per cent disease control

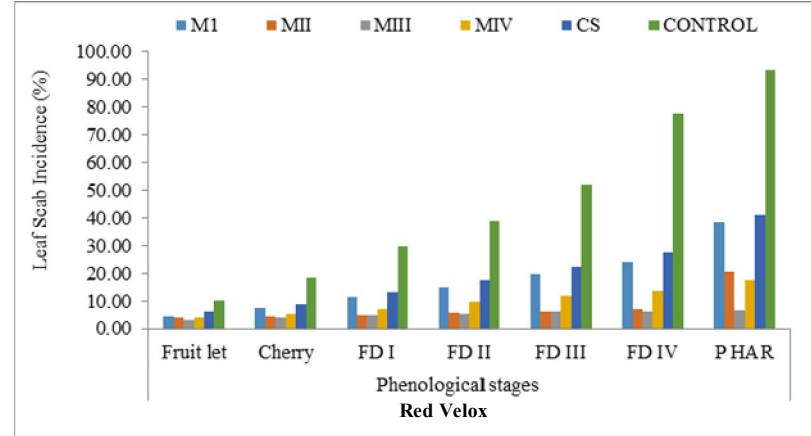
module-I recorded LS intensity and PDC (95.23 & 0.07%) per cent in conventional schedule (00.13 & 91.15%), respectively. However, significantly highest LS intensity of 01.47 per cent was recorded in control and differed statistically with rest of the modules as well as conventional schedule. At FD-I stage, significantly lowest LS intensity & highest PDC of 00.87 & 91.73 per cent was recorded in module-III followed by module-II (01.24 & 87.93%) and module-IV (01.60 & 84.80%), respectively. The conventional schedule recorded 02.53 & 75.97 per cent and significantly highest LS intensity was recorded 10.53 per cent in control, respectively. The influence of FD-IV is evident from the data recorded at pre-harvest stage with significantly lowest LS intensity and highest PDC of 02.60 & 93.98 per cent were observed in module-III followed by module-IV (07.33 & 83.03%) and module-II (08.73 & 79.79%), respectively. Module-I recorded LS incidence & PDC (14.80 & 65.74%) followed by conventional schedule (15.87 & 63.26%) and were statistically at par with each other, respectively. The control experienced highest LS intensity of 43.20 per cent and differed statistically with rest of the modules and conventional schedule.

4.1.5 Comparative efficacy of leaf scab incidence and intensity on tested cultivars

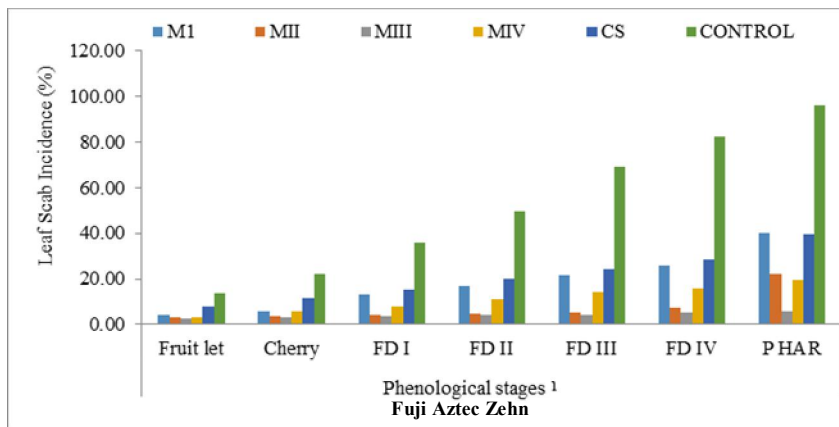
LS incidence and intensity within cultivars showed varied levels among the cultivars (Fig.2 & 4). On overall basis, module-III exhibited lowest leaf scab incidence, intensity and highest PDC among all the cultivars. The comparative and the ascending trend among the cultivars revealed that Gala Redlum experienced lowest leaf scab incidence & highest PDC of 03.09 & 92.09 per cent followed by Super Chief Sandidge having 03.80 & 86.41 per cent, Red Velox 05.14 & 84.56 per cent and Fuji Zehn Aztec 04.09 & 90.37 per cent, respectively. The minimum leaf scab intensity and highest PDC of 01.37 & 93.83 per cent was recorded in case of Gala Redlum followed by Fuji Zehn Aztec (01.77 & 93.50 %), Red Velox (02.08 & 88.48 %) and Super Chief Sandidge (02.38 & 87.50 %), respectively.



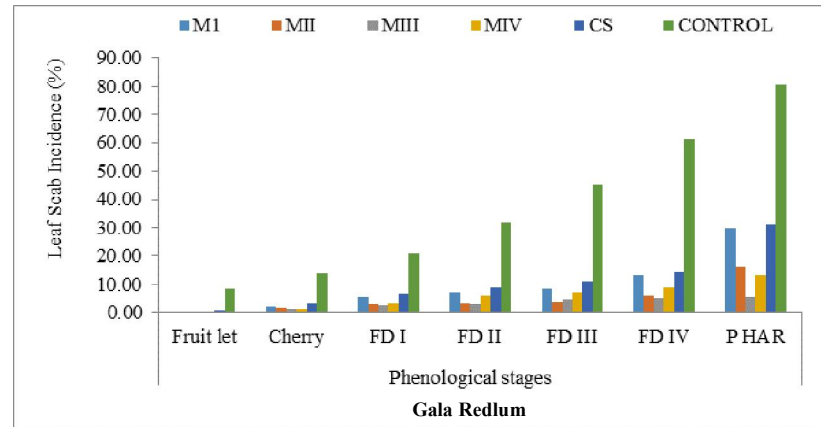
(a)



(b)



(c)



(d)

Fig. 1: Evaluation of phenological based fungicide spray modules on leaf scab incidence of apple on selected cultivars

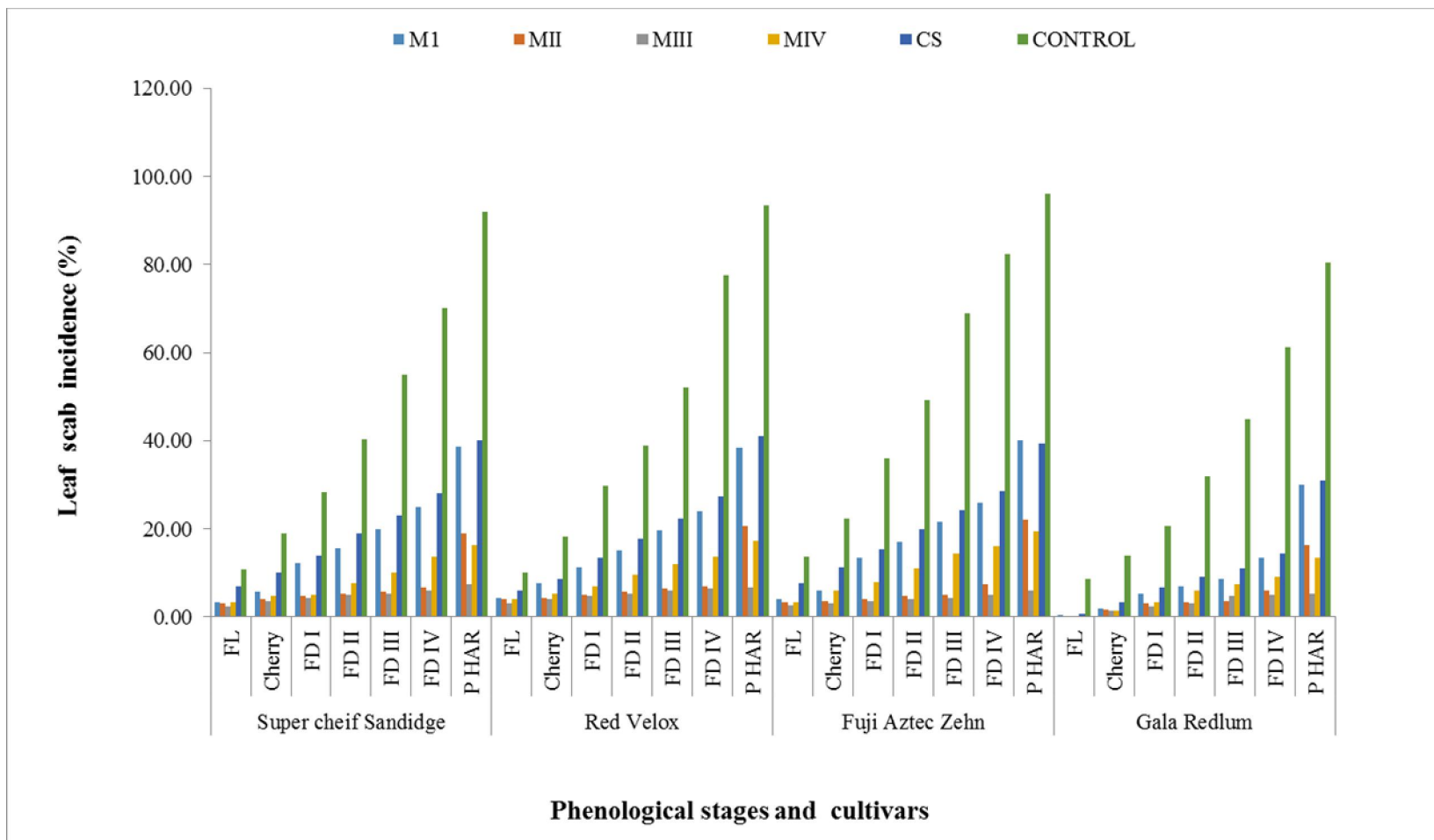


Fig.2: Comparative efficacy of fungicide modules on leaf scab incidence of different cultivars at various phenological stages

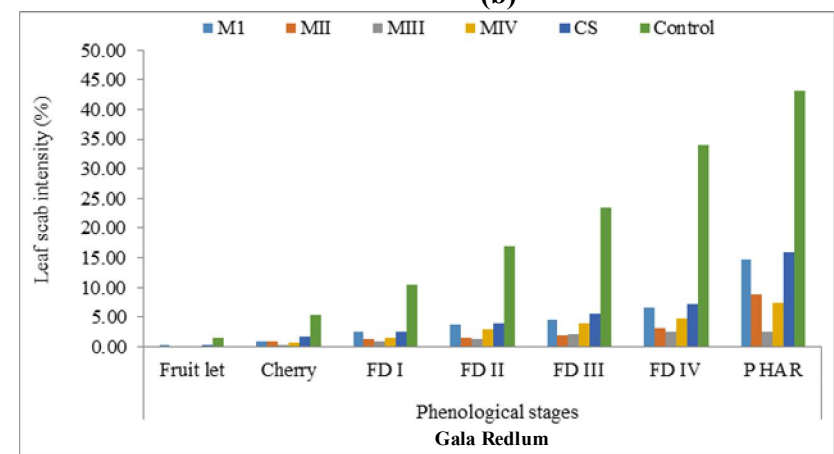
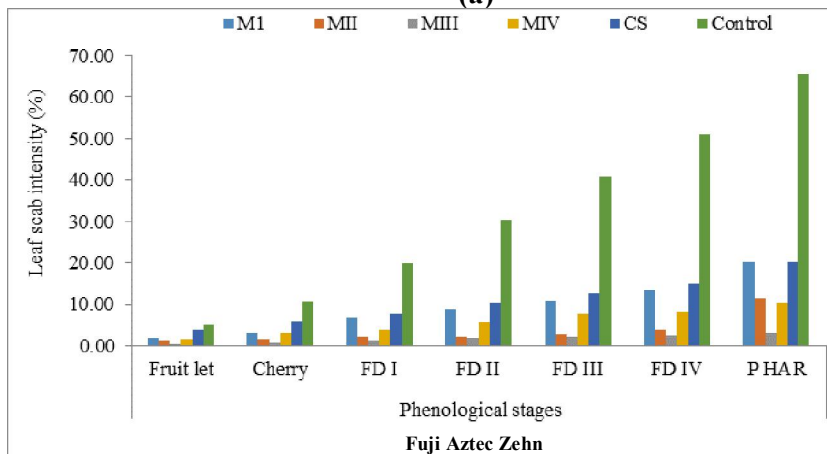
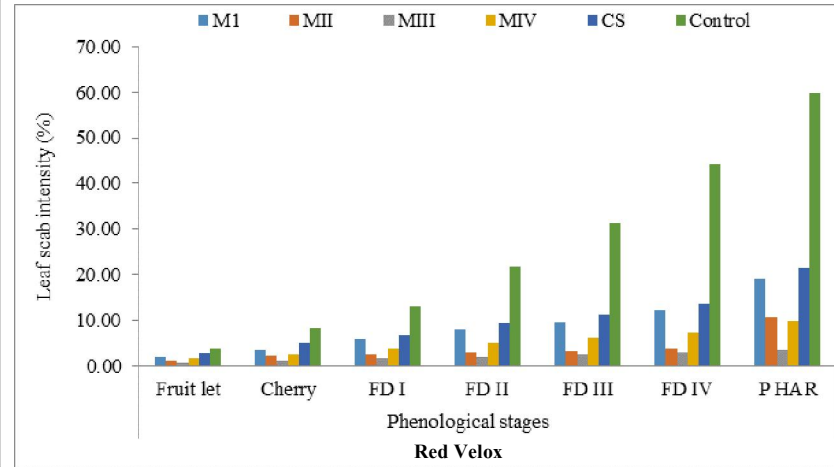
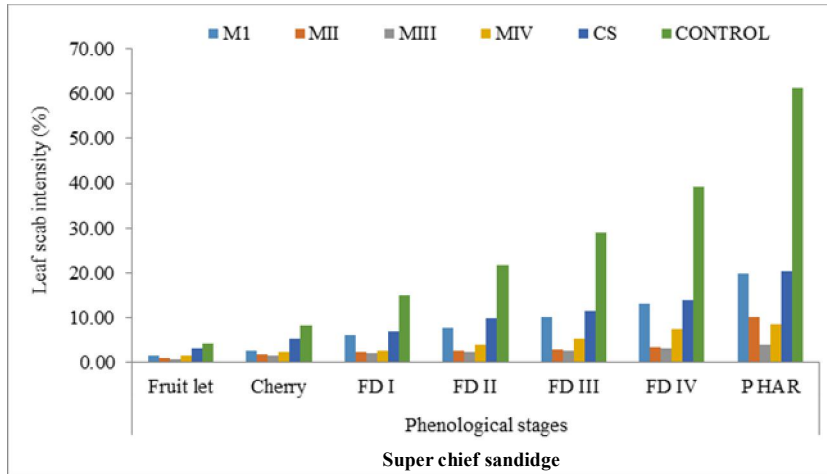


Fig. 3: Evaluation of phenological based fungicide spray modules on leaf scab intensity of apple on selected cultivars

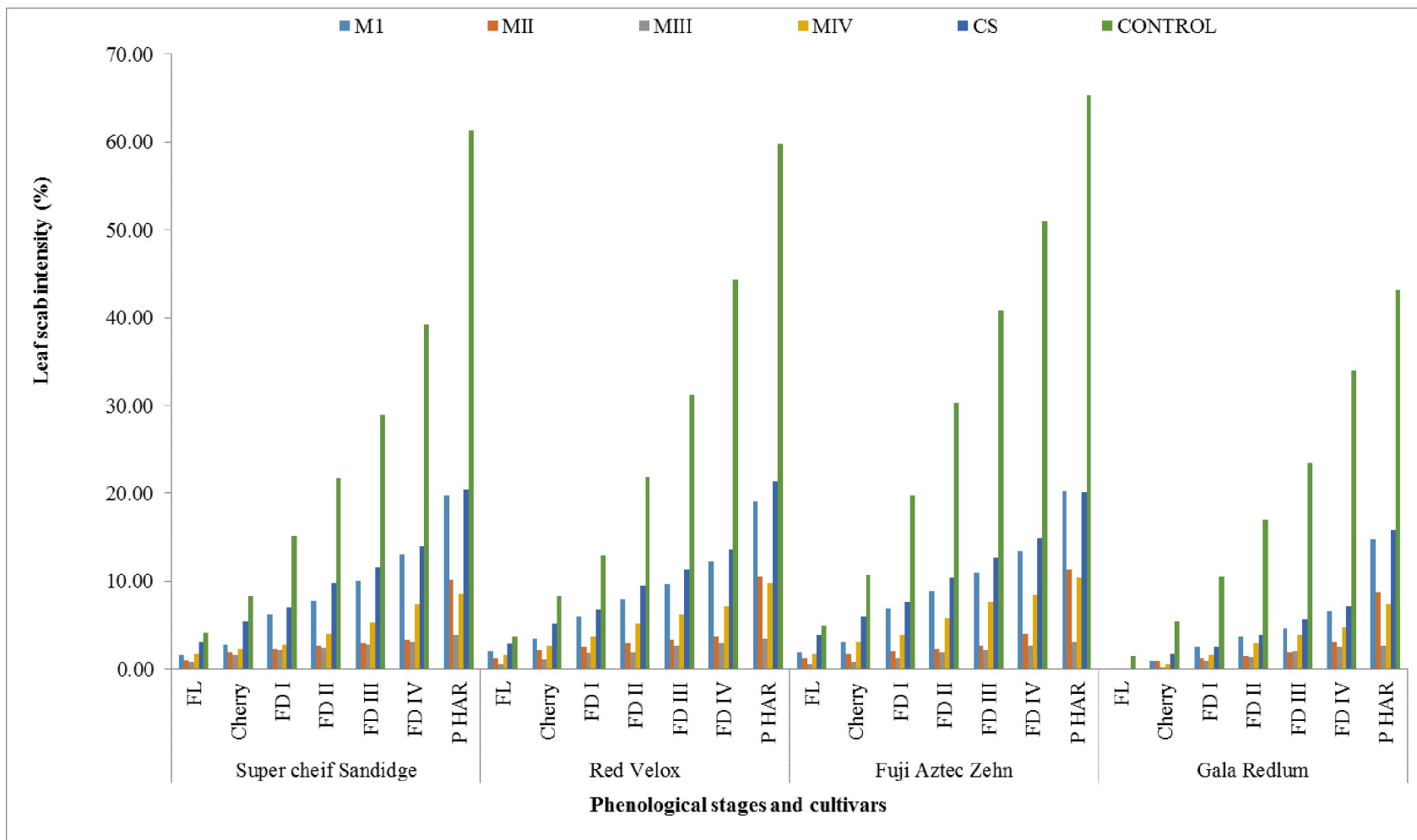


Fig. 4: Comparative efficacy of fungicide modules on leaf scab intensity of different cultivars at various phenological stages

4.2 Fruit scab incidence and intensity

It is evident from the data presented in Table 9-16 clearly depicts that the disease first appeared on fruits at FD-II stage on all the tested cultivars under HD orchard system. The results pertaining to the fruit scab (FS) incidence and intensity on selected cultivars are as under;

4.2.1 Super Chief Sandidge

Analysis of the data (Table 9 & Fig 5a) regarding the FS incidence revealed that the modules were significantly superior in controlling the FS incidence as compared to control. Among the modules, the significantly lowest FS incidence & PDC of 02.50 & 93.45 per cent was registered in module-III followed by module-II (05.24 & 87.60%) and module-IV (06.00 & 85.70%), respectively. The control experienced significantly highest disease incidence of 31.66 per cent followed by conventional schedule with FS incidence and PDC of (10.83 & 71.47%), respectively.

The overall mean of the phenological stages indicated that the stages were significantly different with each other. Irrespective of the number of sprays, an increasing trend in the FS incidence was observed across phenological stages. The significantly least FS incidence of 05.11 per cent was recorded at FD-II & highest 18.66 per cent was observed at pre-harvest, respectively.

The interactive effect of modules x phenological stages on *cv.* Super Chief Sandidge clearly depicts that at FD-II stage, the significantly least FS incidence of 01.33 per cent with PDC of 90.33 per cent was recorded in module-III followed by module-II (02.00 & 86.36%), module-IV (02.67 & 81.79%), module-I (04.67 and 68.16%) and conventional schedule (05.33 and 63.33%), respectively. However, the significantly highest FS incidence of 14.67 per cent was in control and differs statistically with rest of the modules and conventional based schedule. At pre-harvest stage, FS incidence and PDC of 04.00 and 91.78 per cent were observed in module III followed by module-IV (10.67 & 78.07%) and module-II

Table 9: Evaluation of phenological based modules on fruit scab incidence of apple cv. Super Chief Sandidge under HD orchard system

Stages	*FD-II		*FD-III		*FD-IV		Pre-harvest		Mean	
Modules	Incidence	PDC	Incidence	PDC	Incidence	PDC	Incidence	PDC	Incidence	PDC
Module-I	04.67 (12.41)	68.16	06.67 (14.71)	75.59	09.33 (17.62)	74.08	17.33 (24.58)	64.39	09.50 (17.33)	76.71
Module-II	02.00 (06.55)	86.36	02.33 (07.16)	91.47	03.33 (10.39)	90.75	13.33 (21.32)	72.61	05.24 (11.35)	87.60
Module-III	01.33 (05.41)	90.33	02.00 (06.55)	92.68	02.67 (07.43)	92.58	04.00 (11.27)	91.78	02.50 (07.67)	93.45
Module-IV	02.67 (09.26)	81.79	04.67 (12.41)	82.91	06.00 (14.17)	83.33	10.67 (19.03)	78.07	06.00 (13.72)	85.70
Conventional Schedule	05.33 (13.29)	63.33	08.00 (16.34)	70.72	12.00 (20.21)	66.66	18.00 (25.03)	63.01	10.83 (18.72)	71.47
Control (water sprays)	14.67 (22.49)	-	27.33 (31.43)	-	36.00 (36.85)	-	48.67 (44.21)	-	31.66 (33.75)	-
Mean	05.11 (11.57)		08.50 (14.77)		11.55 (17.78)		18.66 (24.24)			

CD (p≤0.05)

Modules	=	2.58
Phenological Stages	=	2.11
Modules x Phenological Stages	=	5.17

Figures within the parenthesis are arc sine angular transformed values

*FD= Fruit Development, PDC= per cent disease control

(13.33 & 72.61%), respectively. The module-I and conventional based schedule were statistically at par with each other with FS incidence and PDC (17.33 and 64.39%) and (18.00 & 63.01%), respectively. The significantly highest FS incidence of 48.67 per cent was recorded in control and was found statistically different from rest of the modules as well as conventional schedule.

An appraisal of the data (Table 10 & Fig. 7a) revealed that the modules were significantly superior in controlling the fruit scab as compared to control. Among the modules, the significantly lowest FS intensity & PDC of (00.80 & 94.58%) was registered in module-III followed by module-II (02.05 & 89.08%), module-IV (02.59 & 86.00%) and module-I (03.63 & 79.62%). The control experienced significantly highest FS intensity of 13.76 per cent, followed by conventional schedule with disease intensity and PDC of (04.02 & 75.69%), respectively. The modules, conventional schedule and control were found statistically different with each other.

It was also apparent that the phenological stages maintained their significance among each other. Irrespective of the number of sprays, an increasing trend in FS intensity was found across phenological stages. The least FS intensity of 01.49 per cent was recorded at FD-II & highest 08.42 per cent was observed at pre-harvest, respectively.

The interactive effect of spray modules and phenological stages on *cv.* Super Chief Sandidge is evident from the data that the lowest FS intensity of 00.27 per cent with highest PDC of 94.87 per cent followed by module-II (00.40 & 92.40%), module-IV (00.87 & 83.49%), module-I (01.07 & 79.69%) and conventional schedule (01.07 & 79.69%), respectively. However, significantly highest FS intensity of 05.27 per cent was recorded in control and was significantly different with rest of the modules and conventional schedule. At pre-harvest stage, module-III and module-IV recorded lowest FS intensity of 01.53 & 04.90 per cent with PDC of 93.25 & 78.41 per cent, respectively. However, the corresponding highest FS intensity of 22.70 per cent was registered in control

Table 10: Evaluation of phenological based modules on fruit scab intensity of apple cv. Super Chief Sandidge under HD orchard system

Stages	*FD-II		*FD-III		*FD-IV		Pre-harvest		Mean	
Modules	Intensity	PDC	Intensity	PDC	Intensity	PDC	Intensity	PDC	Intensity	PDC
Module-I	01.07 (01.43)	79.69	02.53 (01.85)	76.28	03.07 (01.99)	81.28	07.87 (02.97)	65.33	03.63 (02.06)	79.62
Module-II	00.40 (01.17)	92.40	00.80 (01.32)	92.50	01.47 (01.56)	91.03	05.53 (02.55)	75.63	02.05 (01.65)	89.08
Module-III	00.27 (01.12)	94.87	00.67 (01.27)	93.72	01.07 (01.39)	93.47	01.53 (01.56)	93.25	00.88 (01.34)	94.58
Module-IV	00.87 (01.35)	83.49	01.73 (01.64)	83.78	02.87 (01.95)	82.50	04.90 (02.42)	78.41	02.59 (01.84)	86.00
Conventional Schedule	01.07 (01.43)	79.69	02.53 (01.87)	76.28	04.50 (02.33)	72.56	08.00 (02.99)	64.75	04.02 (02.16)	75.69
Control (water sprays)	05.27 (02.50)	-	10.67 (03.39)	-	16.40 (04.17)	-	22.70 (04.86)	-	13.76 (03.75)	
Mean	01.49 (01.50)		03.15 (01.89)		04.89 (02.23)		08.42 (02.89)			

CD (p≤0.05)

Modules = 0.18

Phenological Stages = 0.15

Modules x Phenological Stages = 0.37

Figures within the parenthesis are square root transformed values

*FD= Fruit Development, PDC= per cent disease control

followed by conventional schedule with FS intensity and PDC (08.00 & 64.75%), respectively. The module-III, conventional schedule and control were found significantly different.

4.2.2 Red Velox

Perusal of the data (Table 11 & Fig.5b) indicated that the modules significantly controlled fruit scab incidence as compared to control. Among the modules, the significantly least FS incidence of 03.16 per cent was recorded in module-III with PDC of 91.92 per cent followed by module-II (07.00 & 84.63%) and module-IV (07.50 & 82.85%), respectively. The control recorded significantly highest FS incidence of 30.83 per cent followed by conventional schedule with FS incidence and PDC of (11.83 & 68.82%), respectively.

The phenological stages maintained significance among each other. Irrespective of the number of sprays, an increasing trend in the FS incidence was observed across phenological stages. The least FS incidence of 05.22 per cent was recorded at FD-II & highest 19.00 per cent was observed at pre-harvest, respectively.

The interactive effect of spray modules and phenological stages on *cv.* Red Velox at fruit development-II stage depicts that the lowest FS incidence of 02.00 per cent with PDC of 85.71 per cent was recorded in module-III followed by module-II 02.67 & 80.92 per cent, module-I and module-IV each recorded 03.33 and 76.21 per cent, respectively. However, the highest FS incidence of 14.00 per cent was recorded in control and conventional schedule recorded FS incidence of 06.00 and PDC of 57.14 per cent at the respective phenological stage. At pre-harvest stage, module-III and module-IV recorded FS incidence of 04.67 and 12.00 per cent and PDC of 89.69 & 73.52 per cent followed by module-I and conventional schedule recorded FS incidence and PDC (18.00 & 18.67%) and (60.29 & 58.81%), respectively. However, highest FS incidence of 45.33 per cent was observed in control.

Table 11: Evaluation of phenological based modules on fruit scab incidence of apple cv. Red Velox under HD orchard system

Stages	*FD-II		*FD-III		*FD-IV		Pre-harvest		Mean	
Modules	Incidence	PDC	Incidence	PDC	Incidence	PDC	Incidence	PDC	Incidence	PDC
Module-I	03.33 (10.39)	76.21	06.67 (14.92)	76.73	09.00 (17.40)	74.45	18.00 (25.07)	60.29	09.25 (16.94)	77.49
Module-II	02.67 (07.43)	80.92	03.33 (10.39)	88.38	05.33 (13.29)	84.91	15.33 (23.00)	66.18	07.00 (13.53)	84.63
Module-III	02.00 (06.55)	85.71	02.67 (09.26)	90.68	03.33 (10.14)	90.57	04.67 (12.02)	89.69	03.16 (09.49)	91.92
Module-IV	03.33 (08.56)	76.21	06.00 (14.04)	79.07	08.00 (16.34)	77.35	12.00 (20.21)	73.52	07.50 (14.79)	82.85
Conventional Schedule	06.00 (14.79)	57.14	10.00 (18.37)	65.12	12.67 (20.75)	64.13	18.67 (25.54)	58.81	11.83 (19.67)	68.82
Control (water sprays)	14.00 (21.93)	-	28.67 (32.39)	-	35.33 (36.39)	-	45.33 (42.28)	-	30.83 (33.21)	
Mean	05.22 (11.48)		09.55 (16.54)		12.77 (19.05)		19.00 (24.69)			

CD (p≤0.05)

Modules = 2.85

Phenological Stages = 2.33

Modules x Phenological Stages = N.S

Figures within the parenthesis are arc sine angular transformed values

*FD= Fruit Development, PDC= per cent disease control

It is evident from the data (Table 12 & Fig. 7b), that all the modules were more effective in controlling the fruit scab intensity as compared to control. Among the modules, module-III exhibited the highest control of 93.71 per cent against least fruit scab intensity of 01.13 per cent followed by module-II recorded FS intensity and PDC (02.59 & 90.17%), module-IV (02.66 & 87.46%), respectively. The significantly highest FS intensity of 13.88 per cent was registered in control followed by conventional schedule recorded FS incidence and PDC (04.29 & 78.51%), respectively.

The overall mean of the phenological stages indicated that all the stages were significantly different with each other. The least FS intensity of 01.47 per cent was recorded at FD-II & highest 08.81 per cent was observed at pre-harvest.

The interactive effect of spray modules and phenological stages on *cv.* Red Velox at fruit development-II stage depicts that the highest FS intensity of 05.20 per cent was recorded in control which was significantly different from rest of the modules and conventional based schedule. The significantly lowest FS intensity of 00.40 per cent was recorded in module-III with PDC of 92.30 per cent followed by module-II (00.53 & 89.80%), module-IV (00.80 & 84.61%), module-I (00.80 & 84.61%) and conventional schedule (01.13 & 78.26%), respectively. Subsequently, at pre-harvest stage highest FS intensity of 23.00 per cent was recorded in control which was significantly different from rest of the modules and conventional schedule. The lowest FS intensity of 01.80 per cent was recorded in module-III with PDC of 92.17 per cent followed by module-IV (05.00 & 78.26%), module-II (06.53 & 71.60%), module-I (08.13 & 64.65%) and conventional schedule (08.43 & 63.34%) per cent, respectively.

Table 12: Evaluation of phenological based modules on fruit scab intensity of apple cv. Red Velox under HD orchard system

Stages	*FD-II		*FD-III		*FD-IV		Pre-harvest		Mean	
Modules	Intensity	PDC	Intensity	PDC	Intensity	PDC	Intensity	PDC	Intensity	PDC
Module-I	00.80 (01.33)	84.61	02.20 (01.78)	80.00	03.67 (02.15)	77.52	08.13 (03.02)	64.65	03.70 (02.07)	84.74
Module-II	00.53 (01.22)	89.80	01.20 (01.47)	89.09	02.13 (01.76)	86.95	06.53 (02.74)	71.60	02.59 (01.80)	90.17
Module-III	00.40 (01.17)	92.30	00.80 (01.33)	92.72	01.53 (01.56)	90.63	01.80 (01.65)	92.17	01.13 (01.43)	93.71
Module-IV	00.80 (01.31)	84.61	01.87 (01.68)	83.00	03.00 (01.98)	81.62	05.00 (02.44)	78.26	02.66 (01.85)	87.46
Conventional Schedule	01.13 (01.45)	78.26	03.07 (02.00)	72.09	04.53 (02.32)	72.25	08.43 (03.07)	63.34	04.29 (02.21)	78.51
Control (water sprays)	05.20 (02.48)	-	11.00 (03.43)	-	16.33 (04.14)	-	23.00 (04.89)	-	13.88 (03.73)	-
Mean	01.47 (01.49)		03.35 (01.95)		05.19 (02.32)		08.81 (02.97)			

CD (p≤0.05)

- Modules = 0.22
- Phenological Stages = 0.18
- Modules x Phenological Stages = 0.44

Figures within the parenthesis are square root transformed values

*FD= Fruit Development, PDC= per cent disease control

4.2.3 Fuji Aztec Zehn

Analysis of the data (Table 13 & Fig. 5c) revealed that the modules significantly controlled FS incidence as compared to control. Among the modules, module-III was superior with least FS incidence of 03.83 per cent with PDC of 91.59 per cent followed by module-IV (06.50 & 86.34%) and module-II (07.67 & 84.98%), respectively. The control experienced significantly highest FS incidence of 37.83 per cent followed by conventional schedule having FS incidence & PDC (11.83 & 72.59%), respectively.

Significant difference was observed among phenological stages. Irrespective of the number of sprays, an increasing trend in the FS incidence was observed across phenological stages. The significantly least disease incidence of 05.99 per cent was recorded at FD-II & highest 22.00 per cent was observed at pre-harvest

The interactive effect of spray modules and phenological stages on *cv.* Fuji Aztec Zehn reveals that the significantly lowest FS incidence of 02.67 per cent and per cent disease control (PDC) of 82.58 per cent was recorded in module-III followed by module-II & IV each recorded (03.33 & 78.27%), module-I (05.33 & 65.23%) and conventional schedule (06.00 & 60.86%), respectively. However, the highest FS incidence of 15.33 per cent was recorded in control and is statistically different with rest of the modules and conventional schedule. Similarly, at pre-harvest stage among the modules least FS incidence and highest PDC of 05.33 & 90.81 per cent was observed in module-III followed by module-IV 12.00 & 79.31 per cent, module-II 16.67 & 71.25 per cent, conventional based schedule 19.33 & 66.67 per cent and module-I with 20.67 & 64.36 per cent, respectively. The control recorded significantly highest fruit scab incidence of 58.00 per cent and differs statistically with rest of the modules and conventional schedule.

Table 13: Evaluation of phenological based modules on fruit scab incidence of apple cv. Fuji Aztec Zehn under HD orchard system

Stages	*FD-II		*FD-III		*FD-IV		Pre-harvest		Mean	
Modules	Incidence	PDC	Incidence	PDC	Incidence	PDC	Incidence	PDC	Incidence	PDC
Module-I	05.33 (13.29)	65.23	08.00 (16.34)	75.51	10.67 (19.03)	76.46	20.67 (26.99)	64.36	11.17 (18.91)	76.61
Module-II	03.33 (10.39)	78.27	04.00 (11.53)	87.75	06.67 (14.79)	85.58	16.67 (24.02)	71.25	07.67 (15.18)	84.98
Module-III	02.67 (07.43)	82.58	03.33 (10.39)	89.80	04.00 (11.27)	91.17	05.33 (13.29)	90.81	03.83 (10.60)	91.59
Module-IV	03.33 (10.14)	78.27	04.00 (11.27)	87.75	06.67 (14.71)	85.28	12.00 (20.14)	79.31	06.50 (14.06)	86.34
Conventional Schedule	06.00 (14.04)	60.86	08.67 (16.95)	73.46	13.33 (21.32)	70.59	19.33 (26.06)	66.67	11.83 (19.59)	72.59
Control (water sprays)	15.33 (23.03)	-	32.67 (34.81)	-	45.33 (42.28)	-	58.00 (49.61)	-	37.83 (37.43)	-
Mean	05.99 (13.05)		10.11 (16.88)		14.45 (20.57)		22.00 (26.68)			

CD (p≤0.05)

- Modules = 2.34
- Phenological Stages = 1.91
- Modules x Phenological Stages = 4.69

Figures within the parenthesis are arc sine angular transformed values

*FD= Fruit Development, PDC= per cent disease control

Analysis of the data (Table 14 & Fig. 7c) indicated that the modules were significantly effective in reducing the fruit scab (FS) as compared to control. Among the modules, module-III registered significantly least FS intensity and PDC of 02.51 & 92.43 per cent followed by module-II (03.20 & 92.43%) and module-IV (05.32 & 89.64%), respectively. The corresponding highest disease intensity of 17.55 per cent, was recorded in control followed by conventional schedule with FS intensity and PDC (17.54 & 75.44%), respectively. Statistically module-III was different than control & conventional schedule.

The phenological stages maintained their significance as evident from their overall mean. The significantly least disease intensity 01.67 per cent was recorded at FD-II & highest 11.08 per cent was observed at pre-harvest.

The interactive effect of spray modules and phenological stages on *cv.* Fuji Aztec Zehn at fruit development-II stage depicts that the least FS intensity of 00.27 per cent with highest PDC 95.28 per cent was recorded in module-IV followed by module-III (00.93 and 83.76%), module-II (00.67 & 88.30%), conventional based schedule (01.20 & 79.05%) and module-I (01.27 & 77.83%) having no statistical difference between each other. However, highest FS intensity of 05.73 per cent was recorded in control and was significantly different with rest of all. At pre-harvest stage, the lowest FS intensity and PDC (02.13 & 92.44%) was recorded in module-III followed by module-IV (05.33 & 81.09%), module-II (08.60 & 69.50%) and module-I (11.00 & 60.99%), respectively. The significantly highest FS intensity of 28.20 per cent was recorded in control which was significantly different with rest of the modules and conventional schedule.

Table 14: Evaluation of phenological based modules on fruit scab intensity of apple cv. Fuji Aztec Zehn under HD orchard system

Stages	*FD-II		*FD-III		*FD-IV		Pre-harvest		Mean	
Modules	Intensity	PDC	Intensity	PDC	Intensity	PDC	Intensity	PDC	Intensity	PDC
Module-I	01.27 (01.49)	77.83	02.77 (01.93)	80.93	04.73 (02.38)	78.23	11.00 (03.46)	60.99	04.94 (02.32)	78.96
Module-II	00.67 (01.28)	88.30	01.33 (01.51)	90.84	02.20 (01.78)	89.85	08.60 (03.08)	69.50	03.20 (01.91)	87.21
Module-III	00.93 (01.34)	83.76	01.33 (01.45)	90.84	01.47 (01.55)	93.23	02.13 (01.75)	92.44	02.51 (01.52)	92.43
Module-IV	00.27 (01.12)	95.28	00.93 (01.36)	93.59	03.53 (02.10)	83.75	05.33 (02.47)	81.09	05.32 (01.76)	89.64
Conventional Schedule	01.20 (01.47)	79.05	03.03 (02.00)	79.14	05.80 (02.59)	73.30	11.27 (03.49)	60.03	17.54 (02.39)	75.44
Control (water sprays)	05.73 (02.59)	-	14.53 (03.93)	-	21.73 (04.75)	-	28.20 (05.39)	-	17.55 (04.16)	-
Mean	01.67 (01.55)		03.98 (02.03)		6.67 (02.53)		11.08 (03.27)			

CD (p≤0.05)
 Modules = 0.22
 Phenological Stages = 0.18
 Modules x Phenological Stages = 0.45

Figures within the parenthesis are square root transformed values
 *FD= Fruit Development, PDC= per cent disease control

4.2.4 Gala redlum

An overview of the data (Table 15 & Fig. 5d) on *cv.* Gala Redlum reflected effective fruit scab management by the modules as compared to control. Among the modules, module-III proved significantly superior with lowest FS incidence of 01.17 per cent with PDC of 95.83 per cent followed by module-II (04.33 & 86.63%) and module-IV (05.17 & 82.18%), respectively. The control experienced significantly highest disease incidence of 22.83 per cent followed by conventional schedule having FS incidence and PDC (07.00 & 73.63%), respectively.

The overall mean of the phenological stages reflected significant difference among each other. The significantly least FS incidence of 02.78 per cent was recorded at FD-II & highest 14.22 per cent was registered at pre-harvest stage.

The interactive effect of spray modules and phenological stages on *cv.* Gala Redlum at fruit development-II stage depicts that the lowest FS incidence of 00.00 per cent and PDC of 100 per cent was recorded in module-III followed by module-II (00.67 & 92.27%), module-IV & I each recorded (02.67 & 69.20%) and conventional schedule (02.00 & 76.93%), respectively. However, the highest FS incidence of 08.67 per cent was recorded in control. Similarly, the trend at pre-harvest remains same among the modules with lowest FSI and highest PDC observed in module-III 02.67 & 93.09 per cent followed by module-IV (08.00 & 79.31) per cent, module-II (09.33 & 75.87%), module-I (14.67 & 62.06%) and conventional schedule (12.00 & 68.96%), respectively. However, the highest FS incidence of 38.67 per cent was recorded in control.

Table 15: Evaluation of phenological based modules on fruit scab incidence of apple cv. Gala Redlum under HD orchard system

Stages	*FD-II		*FD-III		*FD-IV		Pre-harvest		Mean	
Modules	Incidence	PDC	Incidence	PDC	Incidence	PDC	Incidence	PDC	Incidence	PDC
Module-I	02.67 (07.68)	69.20	06.00 (14.04)	60.86	07.33 (15.46)	74.43	14.67 (22.49)	62.06	07.67 (14.92)	74.47
Module-II	00.67 (02.70)	92.27	02.67 (09.26)	82.58	04.67 (12.41)	83.71	9.33 (17.75)	75.87	04.33 (10.53)	86.63
Module-III	00.00 (00.00)	100	00.67 (02.70)	95.62	01.33 (05.41)	95.36	02.67 (07.43)	93.09	01.17 (03.89)	95.83
Module-IV	02.67 (09.26)	69.20	04.00 (11.27)	73.90	06.00 (14.04)	79.07	08.00 (16.42)	79.31	05.17 (12.75)	82.18
Conventional Schedule	02.00 (06.55)	76.93	06.00 (14.04)	60.86	08.00 (16.34)	72.09	12.00 (20.11)	68.96	07.00 (14.26)	73.63
Control (water sprays)	08.67 (17.09)	-	15.33 (23.03)	-	28.67 (32.35)	-	38.67 (38.42)	-	22.83 (27.72)	
Mean	02.78 (01.39)		05.77 (12.39)		09.33 (16.00)		14.22 (20.44)			

CD (p≤0.05)

Modules	=	2.72
Phenological Stages	=	2.22
Modules x Phenological Stages	=	N.S

Figures within the parenthesis are arc sine angular transformed values

*FD= Fruit Development, PDC= per cent disease control

A critical review from the data (Table 16 & Fig. 7d) regarding the fruit scab intensity revealed that the modules were significantly effective in controlling the fruit scab as compared to check (control). However, module-III was significantly more effectively than other modules, conventional schedule and control (water sprays). The significantly lowest fruit scab intensity and PDC of 00.50 & 95.74 per cent was observed in module-III followed by module-II with intensity and PDC of (02.11 & 86.04%), module-IV (02.19 & 82.01%) and conventional schedule (03.43 & 70.89%), respectively. However, the corresponding highest FS intensity of 09.38 per cent was registered in control and differs statistically with rest of the modules and conventional schedule.

It was also observed that the phenological stages maintained their significance among each other. Irrespective of the number of sprays, an increasing trend in the disease incidence and intensity was observed across phenological stages. The least FS intensity of 00.93 per cent was recorded at FD-II & highest 06.93 per cent was observed at pre-harvest.

The interactive effect of spray modules and phenological stages on *cv.* Gala Redlum at FD-II stage recorded no FS intensity and 100 per cent disease control in module-III followed by module-II (00.13 & 95.66%), module-I (00.73 & 75.66%), conventional schedule (00.80 & 73.33%) and module-IV (00.93 & 69.00%), respectively. However, the highest FS intensity of 03.00 per cent was recorded in control which is significantly different from rest of the modules and conventional schedule. The complementary spray applied at FD-IV stage significantly reduces the FS intensity and increases the PDC in case of module-III recorded 01.13 & 93.16 per cent, followed by module-IV having 04.00 & 75.80 per cent and module-II 05.53 & 66.54 per cent, respectively at pre-harvest stage. While as, conventional schedule recorded FS intensity and PDC of 07.40 & 55.23 per cent and was found at par with module-I recorded 07.00 & 57.65 per cent, respectively. The significantly highest FS intensity of 16.53 per cent was recorded in control and differs with rest of modules and conventional schedule.

Table 16: Evaluation of phenological based modules on fruit scab intensity of apple cv. Gala Redlum under HD orchard system

Stages	*FD-II		*FD-III		*FD-IV		Pre-harvest		Mean	
Modules	Intensity	PDC	Intensity	PDC	Intensity	PDC	Intensity	PDC	Intensity	PDC
Module-I	00.73 (01.29)	75.66	02.00 (01.72)	63.43	03.00 (01.97)	76.05	07.00 (02.83)	57.65	03.18 (01.95)	75.36
Module-II	00.13 (01.06)	95.66	00.93 (01.38)	82.99	01.87 (01.69)	85.07	05.53 (02.54)	66.54	02.11 (01.67)	86.04
Module-III	00.00 (00.70)	100	00.27 (01.11)	95.06	00.60 (01.25)	95.21	01.13 (01.41)	93.16	00.50 (01.19)	95.74
Module-IV	00.93 (01.38)	69.00	01.33 (01.50)	75.68	02.53 (01.86)	79.80	04.00 (02.23)	75.80	02.19 (01.74)	82.01
Conventional Schedule	00.80 (01.33)	73.33	02.40 (01.82)	56.12	03.13 (02.02)	75.01	07.40 (02.89)	55.23	03.43 (02.01)	70.89
Control (water sprays)	03.00 (01.99)	-	05.47 (02.54)	-	12.53 (03.67)	-	16.53 (04.18)	-	09.38 (03.10)	-
Mean	00.93 (01.34)		02.06 (01.68)		03.94 (02.08)		06.93 (02.68)			

CD (p≤0.05)

Modules	=	0.17
Phenological Stages	=	0.14
Modules x Phenological Stages	=	0.35

Figures within the parenthesis are square root transformed values

*FD= Fruit Development, PDC= per cent disease control

4.2.5 Comparative efficacy of fruit scab incidence and intensity on selected cultivars

Fruit scab incidence and severity within cultivars showed varied levels among the cultivars (Fig.6 & 8). On overall basis, module-III exhibited lowest fruit scab incidence, intensity and highest PDC among all the cultivars. The comparative and ascending trend among the cultivars revealed that Gala Redlum experienced lowest fruit scab incidence & highest PDC of 01.17 & 95.83 per cent followed by Super Chief Sandidge 02.50 & 93.45 per cent, Red velox 03.16 & 91.92 per cent and Fuji Aztec Zehn 03.83 & 91.59 per cent, respectively. The minimum fruit scab intensity and highest PDC of 00.50 & 95.74 per cent was recorded in case of Gala Redlum followed by Super Chief Sandidge 00.88 & 94.58 per cent, Red Velox 01.13 & 74.17 per cent and Fuji Zehn Aztec 02.51 & 92.43 per cent, respectively.

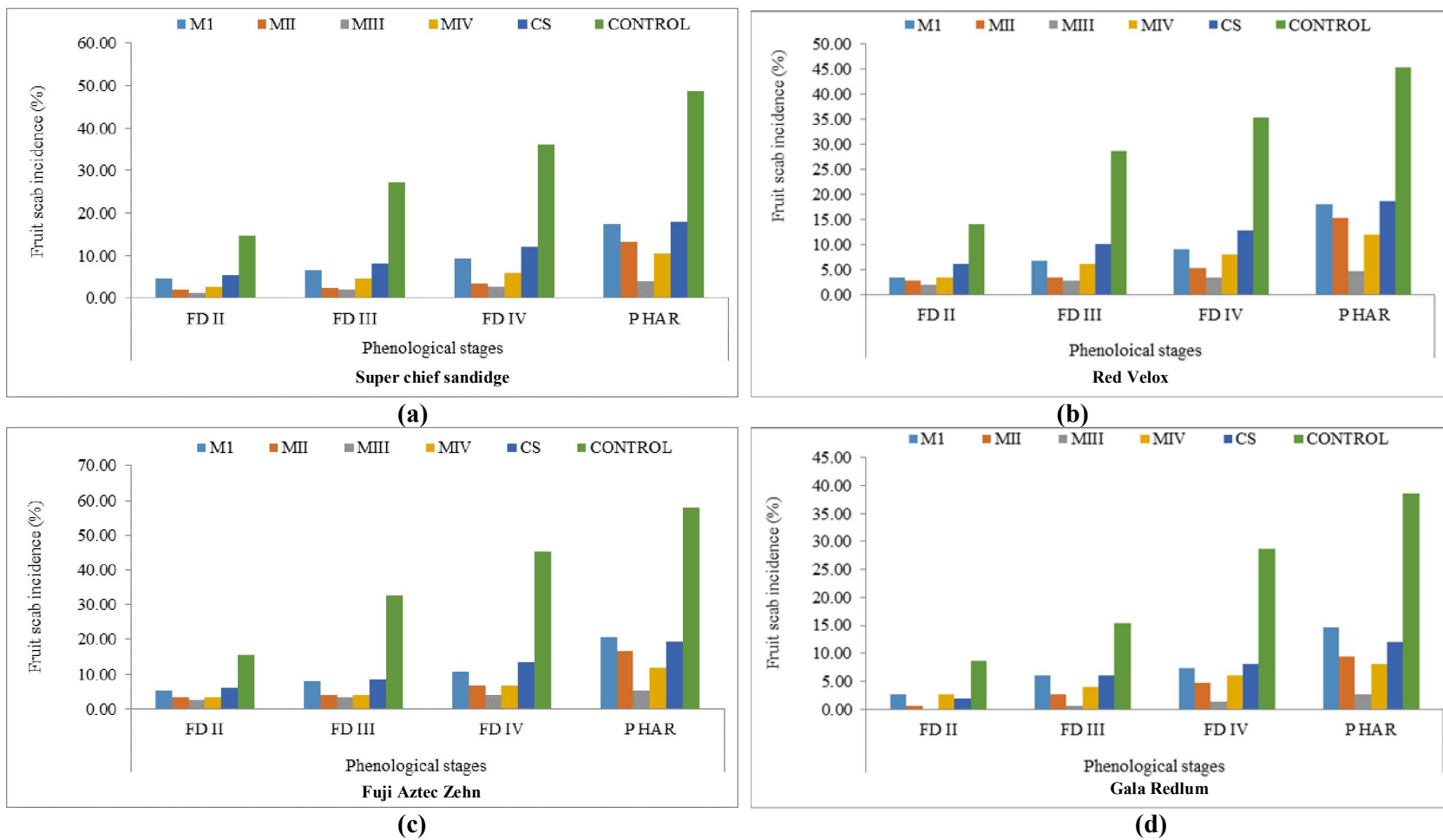


Fig. 5: Evaluation of phenological based modules on fruit scab incidence of apple on selected cultivars

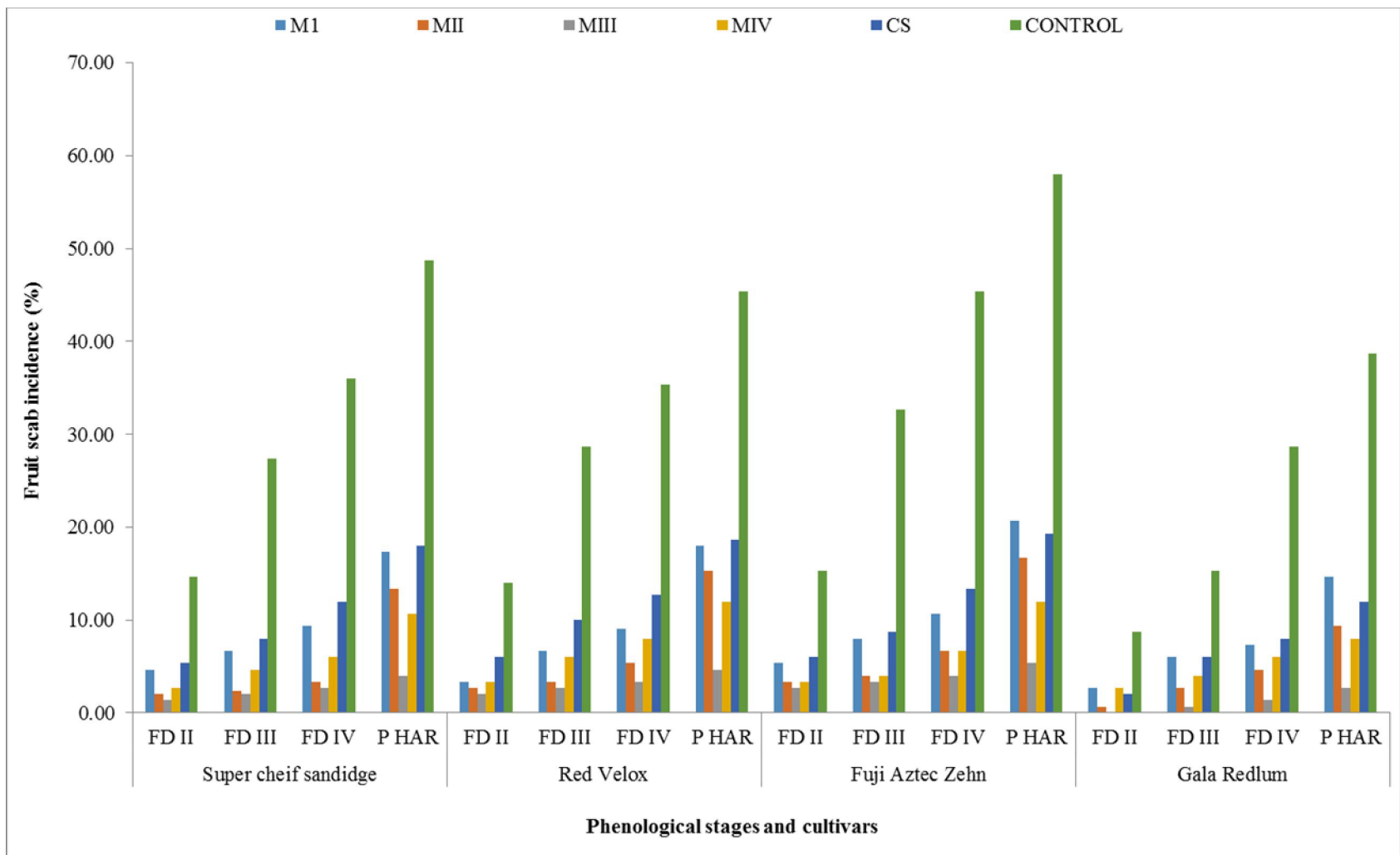


Fig. 6: Comparative efficacy of fungicide spray modules on fruit scab incidence of different cultivars at various phenological stages

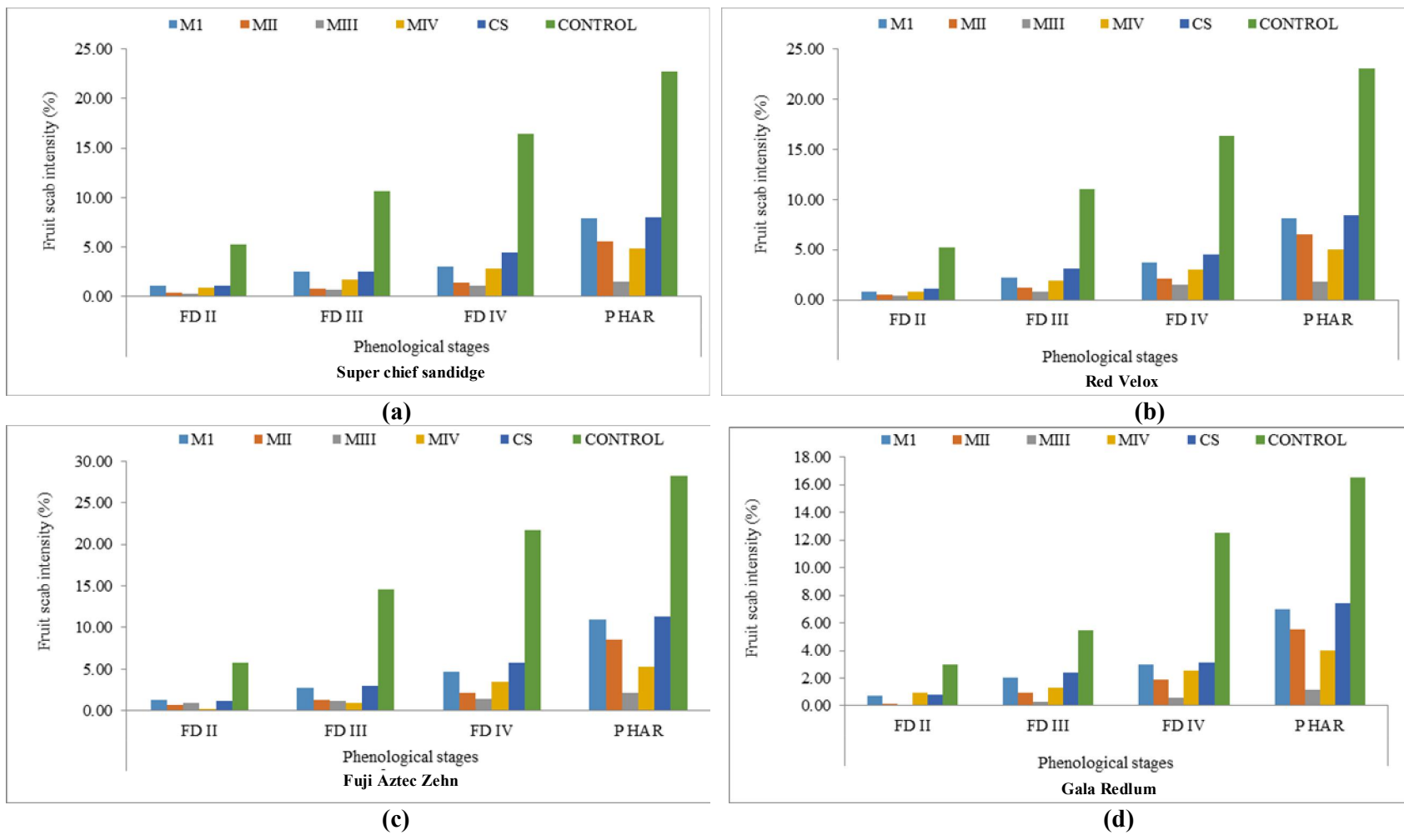


Fig. 7: Evaluation of phenological based fungicide spray modules on fruit scab intensity of apple on selected cultivars

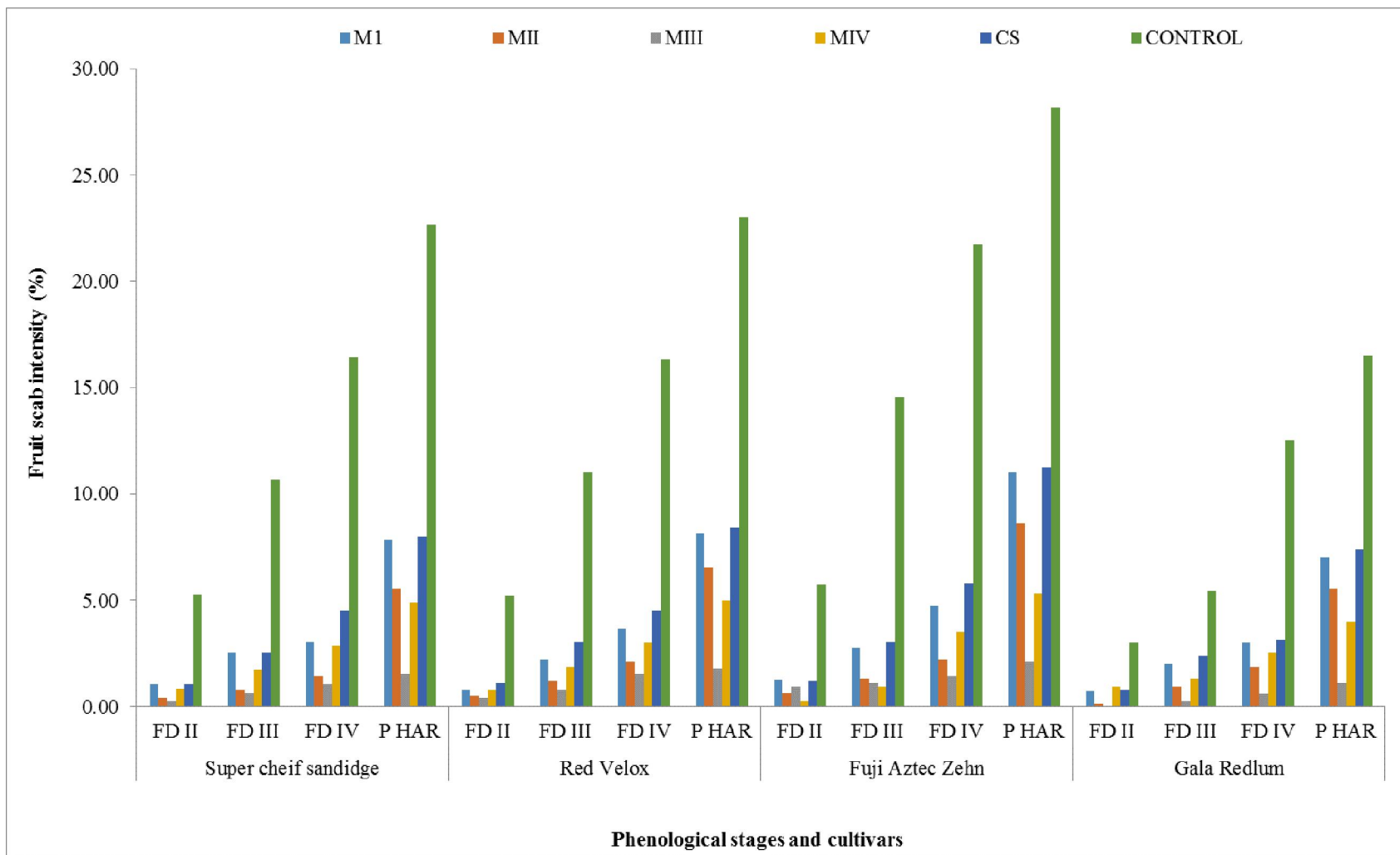


Fig. 8: Comparative efficacy of fungicide spray modules on fruit scab intensity of different cultivars at various phenological stages

4.3 Alternaria leaf blotch incidence and intensity

An overview of the data (Table 17-24) indicates that the disease first appeared on foliage at FD-I stage on all the tested cultivars under HD orchard system. The results pertaining to incidence and intensity of selected cultivars are as under;

4.3.1 Super Chief Sandidge

Analysis of the data (Table 17 & Fig. 9a) indicated significant superiority of the modules over control in controlling Alternaria leaf blotch (ALB). Among the cultivars, module-III was more effective in significantly reducing ALB incidence of 06.13 per cent with PDC of 90.27 per cent, followed by module-II (10.67 & 84.86 %), module-IV (10.80 & 84.10%) and module-I (21.67 & 67.08%), respectively. The control experienced significantly highest ALB incidence of 63.20 per cent followed by conventional schedule with ALB incidence and PDC of (22.53 & 65.44%), respectively.

It was also observed that the phenological stages maintained significance among each other. The significantly least ALB incidence of 10.88 per cent was recorded at FD-I & highest 37.83 per cent was observed at pre-harvest, respectively.

The analyzed data on interactive effect at FD-I stage recorded lowest ALB incidence and highest PDC of 03.33 & 90.30 per cent in module-III followed by module-II (03.67 & 89.30%), module-IV (04.00 & 88.34%), module-I (09.33 & 72.82%) and conventional schedule (10.67 & 68.91%), respectively. However, significantly highest ALB incidence of 34.33 per cent was recorded in control and was significantly different with rest of the modules and conventional schedule evaluated. The module-III was significantly different with conventional module and control. Similarly, at pre-harvest stage highest ALB incidence of 89.67 per cent was recorded in control and the lowest ALB incidence and highest PDC were recorded in module-III (08.67 & 90.33%) followed by module-IV (21.33 & 76.21%), module-II (28.33 & 68.40%), module-I (38.00 & 56.50%) and

Table 17: Evaluation of phenological based modules on Alternaria leaf blotch incidence of apple cv. Super chief sandidge under HD orchard system

Stages	*FD-I		*FD-II		*FD-III		*FD-IV		Pre-harvest		Mean	
Modules	Incidence	PDC	Incidence	PDC	Incidence	PDC	Incidence	PDC	Incidence	PDC	Incidence	PDC
Module-I	09.33 (16.65)	72.82	14.67 (19.95)	68.56	20.67 (24.32)	68.52	24.67 (28.64)	69.03	39.00 (38.62)	56.50	21.67 (25.64)	67.08
Module-II	03.67 (10.75)	89.30	05.33 (12.87)	88.57	07.00 (15.23)	89.34	09.00 (16.34)	88.70	28.33 (32.12)	68.40	10.67 (17.46)	84.86
Module-III	03.33 (10.06)	90.30	04.67 (12.41)	89.99	06.33 (14.43)	90.36	07.67 (15.77)	90.37	08.67 (16.95)	90.33	06.13 (13.92)	90.27
Module-IV	04.00 (11.27)	88.34	06.33 (14.43)	86.43	09.00 (16.35)	86.29	13.33 (21.38)	83.26	21.33 (27.48)	76.21	10.80 (18.18)	84.10
Conventional Schedule	10.67 (16.40)	68.91	15.33 (21.66)	67.15	21.00 (25.57)	68.02	25.67 (29.54)	67.77	40.00 (39.21)	55.39	22.53 (26.48)	65.44
Control (water sprays)	34.33 (35.84)	-	46.67 (43.06)	-	65.67 (54.16)	-	79.67 (63.28)	-	89.67 (71.22)	-	63.20 (53.51)	-
Mean	10.88 (16.83)		15.50 (20.73)		21.61 (25.01)		26.66 (29.16)		37.83 (37.60)			

CD (p≤0.05)

Modules = 1.62

Phenological Stages = 1.48

Modules x Phenological Stages = 3.63

Figures within the parenthesis are arc sine angular transformed values

*FD= Fruit Development, PDC= per cent disease control

conventional schedule (40.00 & 55.39%), respectively. However, module-III was significantly different with module-I, II, IV and conventional schedule.

An appraisal of the data (Table 18 & Fig. 11a) revealed that the modules significantly reduced ALB intensity as compared to check (control). Among the modules, module-III was significantly superior with least intensity & highest PDC (02.68 & 90.86%) followed by module-IV (04.75 & 85.34%), module-II (05.11 & 85.24%) and module-I (09.49 & 69.84%). The control experienced significantly highest ALB intensity of 29.60 per cent followed by conventional schedule having ALB intensity and PDC (10.55 & 65.98%), respectively. The modules, conventional schedule and control were significantly different except module-II and module-IV.

The phenological stages maintained their significance among each other. The least ALB intensity of 04.22 per cent was recorded at FD-I & highest 18.34 per cent was observed at pre-harvest, respectively.

The data pertaining to interactive effect on *Alternaria* leaf blotch (ALB) intensity was recorded at FD-I stage. The lowest ALB intensity and highest PDC of 01.33 & 90.71 per cent was each recorded in module-III and module-II followed by module-IV 01.53 & 89.32 per cent, module-I 03.03 & 78.85 per cent and conventional schedule 03.80 & 73.48 per cent, respectively. Further, module-III was statistically at par with module-II but, was found significantly different from module-I, module IV and conventional schedule. The significantly highest ALB intensity of 14.33 per cent was recorded in control and was significantly different with rest of the modules and conventional schedule. Similarly, at pre-harvest stage the highest ALB intensity of 44.67 per cent was recorded in control. While as, the least ALB intensity and highest PDC was recorded in module-III 03.73 & 91.64 per cent followed by module-IV having 09.73 & 78.21 per cent, module-II 15.13 & 66.12 per cent, module-I 18.20 & 59.25 per cent and conventional schedule 18.60 & 58.36 per cent, respectively. However, module-III was significantly different with module-I, II, IV and conventional schedule.

Table 18: Evaluation of phenological based modules on Alternaria leaf blotch intensity of apple cv. Super Chief Sandidge under HD orchard system

Stages	*FD-I		*FD-II		*FD-III		*FD-IV		Pre-harvest		Mean	
Modules	Intensity	PDC	Intensity	PDC	Intensity	PDC	Intensity	PDC	Intensity	PDC	Intensity	PDC
Module-I	03.03 (08.87)	78.85	06.40 (13.16)	71.33	09.35 (16.55)	67.38	10.49 (19.46)	72.39	18.20 (25.23)	59.25	09.49 (16.65)	69.84
Module-II	01.33 (06.51)	90.71	02.20 (08.50)	90.14	03.13 (10.14)	89.08	03.73 (11.08)	90.18	15.13 (22.82)	66.12	05.11 (11.81)	85.24
Module-III	01.33 (06.31)	90.71	02.00 (08.04)	91.04	02.80 (09.54)	90.23	03.53 (10.65)	90.71	03.73 (11.04)	91.64	02.68 (09.12)	90.86
Module-IV	01.53 (06.94)	89.32	02.60 (09.07)	88.35	03.73 (11.06)	86.98	06.13 (14.32)	83.86	09.73 (18.16)	78.21	04.75 (11.91)	85.34
Conventional Schedule	03.80 (11.17)	73.48	07.27 (15.63)	67.44	10.07 (18.49)	64.87	13.00 (21.11)	65.78	18.60 (25.51)	58.36	10.55 (18.38)	65.98
Control (water sprays)	14.33 (22.21)	-	22.33 (28.17)	-	28.67 (32.35)	-	38.00 (38.01)	-	44.67 (41.92)	-	29.60 (32.53)	-
Mean	04.22 (10.33)		07.13 (13.76)		09.62 (16.36)		12.48 (19.11)		18.34 (24.11)			

CD (p≤0.05)

- Modules = 1.10
- Phenological Stages = 1.00
- Modules x Phenological Stages = 2.46

Figures within the parenthesis are arc sine angular transformed values

*FD= Fruit Development, PDC= per cent disease control

4.3.2 Red Velox

Analysis of the data (Table 19 & Fig. 9b) regarding the ALB incidence revealed that the modules were significantly superior in controlling the ALB incidence as compared to control. Among the modules, module-III was significantly superior with lowest ALB incidence of 05.67 per cent with PDC of 90.63 per cent followed by module-II (09.60 & 85.75%), module-IV (10.40 & 84.15%) and module-I (19.00 & 69.50%), respectively. The control experienced significantly highest ALB incidence of 60.93 per cent followed by conventional schedule having ALB incidence & PDC (21.60 & 65.01%), respectively. Module-II and module-IV were statistically at par with each other and rest of all differs significantly.

There was significant difference among phenological stages as evident from the overall mean. Irrespective of the number of sprays, an increasing trend in the disease incidence was observed across phenological stages. The significantly least ALB incidence of 10.05 per cent was recorded at FD-I & highest 34.89 per cent was observed at pre-harvest, respectively.

The interactive effect of modules and phenological stages against ALB at FD-I stage revealed that the lowest ALB incidence of 03.00 per cent was recorded in module-III which gave PDC of 90.52 per cent and was statistically at par with module-II & IV having ALB incidence and PDC of 03.33 & 89.48 per cent and 03.67 & 88.41 per cent, respectively. The significantly highest ALB incidence of 31.67 per cent was recorded in control. At pre-harvest stage, module-III registered lowest ALB incidence and highest PDC of 08.00 & 90.80 per cent followed by module-IV (20.67 & 76.24%), module-II (25.00 & 71.26%), module-I (30.67 & 64.74%) and conventional schedule (38.00 & 56.32%), respectively. However, control recorded 87.00 per cent ALB incidence and was significantly different with rest of the modules and conventional schedule.

Table 19: Evaluation of phenological based modules on Alternaria leaf blotch incidence of apple cv. Red Velox under HD orchard

Stages	*FD-I		*FD-II		*FD-III		*FD-IV		Pre-harvest		Mean	
Modules	Incidence	PDC	Incidence	PDC	Incidence	PDC	Incidence	PDC	Incidence	PDC	Incidence	PDC
Module-I	08.33 (16.65)	73.69	14.00 (21.95)	67.94	18.33 (25.34)	71.65	23.67 (29.09)	69.52	30.67 (33.60)	64.74	19.00 (25.35)	69.50
Module-II	03.33 (10.49)	89.48	05.00 (12.87)	88.55	06.33 (14.50)	90.21	08.33 (16.72)	89.27	25.00 (29.97)	71.26	09.60 (16.91)	85.75
Module-III	03.00 (09.97)	90.52	04.33 (11.73)	90.08	05.67 (13.68)	91.23	07.33 (15.59)	90.56	08.00 (16.34)	90.80	05.67 (13.46)	90.63
Module-IV	03.67 (10.85)	88.41	06.00 (14.14)	86.26	08.67 (17.09)	86.59	13.00 (21.08)	83.26	20.67 (27.00)	76.24	10.40 (18.03)	84.15
Conventional Schedule	10.33 (18.73)	67.38	14.67 (22.49)	66.40	20.67 (27.00)	68.03	24.33 (29.54)	66.94	38.00 (38.03)	56.32	21.60 (27.16)	65.01
Control (water sprays)	31.67 (34.22)	-	43.67 (41.34)	-	64.67 (53.51)	-	77.67 (61.79)	-	87.00 (68.96)	-	60.93 (51.97)	-
Mean	10.05 (16.84)	-	14.61 (20.75)	-	20.72 (25.18)	-	25.72 (28.97)	-	34.89 (35.65)	-	-	-

CD (p≤0.05)

Modules	=	1.18
Phenological Stages	=	1.08
Modules x Phenological Stages	=	2.64

Figures within the parenthesis are arc sine angular transformed values

*FD= Fruit Development, PDC= per cent disease control

The data presented in Table 20 and Fig. 11b depicted that the modules were more effective in controlling the ALB intensity as compared to check (control). Among the modules, module-III was significantly superior with lowest ALB intensity & highest PDC (02.51 & 91.24%) followed by module IV (04.59 & 85.42%), module-II (04.63 & 86.02%) and module-I (08.53 & 71.50%), respectively. The control experienced significantly highest ALB intensity of 28.65 per cent followed by conventional schedule 10.83 per cent with PDC of 71.47 per cent, respectively. Statistically all the modules, conventional schedule and control differ significantly except module-II & module-IV.

It was also observed that the phenological stages maintained their significance among each other. Irrespective of the number of sprays, an increasing trend in the ALB intensity was observed across phenological stages. The least ALB intensity of 04.03 per cent was recorded at FD-I & highest 17.01 per cent was observed at pre-harvest, respectively.

The interactive effect of modules and phenological stages against ALB at FD-I stage depicts that the least ALB intensity of 01.20 per cent was recorded in module-III with highest PDC of 91.38 per cent and was statistically at par with module-II & IV, having ALB intensity and PDC of (01.27 & 90.88%) and (01.40 & 89.94%), respectively. However, the significantly highest ALB intensity of 13.93 per cent was recorded in control. Similarly, at pre-harvest stage, the lowest ALB intensity and highest PDC of 03.60 & 91.74 per cent was recorded in module-III followed by module-IV having 09.40 & 78.44 per cent, module-II 13.07 & 70.02 per cent, module-I 14.27 & 67.27 per cent and conventional schedule 18.13 & 58.41 per cent, respectively. The significantly highest ALB intensity of 43.60 per cent was observed in control and differs significantly with rest of the modules and conventional module.

Table 20: Evaluation of phenological based modules on Alternaria leaf blotch intensity of apple cv. Red Velox under HD orchard system

Stages	*FD-I		*FD-II		*FD-III		*FD-IV		Pre-harvest		Mean	
Modules	Intensity	PDC	Intensity	PDC	Intensity	PDC	Intensity	PDC	Intensity	PDC	Intensity	PDC
Module-I	02.80 (09.62)	79.89	06.27 (14.48)	70.24	08.60 (17.04)	69.71	10.73 (19.10)	70.41	14.27 (22.17)	67.27	08.53 (16.48)	71.50
Module-II	01.27 (06.39)	90.88	02.13 (08.38)	89.89	03.00 (09.46)	89.43	03.67 (11.01)	89.88	13.07 (21.17)	70.02	04.63 (11.38)	86.02
Module-III	01.20 (06.27)	91.38	01.80 (07.41)	91.45	02.60 (09.20)	90.84	03.33 (10.48)	90.81	03.60 (10.89)	91.74	02.51 (08.85)	91.24
Module-IV	01.40 (06.44)	89.94	02.53 (09.11)	87.99	03.60 (10.89)	87.32	06.00 (14.12)	83.45	09.40 (17.83)	78.44	04.59 (11.68)	85.42
Conventional Schedule	03.60 (10.92)	74.15	07.07 (15.40)	66.44	10.00 (18.40)	64.78	12.40 (20.60)	65.81	18.13 (25.19)	58.41	10.24 (18.10)	65.91
Control (water sprays)	13.93 (21.90)	-	21.07 (27.30)	-	28.40 (32.18)	-	36.27 (37.00)	-	43.60 (41.30)	-	28.65 (31.94)	-
Mean	04.03 (10.26)		06.81 (13.68)		09.36 (16.28)		12.06 (18.72)		17.01 (23.09)			

CD (p≤0.05)
 Modules = 0.77
 Phenological Stages = 0.70
 Modules x Phenological Stages = 1.72

Figures within the parenthesis are arc sine angular transformed values
 *FD= Fruit Development, PDC= per cent disease control

4.3.3 Fuji Aztec Zehn

Analysis of the data (Table 21 & Fig. 9c) reflected the superiority of the modules in reducing ALB as compared to check (control). Among the modules, module-III was significantly superior to rest of the modules with lowest ALB incidence of 05.07 per cent with PDC of 90.70 per cent followed by module-II (08.60 & 86.04%), module-IV (08.87 & 84.87%) and module-I(18.00 & 67.40%), respectively. The control experienced significantly highest ALB incidence of 54.07 per cent followed by conventional schedule having ALB incidence & PDC (19.47 & 64.95%), respectively. Statistically module-I, II and IV were at par with each other and differ with rest of the treatments.

Significant difference was observed among phenological stages as evident from their overall mean. The significantly least ALB incidence of 08.55 per cent was recorded at FD-I & highest 32.44 per cent was observed at pre-harvest, respectively.

The interactive effect of modules and phenological stages against ALB at FD-I stage depicts that the lowest ALB incidence and highest PDC of 02.00 & 92.68 per cent were recorded in module-III followed by module-II having 02.67 & 90.23 per cent, module-IV 03.00 & 89.02 per cent, module-I 08.33 & 69.52 per cent and conventional based spray schedule 08.00 & 70.72 per cent respectively. However, the highest ALB incidence of 27.33 per cent was recorded in control which was significantly different with rest of the modules and conventional schedule. Similarly, at pre-harvest stage highest ALB incidence of 83.33 per cent was recorded in control. However, the least ALB incidence and highest PDC was recorded in module-III 07.33 & 91.20 per cent followed by module-IV having 17.33 & 79.20 per cent, respectively. The modules, conventional schedule and control were statistically different with no significant difference between module-I and conventional schedule.

Table 21: Evaluation of phenological based modules on Alternaria leaf blotch incidence of apple cv. Fuji Aztec Zehn under HD orchard system

Stages	*FD-I		*FD-II		*FD-III		*FD-IV		Pre-harvest		Mean	
Modules	Incidence	PDC	Incidence	PDC	Incidence	PDC	Incidence	PDC	Incidence	PDC	Incidence	PDC
Module-I	08.33 (17.77)	69.52	11.67 (22.49)	69.28	17.00 (27.01)	67.09	23.00 (28.63)	67.14	30.00 (33.16)	63.99	18.00 (25.81)	67.40
Module-II	02.67 (09.26)	90.23	04.00 (11.53)	89.47	05.67 (13.68)	89.02	07.33 (15.65)	89.52	23.33 (28.86)	72.00	08.60 (15.79)	86.04
Module-III	02.00 (06.55)	92.68	04.00 (11.47)	89.47	05.33 (13.26)	89.68	06.67 (14.89)	90.47	07.33 (15.65)	91.20	05.07 (12.36)	90.70
Module-IV	03.00 (08.04)	89.02	05.00 (12.87)	86.84	07.00 (15.31)	86.45	12.00 (20.21)	82.85	17.33 (24.58)	79.20	08.87 (16.20)	84.87
Conventional Schedule	08.00 (16.40)	70.72	13.67 (21.66)	64.02	18.67 (25.57)	63.86	23.67 (29.08)	66.18	33.33 (35.23)	60.00	19.47 (25.59)	64.95
Control (water sprays)	27.33 (31.50)	-	38.00 (38.03)	-	51.67 (45.93)	-	70.00 (56.81)	-	83.33 (66.00)	-	54.07 (47.66)	
Mean	08.55 (14.92)		12.70 (19.67)		17.55 (23.46)		23.77 (27.55)		32.44 (33.91)			

CD (p≤0.05)

Modules = 1.76

Phenological Stages = 1.61

Modules x Phenological Stages = 3.95

Figures within the parenthesis are arc sine angular transformed values

*FD= Fruit Development, PDC= per cent disease control

An appraisal from the data (Table 22 & Fig. 11c) regarding the ALB intensity revealed that the modules were significantly superior in controlling the ALB as compared to control. Among the modules, module-III was significantly superior to other modules, conventional schedule and control in reducing ALB intensity & PDC of (02.29 & 91.14%) followed by module-IV (04.23 & 84.85%), module-II (04.38 & 85.06%) and module-I (08.22 & 69.13%), respectively. The control experienced significantly highest ALB intensity of 25.29 per cent followed by conventional schedule with ALB intensity and PDC (09.49 & 63.72%), respectively.

It was also observed that the phenological stages maintained their significance among each other. Irrespective of the number of sprays, an increasing trend in the ALB intensity was observed across phenological stages. The lowest ALB intensity of 03.61 per cent was recorded at FD-I & highest 15.63 per cent was observed at pre-harvest, respectively.

The interactive effect of modules and phenological stages against ALB at FD-I stage depicts that the lowest ALB intensity and highest PDC of 00.80 & 93.58 per cent was recorded at FD-I stage in module-III followed by module-II and module-IV each recorded (01.20 & 90.37%), module-I (02.73 & 78.10%) and conventional schedule (03.27 & 73.77%), respectively. The significantly highest ALB intensity of 12.47 per cent was recorded in control and was significantly different with rest of the modules and conventional schedule. The module-II was statistically at par with module-IV but was found significantly different from module-I, module III and conventional module. Similarly, at pre-harvest stage significantly highest ALB intensity of 39.87 per cent was recorded in control which was devoid of any fungicidal spray. The least ALB intensity and highest PDC of (03.40 & 91.47 %) was recorded in module-III followed by module-IV (08.60 & 78.42%), module-II (12.33 & 69.07%), module-I (13.87 & 65.21%) and conventional schedule (15.73 & 60.54%), respectively. The module-III was significantly different from module-I, II, IV and conventional schedule.

Table 22: Evaluation of phenological based modules on Alternaria leaf blotch intensity of apple cv. Fuji Aztec Zehn under HD orchard system

Stages	*FD-I		*FD-II		*FD-III		*FD-IV		Pre-harvest		Mean	
Modules	Intensity	PDC	Intensity	PDC	Intensity	PDC	Intensity	PDC	Intensity	PDC	Intensity	PDC
Module-I	02.73 (09.48)	78.10	05.20 (14.61)	71.84	08.17 (17.77)	64.78	11.13 (18.91)	65.72	13.87 (21.81)	65.21	08.22 (16.52)	69.13
Module-II	01.20 (06.19)	90.37	02.07 (08.24)	88.79	02.83 (09.61)	87.80	03.47 (10.66)	89.31	12.33 (20.54)	69.07	04.38 (11.05)	85.06
Module-III	00.80 (04.13)	93.58	01.67 (07.32)	90.95	02.47 (08.95)	89.35	03.13 (10.14)	90.36	03.40 (10.58)	91.47	02.29 (08.22)	91.14
Module-IV	01.20 (05.06)	90.37	02.33 (08.74)	87.38	03.40 (10.59)	85.34	05.60 (13.62)	82.75	08.60 (17.02)	78.42	04.23 (11.01)	84.85
Conventional Schedule	03.27 (10.38)	73.77	06.87 (15.17)	62.80	09.73 (18.14)	58.06	11.87 (20.12)	63.44	15.73 (23.27)	60.54	09.49 (17.41)	63.72
Control (water sprays)	12.47 (20.66)	-	18.47 (25.43)	-	23.20 (28.77)	-	32.47 (34.71)	-	39.87 (39.13)	-	25.29 (29.74)	-
Mean	03.61 (09.32)		06.10 (13.25)		08.30 (15.64)		11.27 (18.03)		15.63 (22.06)			

CD (p≤0.05)

Modules = 1.17

Phenological Stages = 1.07

Modules x Phenological Stages = 2.62

Figures within the parenthesis are arc sine angular transformed values

*FD= Fruit Development, PDC= per cent disease control

4.3.4 Gala Redlum

The perusal of the data (Table 23 & Fig. 9d) reflected that the modules were significantly superior in controlling the ALB as compared to check (control). Among the modules, module-III was significantly superior in reducing ALB incidence of 02.00 per cent with PDC of 96.16 per cent followed by module-II (05.00 & 91.78%), module-IV (05.33 & 89.89%) and module-I (12.67 & 75.20%), respectively. The control experienced significantly highest ALB incidence of 47.13 per cent followed by conventional schedule having ALB incidence & PDC (14.73 & 70.26%), respectively. All the modules differ significantly with each other having no statistical difference between module-II & module-IV.

The overall mean of the phenological stages indicated significant difference among each other. An increasing trend in the ALB incidence was observed across phenological stages, irrespective of the number of sprays. The least ALB incidence of 05.22 per cent was recorded at FD-II & highest 26.38 per cent was observed at pre-harvest, respectively.

The interactive effect of modules and phenological stages against ALB at FD-I stage depicts that the significantly lowest ALB incidence 00.33 per cent with PDC of 98.40 per cent was observed in module-III which was statistically identical with module-II (00.67 & 96.75%) and module-IV (01.33 & 93.56%), respectively. The control recorded significantly highest ALB incidence of 20.67 per cent which differ significantly with rest of the modules and conventional schedule. Similarly, at pre-harvest stage, the trend in reducing the disease again dominated by module-III with significantly lowest ALB incidence and highest PDC of 03.33 & 95.65 per cent followed by module-IV having 11.33 & 85.22 per cent, module-II 16.67 & 78.25 per cent and module-I 24.00 & 68.69 per cent and conventional schedule 26.33 & 65.65 per cent, respectively. The significantly highest ALB incidence of 76.67 per cent was recorded in control which differs significantly with rest of the modules as well as conventional schedule.

Table 23: Evaluation of phenological based modules on Alternaria leaf blotch incidence of apple cv. Gala Redlum under HD orchard system

Stages	*FD-I		*FD-II		*FD-III		*FD-IV		Pre-harvest		Mean	
	Incidence	PDC	Incidence	PDC	Incidence	PDC	Incidence	PDC	Incidence	PDC	Incidence	PDC
Module-I	03.33 (10.49)	83.88	07.33 (15.69)	77.09	11.67 (19.96)	74.06	17.00 (24.33)	72.28	24.00 (29.31)	68.69	12.67 (19.96)	75.20
Module-II	00.67 (03.82)	96.75	01.33 (05.23)	95.84	02.67 (09.08)	94.06	03.67 (10.85)	94.01	16.67 (24.04)	78.25	05.00 (10.60)	91.78
Module-III	00.33 (01.91)	98.40	01.00 (04.62)	96.87	02.33 (08.46)	94.82	03.00 (09.87)	95.10	03.33 (10.33)	95.65	02.00 (07.04)	96.16
Module-IV	01.33 (05.23)	93.56	02.33 (07.16)	92.71	05.00 (12.87)	88.88	06.67 (14.84)	89.12	11.33 (19.63)	85.22	05.33 (11.95)	89.89
Conventional Schedule	05.00 (12.87)	75.81	09.35 (17.74)	70.78	13.67 (21.67)	69.62	19.33 (26.07)	69.48	26.33 (30.83)	65.65	14.73 (21.84)	70.26
Control (water sprays)	20.67 (27.00)	-	32.00 (34.42)	-	45.00 (42.11)	-	61.33 (51.54)	-	76.67 (61.10)	-	47.13 (43.23)	
Mean	05.22 (10.22)		08.89 (14.14)		13.39 (19.02)		18.50 (22.92)		26.38 (29.21)			

CD (p≤0.05)

Modules	=	1.19
Phenological Stages	=	1.74
Modules x Phenological Stages	=	4.28

Figures within the parenthesis are arc sine angular transformed values

*FD= Fruit Development, PDC= per cent disease control

An overview of the data (Table 24 & Fig.11d) indicated that the modules were effectively reduced ALB as compared to control. Among the modules, module-III proved significantly superior in reducing ALB intensity & PDC (00.84 & 96.61%) followed by module-IV with intensity and PDC of (02.25 & 90.80%), module-II (02.35 & 91.45%) and module-I (05.81 & 75.29%), respectively. The control experienced significantly highest ALB intensity of 21.31 per cent followed by conventional schedule having ALB intensity and PDC (06.76 & 70.17%), respectively. Module-II and module-IV were identical to each other statistically.

An increasing trend in the ALB intensity was observed across phenological stages, irrespective of the number of sprays. The least ALB intensity of 02.31 per cent was recorded at FD-I & highest 11.67 per cent was observed at pre-harvest, respectively.

The interactive effect of modules and phenological stages against ALB at FD-I stage depicts that the lowest ALB intensity of 00.13 per cent was recorded in module-III with PDC of 98.66 per cent and was statistically at par with module-II recorded (00.20 & 97.94%), respectively. Significantly highest ALB intensity of 09.73 per cent was recorded in control. Similarly, at pre-harvest stage, the significantly lowest ALB intensity and highest PDC of 01.60 & 95.17 per cent was recorded in module-III followed by module-IV having (04.93 & 85.1%), module II (07.73 & 76.66%), module-I (10.87 & 67.18%) and conventional schedule (11.80 & 64.38%), respectively. Significantly highest ALB intensity of 33.13 per cent was observed in control in which no fungicidal spray was done.

Table 24: Evaluation of phenological based modules on Alternaria leaf blotch intensity of apple cv. Gala Redlum under HD orchard system

Stages	*FD-I		*FD-II		*FD-III		*FD-IV		Pre-harvest		Mean	
Modules	Intensity	PDC	Intensity	PDC	Intensity	PDC	Intensity	PDC	Intensity	PDC	Intensity	PDC
Module-I	01.40 (06.76)	85.61	03.00 (09.94)	79.82	05.53 (13.59)	73.24	08.27 (16.69)	70.60	10.87 (19.23)	67.18	05.81 (13.24)	75.29
Module-II	00.20 (02.06)	97.94	00.60 (03.47)	95.96	01.47 (06.59)	92.88	01.73 (07.45)	93.84	07.73 (16.11)	76.66	02.35 (07.14)	91.45
Module-III	00.13 (01.20)	98.66	00.27 (02.41)	98.18	00.87 (05.21)	95.79	01.33 (06.54)	95.27	01.60 (07.14)	95.17	00.84 (04.50)	96.61
Module-IV	00.47 (03.12)	95.16	00.93 (04.52)	93.74	01.93 (07.85)	90.66	03.00 (09.87)	89.33	04.93 (12.80)	85.11	02.25 (07.63)	90.80
Conventional Schedule	01.93 (07.90)	80.16	04.40 (12.07)	70.41	06.53 (14.78)	68.40	09.13 (17.57)	67.54	11.80 (20.02)	64.38	06.76 (14.47)	70.17
Control (water sprays)	09.73 (18.15)	-	14.87 (22.66)	-	20.67 (27.02)	-	28.13 (32.00)	-	33.13 (35.12)	-	21.31 (26.99)	-
Mean	02.31 (06.53)		04.01 (09.18)		06.16 (12.51)		08.59 (15.02)		11.67 (18.40)			

CD (p≤0.05)

Modules = 1.26

Phenological Stages = 1.15

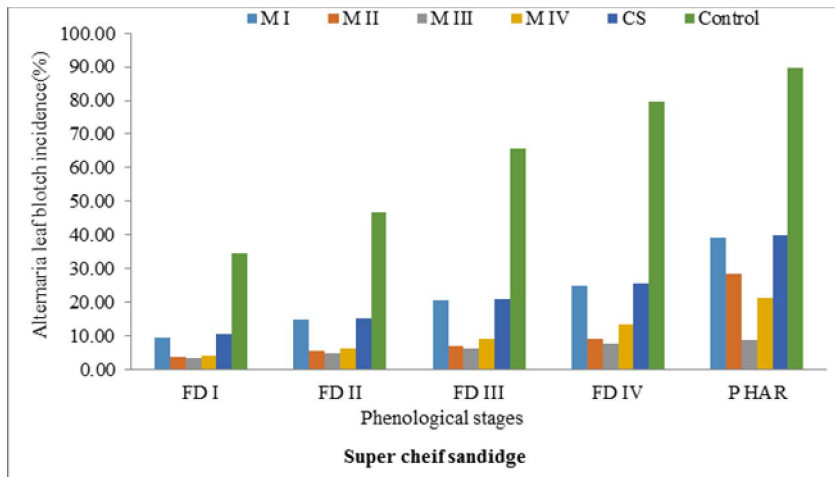
Modules x Phenological Stages = 2.82

Figures within the parenthesis are arc sine angular transformed values

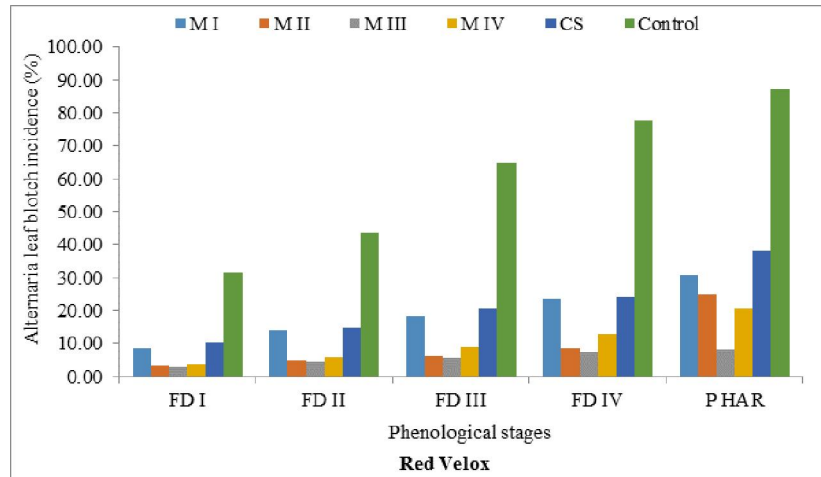
*FD= Fruit Development, PDC= per cent disease control

4.3.5 Comparative efficacy of Alternaria leaf blotch incidence on selected cultivars

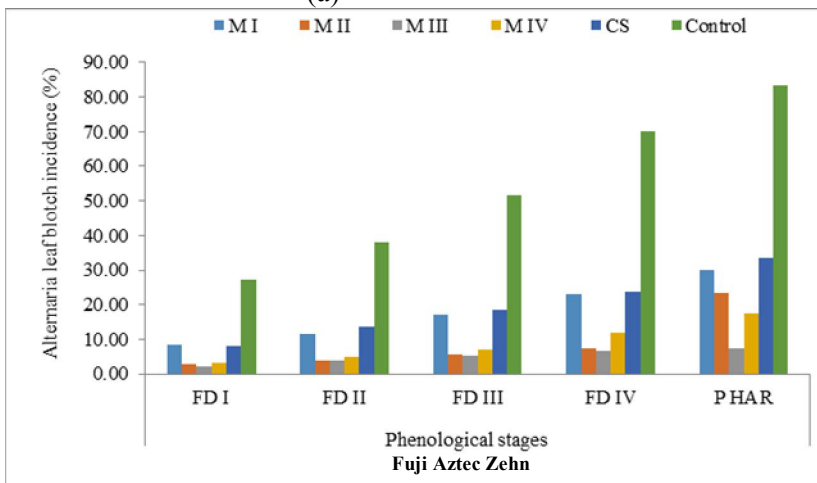
Varied levels of ALB incidence and intensity were evident among cultivars and modules (Fig.10 & 12). On overall basis, module-III exhibited lowest ALB incidence and intensity and highest PDC in all the selected cultivars. Among the cultivars, ALB incidence in ascending trend revealed that Gala Redlum recorded least ALB incidence and highest PDC (02.00 & 96.16 %) followed by Fuji Zehn Aztec (05.07 & 90.70%), Red Velox (05.67 & 90.63%) and Super Chief Sandidge (06.13 & 90.27%), respectively. The lowest ALB intensity and highest PDC (00.84 & 96.61%) was recorded in case of Gala Redlum followed by Fuji Zehn Aztec (02.29 & 91.14 %), Red Velox (02.51 & 91.24%) and Super Chief Sandidge (02.68 & 90.86 %), respectively.



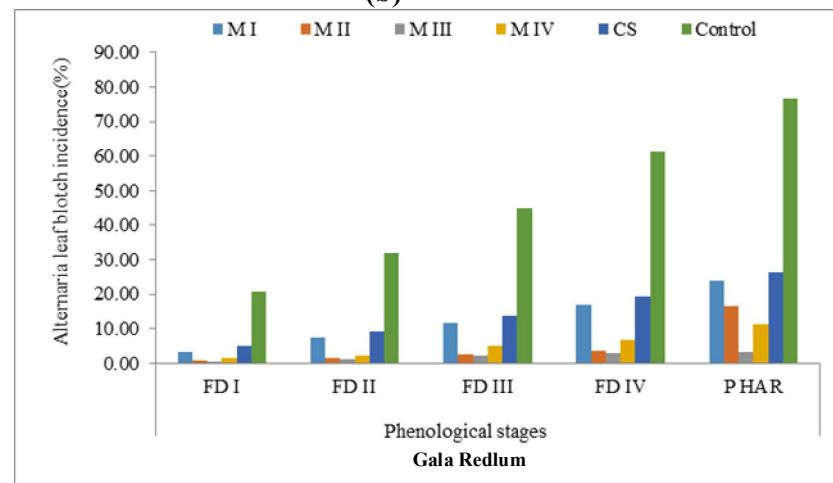
(a)



(b)



(c)



(d)

Fig. 9: Evaluation of phenological based fungicide spray modules on Alternaria leaf blotch incidence of apple on selected cultivars

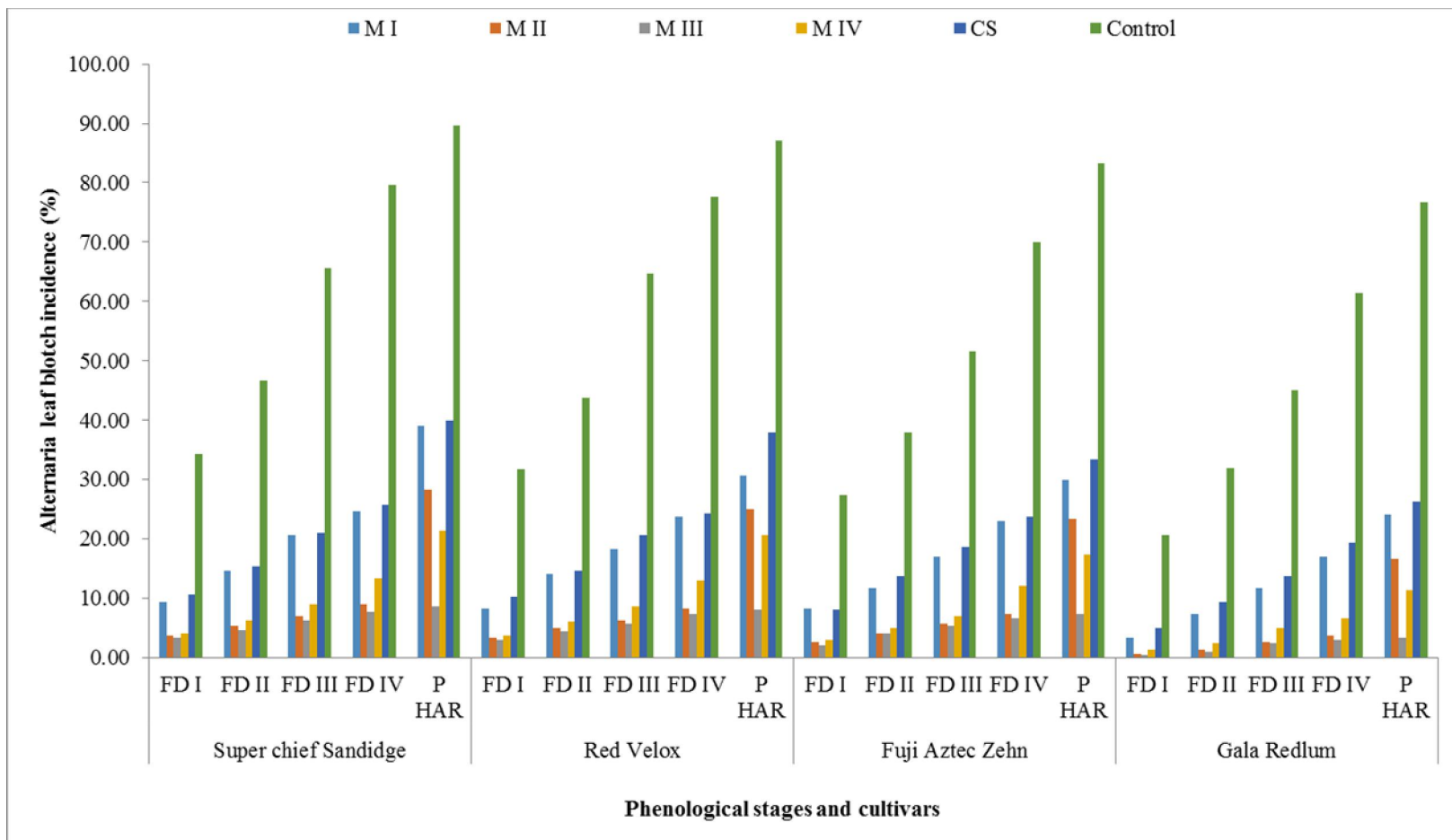
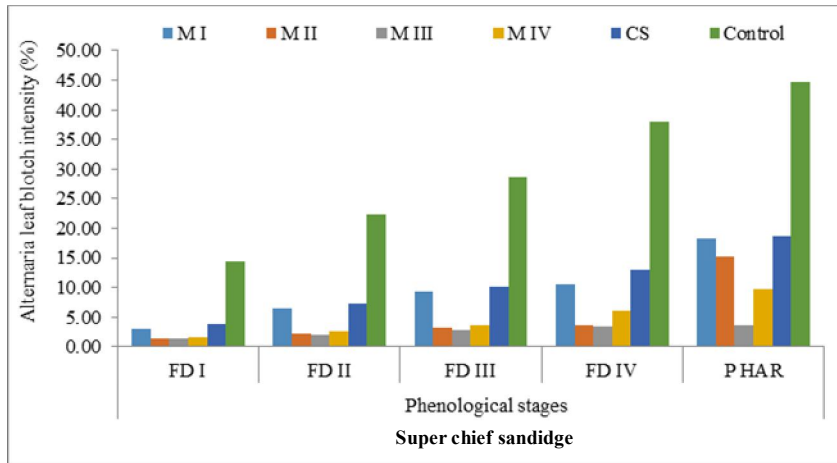
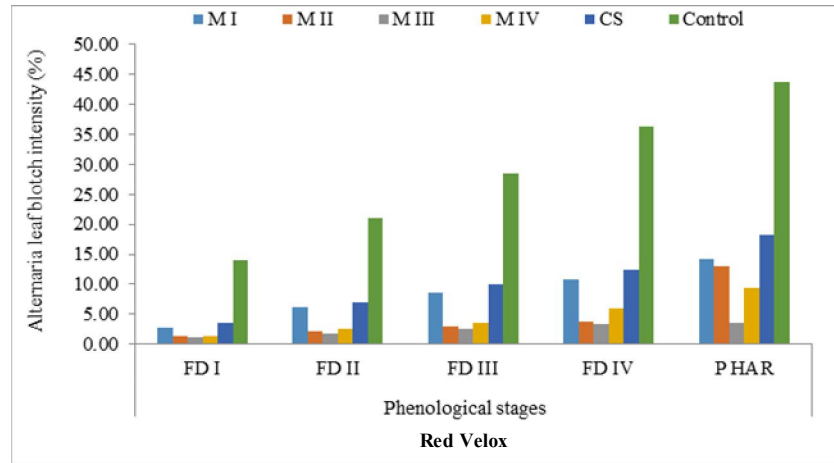


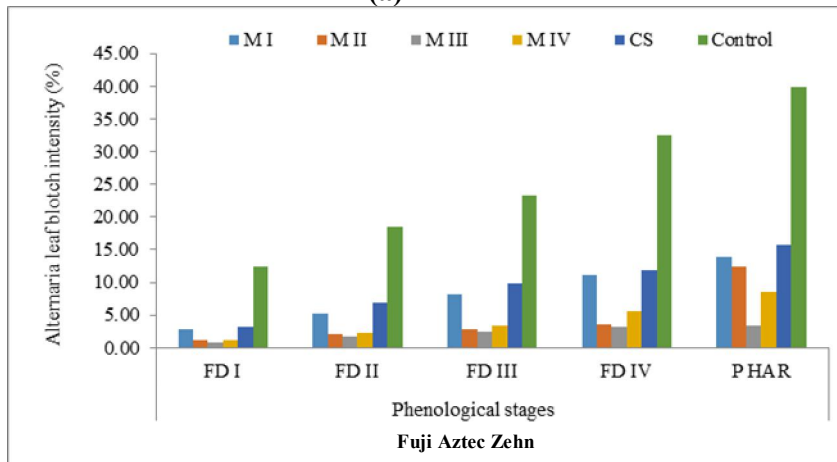
Fig. 10: Comparative efficacy of fungicide spray modules on Alternaria leaf blotch incidence of different cultivars at various phenological stages



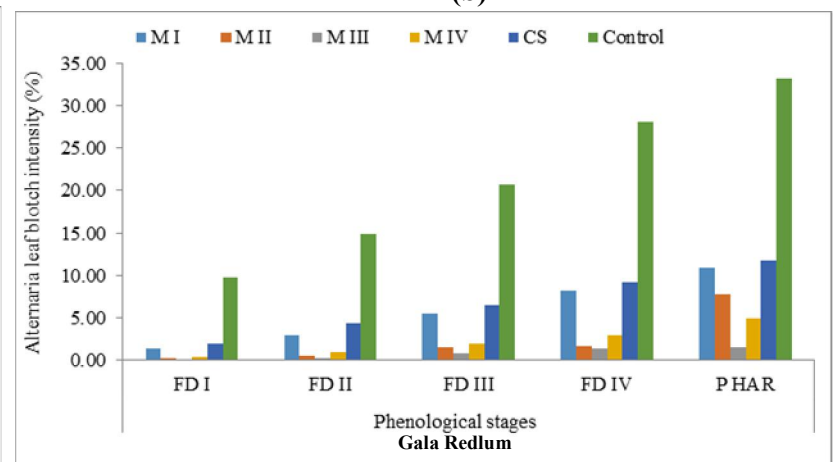
(a)



(b)



(c)



(d)

Fig.11:Evaluation of phenological based modules on Alternaria leaf blotch intensity of apple on selected cultivars

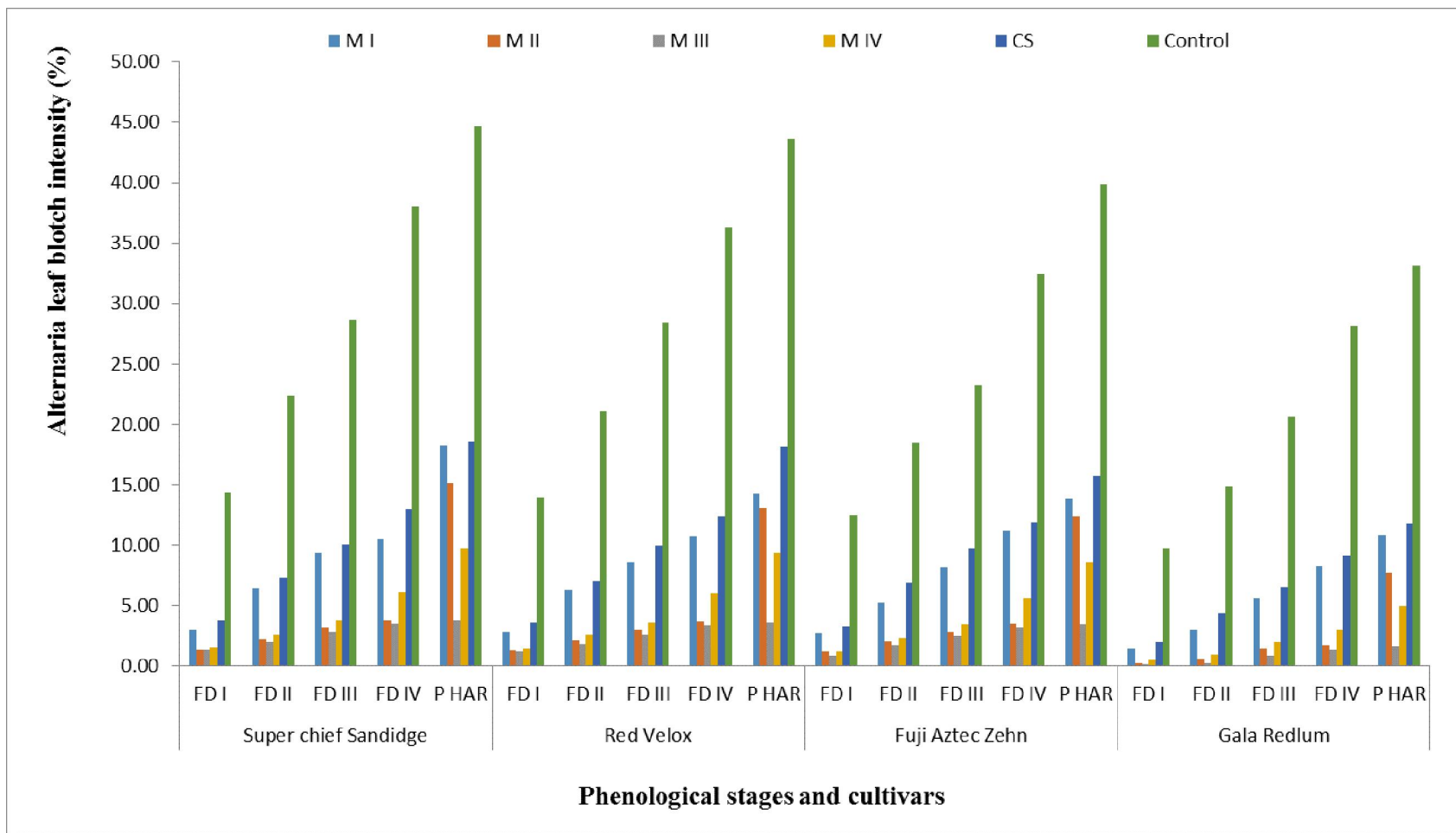


Fig. 12: Comparative efficacy of fungicide spray modules on Alternaria leaf blotch intensity of different cultivars at various phenological stages

4.4 Phytotoxic effects

The observations pertaining to the phytotoxic effects of fungicides were recorded by adopting visual assessment scale (0-10 scale). The phytotoxic effects in the form of leaf necrosis, leaf tip injury, wilting, vein clearing, russetting, epinasty and hyponasty were recorded. The tested fungicides were applied on Super Chief Sandidge, Fuji Aztec Zehn, Gala Redlum, Jona Gold, Granny Smith, Jeromine and Red Velox at FD-I stage on 27.05.19. Subsequently, phytotoxic effects were recorded at 1st, 3rd, 5th, 7th and 10th days after application (DAA) of fungicide. However, the phytotoxicity in the form of leaf brittleness and curling was recorded as present (+) or absent (-).

During the course of phytotoxicity study only three types of effects were observed *viz.*, leaf brittleness, curling and fruit russetting on some cultivars. Phytotoxic effect in term of leaf brittleness (Table 25 & Plate 6) was observed only in case of tebuconazole 8% + captan 32% 40 SC (0.5%), zineb 68% + hexaconazole 4% 72WP (0.2%) which appeared after three days of application and difenaconazole 25EC (0.06%) after five days of application on cultivar Red Velox, Gala Redlum, Fuji Aztec Zehn and Granny Smith.

Further, metiram 55% + pyraclostrobin 5% 60 WG (0.2%) and zineb 68% + hexaconazole 4% 72 WP (0.2%) at double the recommended concentration (Table 26 & Plate 6) showed leaf curling on *cv.* Granny Smith after three days of application.

However, 20 per cent fruit russetting (Table 27 & Plate 6) with rating of 2 was recorded on *cv.* Red Velox and 10 per cent with rating of 1 each in Granny Smith and Jeromine when sprayed with tebuconazole 8% + captan 32% 40 SC (0.5%) concentration.

Table 25: Phytotoxic effect in the form of leaf brittleness caused by different fungicide on some tested cultivars of apple at FD-I stage during 2019 season

Chemical Name	Conc. (%)	Leaf Brittleness*						
		Red Velox	Gala Redlum	Fuji Aztec Zehn	Granny Smith	Jona Gold	S. Chief Sandidge	Jeromine
zineb 68%+hexaconazole 4% 72WP	0.20	+	+	+	+	-	-	-
metiram 55% + pyraclostrobin 5% 60 WG	0.20	-	-	-	-	-	-	-
captan 70%+hexaconazole 5% 75WP	0.10	-	-	-	-	-	-	-
dodine 65 WP	0.12	-	-	-	-	-	-	-
ziram 80WP	0.40	-	-	-	-	-	-	-
propineb 70 WP	0.60	-	-	-	-	-	-	-
difenaconazole 25EC	0.06	+	+	+	+	-	-	-
mancozeb 75WP	0.60	-	-	-	-	-	-	-
captan 50WP	0.60	-	-	-	-	-	-	-
flusilazole 40EC	0.04	-	-	-	-	-	-	-
carbendazim 12% + mancozeb 63% 75 WP	0.50	-	-	-	-	-	-	-
trifloxytrobin 25% + tebuconazole 50% 75WG	0.08	-	-	-	-	-	-	-
tebuconazole 8% + captan 32% 40 SC	0.50	+	+	+	+	-	-	-

*+=Present; -=Absent

Table 26: Phytotoxic effect in the form of leaf curl caused by different fungicide on some tested cultivars of apple at FD-I stage during 2019 season

Chemical Name	Conc. (%)	Leaf Curling*						
		Red Velox	Gala Redlum	Fuji Aztec Zehn	Granny Smith	Jona Gold	S. Chief Sandidge	Jeromine
zineb 68%+hexaconazole 4% 72WP	0.20	-	-	-	+	-	-	-
metiram 55% + pyraclostrobin 5% 60 WG	0.20	-	-	-	+	-	-	-
captan 70%+hexaconazole 5% 75WP	0.10	-	-	-	-	-	-	-
dodine 65 WP	0.12	-	-	-	-	-	-	-
ziram 80WP	0.40	-	-	-	-	-	-	-
propineb 70 WP	0.60	-	-	-	-	-	-	-
difenaconazole 25EC	0.06	-	-	-	-	-	-	-
mancozeb 75WP	0.60	-	-	-	-	-	-	-
captan 50WP	0.60	-	-	-	-	-	-	-
flusilazole 40EC	0.04	-	-	-	-	-	-	-
carbendazim 12% + mancozeb 63% 75 WP	0.50	-	-	-	-	-	-	-
trifloxystrobin 25% + tebuconazole 50% 75WG	0.08	-	-	-	-	-	-	-
tebuconazole 8% + captan 32% 40 SC	0.50	-	-	-	-	-	-	-

*+=Present; -=Absent

Table 27: Phytotoxic effect in the form of fruit russetting caused by different fungicide on some tested cultivars of apple at FD-I stage during 2019 season

Chemical Name	Conc. (%)	Fruit Russetting*						
		Red Velox	Gala Redlum	Fuji Aztec Zehn	Granny Smith	Jona Gold	S. Chief Sandidge	Jeromine
zineb 68%+hexaconazole 4% 72WP	0.20	0	0	0	0	0	0	0
metiram 55% + pyraclostrobin 5% 60 WG	0.20	0	0	0	0	0	0	0
captan 70%+hexaconazole 5% 75WP	0.10	0	0	0	0	0	0	0
dodine 65 WP	0.12	0	0	0	0	0	0	0
ziram 80WP	0.40	0	0	0	0	0	0	0
propineb 70 WP	0.60	0	0	0	0	0	0	0
difenaconazole 25EC	0.06	0	0	0	0	0	0	0
mancozeb 75WP	0.60	0	0	0	0	0	0	0
captan 50WP	0.60	0	0	0	0	0	0	0
flusilazole 40EC	0.04	0	0	0	0	0	0	0
carbendazim 12% + mancozeb 63% 75 WP	0.50	0	0	0	0	0	0	0
trifloxystrobin 25% + tebuconazole 50% 75WG	0.08	0	0	0	0	0	0	0
tebuconazole 8% + captan 32% 40 SC	0.50	20	0	0	10	0	0	10

*+=Present; -=Absent



Fruit russetting in Red Velox



Curling in Granny Smith



Brittleness in Fuji Aztec Zehn



Brittleness in Jeromine



Fruit russetting in Granny Smith



Brittleness in Gala Redlum

Plate 6: Phytotoxic assessment of various fungicides on selected cultivars

Chapter-5

DISCUSSION

Apple diseases are the main production constraints both qualitatively as well as quantitatively. Among the most dreaded diseases, scab and *Alternaria* leaf blotch are infecting all the important commercial cultivars of apple. Further, the diseases became endemic and cause extensive losses to the apple industry that is economically the backbone of Kashmir valley. Since, several years high density exotic plantation of apple are being introduced in bulk to Kashmir valley. Firstly, the introduced high density plantation is highly susceptible in nature against the prevalent scab and *Alternaria* leaf blotch. Secondly, the development of spray schedule especially for high density orchard system under Kashmir conditions is the need of hour. The schedule applicable under conventional orchard system is not effective under high density orchard system as reported by Adeeba *et al.* (2019). Therefore, the present investigation necessitated to evaluate and validate the spray schedule under HD orchard system in Kashmir valley.

Apple growers usually adopt a zero tolerance policy towards pathogens and major insect pests (Percival and Boyle, 2005) and require frequent application of synthetic pesticides throughout the growing season (Eccel *et al.*, 2009). Throughout the world, fungicides are the frontline weapon against diseases and are still one of the most widely used means of combating plant pathogens and forms an effective component of the disease management as non-chemical alternatives do not exist (Jones, 1995). Different management strategies have been developed to prevent the disease efficiently through scheduled application of fungicides in a protective spray programme (Gupta, 1985), besides, application of systemic and sterol-inhibiting (SBI) fungicides (Thakur and Gupta, 1990; Thakur *et al.*, 1992). In general, control measures are based largely on protective fungicide sprays timed according to the developmental stage of the trees and ascospore maturity and release from overwintering leaves (MacHardy and Jeger,

1982). These treatments are supplemented by curative sprays applied after infection have occurred (MacHardy and Gadoury, 1989; Penrose, 1989).

During the present study, evaluation of modules, conventional schedule were carried out and compared with control which was devoid of any fungicide spray. Conventional schedule comprised of seven sprays *viz.*, mancozeb 75WP (0.3%) at green tip, captan 70%+hexaconazole 5% 75WP (0.05%) at pink bud, difenaconazole 25EC (0.03%) at 60-70 per cent at petal fall, dodine 65 WP (0.06%) at fruit let, zineb 68%+hexaconazole 4% 72WP (0.1%) at FD-I, captan 70%+hexaconazole 5% 75WP (0.05%) at FD-II and propineb 70 WP (0.3%) at FD-III evaluated at respective phenological stages. The module-I included seven sprays of conventional schedule plus complementary spray at 40 per cent petal fall stage with flusilazole 40EC (0.02%). Module-II comprised of stages and sprays of module-I plus complementary spray at cherry size stage with metiram 55%+pyraclostrobin 5% 60 WG (0.1%). Subsequently, the module-III consisted of three complementary phenological stage based sprays at 40 per cent petal fall (flusilazole 40EC @ 0.02%), cherry size (metiram 55%+pyraclostrobin 5% 60 WG @ 0.1%) and at fruit development-IV (FD-IV) with zineb 75 WP @ 0.30 %. Next, module-IV consisted of only protectants fungicide sprays recommended in the conventional schedule of the host university *viz.* mancozeb 75 WP, captan 50 WP, dodine 65 WP, propineb 70 WP, mancozeb 75 WP, captan 50 WP, dodine 65 WP, propineb 70 WP, Ziram 80 WP, Zineb 75 WP evaluated at green tip, pink bud, 40 per cent petal fall, petal fall, fruit-let, cherry size, FD-I, FD-II, FD-III and FD-IV respectively. The control was set as a check with no fungicide treatment, rather water was sprayed at respective phenological stages.

The prevailing suitable weather conditions and the extent time interval between pink bud and petal fall stage was the purpose behind the evaluation of 40 per cent petal fall stage. Secondly, the cherry size stage was targeted to reduce time interval between fruit-let & FD-I as well as to keep secondary scab and *Alternaria* leaf blotch under control during the period. Finally, the stage FD-IV

was assessed with the objective that the last spray under conventional orchards is at FD-III, but under HD orchard system the crop so far assessed depicts that it gets succumbed to ALB and scab due to excess time interval.

The evaluation of complimentary phenological stage based sprays against leaf and fruit scab on Super Chief Sandidge during 2019 season indicated that the significantly lowest leaf scab (LS) incidence of 03.80 per cent with highest per cent disease control (PDC) of 86.41 per cent and corresponding lowest LS intensity & highest PDC of (02.38 & 87.50 %) was observed in module-III. The significantly highest LS incidence of 45.04 per cent and LS intensity of 25.56 per cent was registered in control. Similarly, fruit scab (FS) analysis of Super Chief Sandidge also followed the same trend as that of leaf scab. The significantly lowest FS incidence of 02.50 per cent with highest PDC of 93.45 per cent and corresponding least FS intensity & highest PDC (00.80 & 94.58%) was registered in module-III. The control experienced significantly highest incidence of 31.66 per cent and intensity of 13.76 per cent, respectively.

The response of complementary phenological stage based sprays on Red Velox indicated that the significantly lowest LS incidence of 05.14 per cent with highest PDC of 84.56 per cent and corresponding lowest LS intensity & highest PDC (02.08 & 88.48%) was observed in module-III. The significantly highest LS incidence of 45.71 per cent and LS intensity of 26.01 per cent was registered in control. Fruit scab analysis of cultivar Red Velox provided significantly lowest FS incidence of 03.16 per cent with highest PDC of 91.92 per cent and least FS intensity & increased PDC (01.13 & 93.71%) was registered in module-III. The control experienced significantly highest incidence of 30.83 per cent and intensity of 13.88 per cent, respectively.

The evaluation of modules with complimentary sprays at various phenological stages on Fuji Aztec Zehn depicted significantly lowest LS incidence & highest PDC (05.07 & 90.70%) and corresponding lowest LS intensity & highest PDC (02.29% & 91.14%) was recorded in module III. The

significantly highest LS incidence of 54.07 per cent and LS intensity of 25.29 per cent was registered in control. Fruit scab analysis of Fuji Aztec Zehn also followed the same trend as evident in leaf scab with significantly least FS incidence & highest PDC of 03.83 & 91.59 per cent and least FS intensity & highest PDC (02.51 & 92.43%) in module III. The control recorded significantly highest LS incidence of 37.83 per cent and FS intensity of 17.55 per cent, respectively.

The evaluation of spray modules at various phenological stages on Gala Redlum during 2019 season revealed significantly lowest LS incidence & highest PDC of 03.09 & 92.09 per cent and corresponding lowest LS intensity & highest PDC (01.37 & 93.83 %) was observed in module-III. The significantly highest LS incidence of 37.42 per cent and intensity of 19.30 per cent was registered in control. The lowest fruit scab incidence of 01.17 per cent with PDC of 95.83 per cent and corresponding least FS intensity & highest PDC (00.50 & 95.74%) was registered in module-III. The significantly highest FS incidence of 22.83 per cent and intensity of 09.38 per cent was observed in control.

The most destructive disease of apple (*Malus x domestica* Borkh.) is caused by *Venturia inaequalis* (Cooke) Wint. (MacHardy, 1996) and leads to considerable losses year after year in India (Anonymous, 1998). To control apple scab in most of the commercial apple cultivars 15 to 22 fungicide applications are required annually (Holb *et al.*, 2005). To combat apple diseases a spray schedule comprising 5 to 18 fungicide sprays depending on cultivar susceptibility, weather conditions and disease pressure is practiced (MacHardy, 1996). In Kashmir valley Qazi and Mir (2002) reported that cover spray given at green tip does not provide comparatively good protection through pink bud, bloom, petal fall and fruit-let stages. Further, suggested that applying three consecutive sprays at green tip, pink bud and petal fall stages provided effective control of primary scab. Also, observed that three to four infection periods occurred in between pink bud and fruit-let stages.

The ineffectiveness of conventional spray schedule on HD orchard system as observed in current study are in conformity with the study carried out by Adeeba *et al.* (2019). They evaluated the conventional fungicide spray schedule, for the management of apple diseases under HD system for its efficacy against the major diseases on three cultivars *viz.*, Super Chief Sandidge, Fuji Zehn Aztec and Gala Redlum and found that the conventional spray schedule was unable to provide satisfactory disease control. The spray schedule was reported to provide 70.07 to 74.27 per cent and 63.96 to 79.97 per cent control of leaf scab incidence and intensity as against 93.89 and 95.17 per cent, respectively, in conventional system. Similarly, the spray schedule offered 63.96 to 70.31 and 63.21 to 68.21 per cent control of fruit scab incidence and intensity as against 92.31 to 90.04 per cent, respectively in conventional system.

Similar, results have been observed by various workers throughout the world. The investigations carried out by Singh and Kumar (1999b) on evaluation of five fungicides schedules against scab at different phenological stages of apple recorded significant disease reduction in leaves and fruits against primary and secondary infection. Further, at petal fall stage, constantly recorded the maturity of ascospores and found that the petal fall spray is the most suitable stage to target the primary scab. Subsequently, suggested that applying carbendazim (0.05%) and thiophanate methyl (0.01%) at petal fall were able to mask the appearance of reddish-brown flecks in the leaves and inhibits the pseudothecial growth and development as well as ascospore productivity. The report is consistent with the earlier reports of Thakur and Gupta (1990) on pre-symptom activity of these fungicides. Similarly, Schwabe *et al.* (1984) showed that the effect of thiophanate methyl and carbendazim as first spray during abscission of petals were more effective in controlling disease infection and appearance of chlorotic spots. Further, suggested that mancozeb, bitertanol and chlorothalonil as first spray were less effective in the suppression of symptom development and allowed the production of sporulation on scab lesions.

Sharma (1995) studied different spray schedule for the control of primary infection of apple scab and concluded that carbendazim play a decisive role in controlling scab when applied at petal fall stage. Consequently, the schedule comprising spray of difolatan at green tip, benlate at petal fall, hexacap at walnut size, mancozeb at 15-20 days before harvest and urea at pre-leaf fall stage of tree was effective in reducing the number of viable conidia.

Ergosterol biosynthesis inhibitors (ESBI's) possess excellent post-infection and pre-symptom fungitoxicant activity has been reported from different parts of the world. Amongst these, bitertanol, difenconazole, fenarimol, flusilazole, hexaconazole, myclobutanil, penconazole, pyrifenoxy, triademifon, triforine etc. have been observed to be more effective as curatives and/ or eradicators than the protectants against apple scab pathogen (Thakur *et al.*, 1992; Wilcox *et al.*, 1992, Araya and Fujita, 1996; Anonymous, 2000). In Mexico, Mendoza *et al.*, 1991 observed that sprays of tetraconazole, bitertanol, hexaconazole or triadimenol at 15-day intervals effectively controlled apple scab but chlorothalonil was not effective. However in India, Thakur and Malhotra (1995) also recorded effective scab control with protective action of ESBI's. Biggs and Warner (1987), Wilcox *et al.* (1992) and Sharma and Gupta (1995) recorded that ESBI's reduced germinability and quantity of conidia and showed curative and protectant effects against *V. inaequalis* under field conditions. Systemic fungicides other than ESBI's like dodine, thiophanate methyl and carbendazim did not possess post-infection action beyond 48 hrs (Thakur and Gupta, 1987).

The response of modules against Alternaria leaf blotch (ALB) on cultivar Super Chief Sandidge during the year 2019 cropping season revealed that among the modules, module-III recorded significantly superior in reducing ALB, with lowest ALB incidence & highest PDC (06.13 & 90.27 %) and corresponding least ALB intensity of 18.66 per cent & PDC of 90.27 per cent, respectively. Similarly, on cultivar Red Velox ALB was again significantly recorded lowest incidence and highest PDC (05.67 & 90.63%) with corresponding least ALB intensity and

highest PDC of 02.51 & 91.24 per cent reflected by module-III. The control exhibited significantly highest ALB incidence of 60.93 per cent with corresponding least ALB intensity of 28.65 per cent, respectively. On Fuji Aztec Zehn, module-III proved significantly superior in controlling ALB than rest of the modules with significantly lowest ALB incidence & highest PDC of 05.07& 90.70 per cent and ALB intensity and PDC of 02.29 & 91.14 per cent, respectively. The significantly highest ALB incidence 54.07 per cent and ALB intensity of 25.29 per cent was recorded in control, respectively. On cultivar Gala Redlum, module-III again proved effective in reducing Alternaria leaf blotch (ALB) than rest of the modules with significantly lowest Alternaria leaf blotch (ALB) incidence & highest PDC (02.00 & 96.16%) with ALB intensity and PDC (00.84 & 96.61%) was recorded in module-III. The control exhibited significantly highest ALB incidence and intensity 47.13 and 21.31 per cent, respectively.

The literature screened pertained to influence of fungicides against Alternaria leaf blotch at a particular stage is not available and therefore general literature on overall response of fungicides against ALB is supported. The studies reported by various workers on suitable chemical control of *A. mali* has been achieved through use of fungicides such as iprodione, mancozeb and captan (Asari and Takahashi, 1988), polyoxin, captafol (Filajdac and Sutton, 1992), dodine, zineb, mancozeb + hexaconazole (Sharma *et al.*, 2005), hexaconazole, copper oxychloride, ziram (Shahzad, 2009), propineb, mancozeb and diniconazole (Hu *et al.*, 2006), tebuconazole (Qu *et al.*, 2007) and penconazole (Sofi *et al.*, 2013). An effective spray program for the control of apple scab (*V. inaequalis*), simultaneously take care of ALB (Sharma and Sharma, 1991). Kim *et al.* (1982) found captafol, chlorothalonil, polyoxin B very effective in controlling this disease in Korea. Whileas, bordeaux mixture showed poor results in managing Alternaria leaf blotch of apple in Korea (Youl *et al.*, 1995).

The phytotoxic test was carried at FD-I stage on different cultivars *viz.*, Super Chief Sandidge, Fuji Aztec Zehn, Gala Redlum, Jona Gold, Granny smith,

Jeromine and Red Velox at double the recommended concentration of fungicide molecules *viz.*, zineb 68%+hexaconazole 4% 72WP (Avtar 72WP) @ 0.2 per cent, metiram 55% + pyraclostrobin 5% 60WG (CabrioTop 60WG) @ 0.2 per cent, captan 70%+hexaconazole 5% 75WP (Rely 75WP) @ 0.1 per cent, dodine 65 WP (Super Star 65WP) @ 0.12 per cent, ziram 80 WP (Zed-78 80WP) @ 0.40 per cent, propineb 70 WP (Antracal 70 WP) @ 0.60 per cent, difenaconazole 25EC (Score 25EC) @ 0.06 per cent, mancozeb 75WP (Dithane M-45 75WP) @ 0.60 per cent, Captan 50WP (Captan 50WP) @ 0.60 per cent, flusilazole 40 EC (Governor 40 EC) @ 0.04 per cent, carbendazim 12% + mancozeb 63% 75 WP (Saathi 75WP) @ 0.5 per cent, trifloxystrobin 25% + tebuconazole 50% 75WG (Nativo 75 WG) @ 0.08 per cent and tebuconazole 8%+captan 32% 40 SC (Shamir 40 SC) @ 0.5 per cent.

The phytotoxic effects in the form of leaf necrosis, leaf tip injury, wilting, vein clearing, russetting, epinasty and hyponasty were recorded by adopting visual assessment scale (0-10 scale). Subsequently, the phytotoxic effects were observed at 1st, 3rd, 5th, 7th and 10th days after application (DAA) of fungicide.

During the course of study only three types of phytotoxic effects were registered *viz.*, leaf brittleness, curling and fruit russetting on some cultivars. Phytotoxic effect in term of leaf brittleness was observed only in case of tebuconazole 8% + captan 32% 40 SC (0.5%), zineb 68% + hexaconazole 4% 72WP (0.2%) after three days and difenaconazole 25EC (0.06%) after five days of application on cultivar Red Velox, Gala Redlum, Fuji Aztec Zehn and Granny Smith. Further, metiram 55% + pyraclostrobin 5% 60 WG (0.2%) and zineb 68% + hexaconazole 4% 72 WP (0.2%) at double the recommended concentration resulted in leaf curling on *cv.* Granny Smith after three days of application. The phytotoxicity in the form of leaf brittleness and curling were recorded as present (+) or absent (-). However, 20 per cent fruit russetting with rating of 2 was recorded on *cv.* Red Velox and 10 per cent with rating of 1 each in Granny Smith

and Jeromine when sprayed with tebuconazole 8% + captan 32% 40 SC (0.5%) concentration.

The relevant literature with regard to phytotoxicity on specific apple cultivars and fungicides used in experiment is not available. Therefore, general literature with regard to phytotoxicity is supported to justify the importance of the study. Phytotoxic effect of fungicide azoxystrobin 18.2%+ tebuconazole 11.4% 29.6 SC @ 0.1 per cent concentration was reported in cultivars Mollies Delicious and Gala Redlum in the form of burning after 24 hours after application (Anonymous, 2016). Similarly, during the year 2016-17, the fungicide azoxystrobin + difenaconazole 32.5 SC found phytotoxic to cultivar Mollies Delicious and Gala varieties. However, the fungicide did not show any sign of phytotoxicity on the cultivar Oregon Spur and Red Delicious (Anonymous, 2018b).

Rosenberger (2014) analyzed that captan can damage all cultivars of apples, even though some cultivars may exhibit more damage than others. The author also observed that the fungicide azoxystrobin caused phytotoxicity to leaves and fruits of McIntosh and Gala varieties. Besides, reported that the degree of damage exhibited by various cultivars often depends on the growth stage and weather at the time of spray as well as the cultivar susceptibility frequency to injury. Also, suggested that the complexity of spray programs using complex tank mixtures causes spray injuries at petal fall and first cover. Further, reported that combining numerous products in a single application increases the probability of incompatibility among the various adjuvants included in the formulations. Butt *et al.* (1973) sprayed various fungicides at pink bud on seven apple cultivars including Cox's Orange Pippin, Golden Delicious and Jonathan and found binapacryl or dinocap compounds more phytotoxic without substantially or consistently improving the control of *Podosphaera leucotricha*.

Chapter-6

SUMMARY AND CONCLUSION

The present study entitled “Validation of fungicide spray schedule for management of fungal foliar diseases of apple (*Malus x domestica* Borkh.) under high density orchard system” was conducted under high density apple orchard block of Division of Fruit Science and Fruit Pathology Laboratory of the Division of Plant Pathology, FOH, SKUAST-K, Shalimar during March-September, 2019 season.

In the investigation, four fungicide modules, conventional schedule and control were evaluated on four cultivars *viz.*, Super Chief Sandidge, Fuji Aztec Zehn, Gala Redlum and Red Velox under high density orchard system against scab and *Alternaria* leaf blotch. The efficacy of modules were compared with conventional schedule and control (water sprays only). The conventional schedule tested and recommended at different phenological stages of apple under conventional (seedling rootstock) orchard system in Kashmir valley. The conventional schedule for 2019 season was adopted which include sprays at green tip (mancozeb 75WP @ 0.3%), pink bud (captan 70%+hexaconazole 5% 75WP @ 0.05%), 60-70 per cent petal-fall (difenaconazole 25EC @ 0.03%), fruit-let (dodine 65 WP @ 0.06%), FD-I (zineb 68%+hexaconazole 4% 72WP @ 0.1%), FD-II (captan 70%+hexaconazole 5% 75WP @ 0.05%) and FD-III (propineb 70 WP @ 0.3%). The plants in each selected cultivars were sprayed with water only at their respective phenological stages serves as control (water sprays only).

Exploration of crucial phenological stages of apple under high density (HD) orchard conditions was the aim of the present studies in order to keep the outrageous scab and *Alternaria* pathogens under check. Different spray modules were designed on the basis of time interval between stages and influence of disease(s). In addition to conventional schedule sprays, module-I consisted of complementary fungicide spray at 40 per cent petal-fall sprayed with flusilazole

40EC @ 0.02 per cent. The aim of the evaluating 40 per cent petal-fall was to target primary scab and crucial in terms of prevailing favourable weather conditions, ascospore maturity and dispersal. In case of module-II, which consisted of complementary fungicide sprays at 40 per cent petal-fall (flusilazole 40EC @0.02%) and cherry size (metiram 55% + pyraclostrobin 5% 60 WG @ 0.1%). The focus of module-II was to manage secondary scab and Alternaria leaf blotch which plays significant and deciding role on overall health and economics of the crop harvest. The module-III consisted of three complementary fungicide sprays at 40 per cent petal-fall (flusilazole 40EC @ 0.02%), cherry size (metiram 55%+pyraclostrobin 5% 60 WG @ 0.1%) and at FD-IV (Zineb 75WP @ 0.3%). The aim behind the complimentary spray was to minimize the inoculum built up *vis-à-vis* to avoid storage rot/pre-mature leaf fall that leads to non-bearing capacity of fruit buds next year. However, in case of module-IV only recommended contact fungicides were applied at green tip (mancozeb 75WP@ 0.3%), pink bud (captan 50 WP @ 0.3%), 40 per cent petal-fall (dodine 65 WP @ 0.06%), 60-70 per cent petal-fall (propineb 70 WP @ 0.3%), fruit-let (mancozeb 75WP@ 0.3%), cherry size (dodine 65 WP @ 0.06%), FD-I (captan 50 WP @ 0.3%), FD-II (propineb 70 WP @ 0.3%), FD-III (ziram 80 WP @ 0.3%) and FD-IV (zineb 75WP @ 0.3%). The need for evaluating and developing protectant fungicide spray schedule is the need of the hour. In view of the facts, that the systemic fungicides are costly, develops resistance quickly and persist in soil, water and food for longer periods.

The study revealed that all the modules were significantly superior in controlling both the diseases as compared to control. Leaf scab incidence and intensity within cultivars showed varied levels among the cultivars. On overall basis, module-III exhibited lowest leaf scab incidence, intensity and highest PDC among all the cultivars. The comparative and the ascending trend among the cultivars revealed that Gala Redlum experienced lowest leaf scab incidence & highest PDC of 03.09 & 92.09 per cent followed by Super Chief Sandidge having

03.80 & 86.41 per cent, Red Velox 05.14 & 84.56 per cent and Fuji Zehn Aztec 04.09 & 90.37 per cent, respectively. The minimum leaf scab intensity and highest PDC of 01.37 & 93.83 per cent was recorded in case of Gala Redlum followed by Fuji Zehn Aztec (01.77 & 93.50 %), Red Velox (02.08 & 88.48 %) and Super Chief Sandidge (02.38 & 87.50 %), respectively.

Fruit scab incidence and severity within cultivars showed varied levels among the cultivars. On overall basis, module-III exhibited lowest fruit scab incidence, intensity and highest PDC among all the cultivars. The comparative and ascending trend among the cultivars revealed that Gala Redlum experienced lowest fruit scab incidence & highest PDC of 01.17 & 95.83 per cent followed by Super Chief Sandidge 02.50 & 93.45 per cent, Red Velox 03.16 & 91.92 per cent and Fuji Aztec Zehn 03.83 & 91.59 per cent, respectively. The minimum fruit scab intensity and highest PDC of 00.50 & 95.74 per cent was recorded in case of Gala Redlum followed by Super Chief Sandidge 00.88 & 94.58 per cent, Red Velox 01.13 & 74.17 per cent and Fuji Aztec Zehn 02.51 & 92.43 per cent, respectively.

Varied levels of *Alternaria* leaf blotch incidence and intensity were evident among cultivars and modules. On overall basis, module-III exhibited lowest ALB incidence and intensity and highest PDC in all the selected cultivars. Among the cultivars, ALB incidence in ascending trend revealed that Gala Redlum recorded least ALB incidence and highest PDC (02.00 & 96.16 %) followed by Fuji Zehn Aztec (05.07 & 90.70%), Red Velox (05.67 & 90.63%) and Super Chief Sandidge (06.13 & 90.27%), respectively. The lowest ALB intensity and highest PDC (00.84 & 96.61%) was recorded in case of Gala Redlum followed by Fuji Zehn Aztec (02.29 & 91.14 %), Red Velox (02.51 & 91.24%) and Super Chief Sandidge (02.68 & 90.86 %), respectively.

The studies on phytotoxic effect of different fungicide molecules was carried out at FD-I stage on different selected test cultivars of apple *viz.*, Super Chief Sandidge, Fuji Zehn Aztec, Gala Redlum, Jona Gold, Granny Smith,

Jeromine and Red Velox. The fungicides used for assessing phytotoxicity on different cultivars were zineb 68%+hexaconazole 4% 72WP (Avtar 72WP) @ 0.2 per cent, metiram 55% + pyraclostrobin 5% 60WG (CabrioTop 60WG) @ 0.2 per cent, captan 70%+hexaconazole 5% 75WP (Rely 75WP) @ 0.1 per cent, dodine 65 WP (Super Star 65WP) @ 0.12 per cent, ziram 80 WP (Zed-78 80WP) @ 0.40 per cent, propineb 70 WP (Antracal 70 WP) @ 0.60 per cent, difenaconazole 25EC (Score 25EC) @ 0.06 per cent, mancozeb 75WP (Dithane M-45 75WP) @ 0.60 per cent, Captan 50WP (Captan 50WP) @ 0.60 per cent, flusilazole 40 EC (Governor 40 EC) @ 0.04 per cent, carbendazim 12% + mancozeb 63% 75 WP (Saathi 75WP) @ 0.5 per cent, trifloxystrobin 25% + tebuconazole 50% 75WG (Nativo 75 WG) @ 0.08 per cent and tebuconazole 8%+captan 32% 40 SC (Shamir 40 SC) @ 0.5 per cent.

The phytotoxic effects in the form of leaf necrosis, leaf tip injury, wilting, vein clearing, russeting, epinasty and hyponasty were recorded on 1st, 3rd, 5th, 7th and 10th days after application (DAA) of fungicide at fruit development stage-I. The level of phytotoxicity was estimated by visual assessment using 0-10 scale. Phytotoxic effect in term of leaf brittleness was registered only in case of tebuconazole 8% + captan 32% 40 SC (0.5%), zineb 68% + hexaconazole 4% 72WP (0.2%) and difenaconazole 25EC (0.06%) on cultivar Red Velox, Gala Redlum, Fuji Aztec Zehn and Granny Smith. Further, metiram 55% + pyraclostrobin 5% 60 WG (0.2%) and zineb 68% + hexaconazole 4% 72 WP (0.2%) at double the recommended concentration resulted in leaf curling on *cv.* Granny Smith after three days of application. However, 20 per cent fruit russeting with rating of 2 was recorded on *cv.* Red Velox and 10 per cent with rating of 1 each in Granny Smith and Jeromine when sprayed with tebuconazole 8% + captan 32% 40 SC (0.5%) concentration.

In light of present investigations, it is deduced that:-

- All the four modules and the conventional based schedule significantly controlled disease incidence and intensity of leaf/fruit scab and *Alternaria*

leaf blotch as compared to control. Module-III recorded lowest leaf incidence, intensity and highest PDC in *cv.* Gala Redlum followed by, *cv.* Super Chief Sandidge, Fuji Zehn Aztec and Red Velox. Similarly in fruit scab, module-III was found superior over all the three modules with significantly lowest fruit scab incidence, intensity and highest PDC registered in *cv.* Gala Redlum, followed by *cv.* Super Chief Sandidge, Red Velox and Fuji Zehn Aztec. Accordingly, the data on Alternaria Leaf Blotch depicts more efficiency of Module-III than rest of the modules and registered least disease incidence, intensity and highest PDC in *cv.* Gala Redlum followed by Fuji Aztec Zehn, Red Velox and Super Chief Sandidge, respectively.

- The basis, on which the additional sprays at different phenological stages were decided, is supported by the appearance of phenological stages during 2019 season. Hence, the probability of disease development during these intervals is more, because of the fact that the efficacy of fungicides depletes beyond a specific time.
- The prime focus of the study was to target primary scab management in between pink bud & petal fall and the spray proved crucial as obvious in the data for laying one of the foundation stone in the management of scab and further development.
- The most important period between fruit-let to FD-I named as cherry size in which secondary scab and Alternaria leaf blotch plays significant and deciding role on overall health and economics of the crop harvest. During the investigation, it was found that the cherry size stage will be deciding factor by keeping both the diseases at bay in making the HD orchard system more profitable in our valley conditions.
- The high susceptibility frequency of studied cultivars and inoculum built up for next year as the disease(s) multiplies manifolds necessitates the

inclusion of FD-IV as compulsory spray as observed during the investigation.

- In the investigation, module-III proved superior in minimizing the gap between the stages as well as managing the major diseases *viz.*, scab and Alternaria leaf blotch.
- Phytotoxic effects in term of leaf brittleness was observed in case of cultivars *viz.*, Red Velox, Gala Redlum, Fuji Aztec Zehn and Granny Smith when sprayed with tebuconazole 8% + captan 32% 40SC @ 0.5 per cent, zineb 68% + hexaconazole 4% 72WP @ 0.2 per cent and difenaconazole 25EC @ 0.06 per cent, respectively. However, russetting was observed on fruits of cv. Red Velox, Granny Smith and Jeromine when sprayed with tebuconazole 8% + captan 32% 40 SC @ 0.5 per cent. Further, curling of leaves on cultivar Granny Smith was observed with double the recommended concentration of the molecules *viz.*, metiram 55% + pyraclostrobin 5% 60 WG and zineb 68% + hexaconazole 4% 72 WP.

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CERTIFICATE

Certified that all the corrections/amendments as suggested by External Examiner Dr. Vishal Gupta, Assistant Professor, Division of Plant Pathology, Faculty of Agriculture, SKUAST-Jammu during Viva-Voce examination held on 25-03-2021 have been incorporated in the manuscript entitled “**Validation of fungicide spray schedule for management of fungal foliar diseases of apple (*Malus x domestica* Borkh.) under high density orchard system**” submitted by **Ms. Urfy Jan (Regd. No. MSH/2018/219)**.

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