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Short communications

Effect of passage on the development of thiophanate methyl resistance in *Alternaria alternata* (Fries) Keissler causing brown spot of tobacco

Sonali M. Kumbhar[1*], S. K. Mengane[1] and S. T. Ingle[2]

[1]*Department of Botany, M. H. Shinde Mahavidyalaya, Tisangi 416 206, Maharashtra, India*
[2]*Department of Botany, DKASC College, Ichalkaranji 416 115, Maharashtra, India*

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Abstract

This study was conducted to investigate the *in vivo* development of thiophanate-methyl resistance in *Alternaria alternata* (Fries) Keissler, the causal agent of brown spot disease in tobacco. The experiment evaluated the effects of repeated fungicide exposure through three different passage strategies: continuous, alternate and mixture. A sensitive isolate of *A. alternata* obtained from Jainyal village, Kolhapur, Maharashtra, was subjected to eight successive passages with thiophanate-methyl (200 ppm). Continuous exposure led to a significant increase in both fungicide resistance and disease infection. In contrast, alternate and mixture passage effectively suppressed the development of resistance and reduced infection rates. Alternating thiophanate-methyl with chlorothalonil and copper oxychloride (200 ppm each) resulted in inhibition of pathogen growth by the 2nd passage, reducing the disease infection and showed only 10% and 20% infection, respectively. Similarly, alternating thiophanate-methyl with carbendazim and mancozeb (200 ppm each) achieved a notable reduction in infection by the 1st passage. Mixtures of thiophanate-methyl with carbendazim and copper oxychloride separately, also suppressed pathogen growth in the 2nd passage, with corresponding infection levels of 10% and 20%. Notably, combining thiophanate-methyl with chlorothalonil and mancozeb (200 ppm each) led to complete inhibition of both pathogen growth and infection at the 1st passage. These findings highlight the effectiveness of fungicides used alternately and in mixed form, in decreasing resistance development and managing *A. alternata* infections in tobacco.

Keywords: *Alternaria alternata,* Mancozeb, Passage, Thiophanate-methyl, Tobacco

India is an agricultural country, recognized as the second-largest producer and manufacturer of tobacco and exports it on a large scale. According to the Tobacco Board of Andhra Pradesh (2023), India has exported the tobacco and it's products approximately 2,91,181.74mtand has earned 9,739.75 crore during 2022-2023. Tobacco is used as traditional and folk medicine in various countries. The leaves are traditionally used as tranquilizers, spasmolytics, and help to kill parasites, as well as to treat poisonous bites and stings, strangulated hernia, orchitis, skin diseases, ringworms, wounds, and ulcers, and the plant itself has insecticidal properties.The use of mancozeb + carbendazim at the rate of 300ppm inhibited 96.90% mycelial growth of *A. alternata in vitro*, while under field conditions, the two sprays of mancozeb and carbendazim were used in mixture (0.2%), the blight of fennel disease is inhibited by 71.53% (Meena et al., 2020).

The management of *A. alternata* leaf spot on Ber under field conditions was studied by using three different fungicide mixtures: Tebuconazole 25% + Trifloxystrobin 50% WG, Azoxystrobin 18.2% + Difenoconazole 11.4% SC, and Carbendazim 12% + Mancozeb 63% W Peach applied at 0.05%. These fungicide mixtures resulted in disease intensity reduction and effective disease control by 76.67%, 72.50%, and 65.42%, respectively. (Kumar and Singh, 2020). The disease leaf blight of blond Psyllium caused by *Alternaria alternata* was investigated under field conditions using a combination of Mancozeb and Carbendazim (0.2%) which resulted in a 31.07% reduction in disease intensity, while the application of Mancozeb alone at 0.25% reduced the disease intensity by 20.71% (Choudhary et al., 2017).

Under field conditions, the intensity of fruit rot disease of Chilli caused by *Alternaria alternata*was significantly reduced by 83.72% by applying two foliar sprays ofthe formulation of tebuconazole (50%) and trifloxystrobin (25%) at a concentration of 0.20% applied at an interval of 15 days (Ginoya and Gohel, 2015). Sequential applications of chlorothalonil (0.2%), thiophanate-methyl (0.10%), and copper oxychloride (0.3%) effectively mitigated the incidence of *Chrysanthemum* leaf blight disease caused by *A. alternata* (Fr.) Keissler (Kamanna et al., 2010). Amixture of Ziram and Mancozeb (0.3%) was highly effective in

* Author for Correspondences: Phone : ; Email: sonalikumbhar547@gmail.com

controlling *Alternaria* species which causes blight of Sunflower (Sindhamathar et al., 1976).The leaf spot disease of cauliflower caused by *Alternaria* was significantly reduced *in vivo* using Mancozeb and Azoxystrobin at concentrations of 0.25% and 0.1%, respectively (Valvi et al., 2019). The fungicide Score (Difenoconazole 25% EC), at a concentration of 0.05%, demonstrated the highest efficacy in controlling tomato blight (Kumar et al., 2017). In managing *Alternaria alternata* which causes Gerbera blight, various fungicides such as tricyclazole (0.1%), Bordeaux mixture (0.6%), and a combination of iprodione and carbendazim (0.1%) were effective in controlling the disease by 96.59%, 95.85% and 95.88% respectively under polyhouse conditions (Nagrale et al., 2012). In the management of chili leaf spot, sequential treatments with Indofil M-45 (0.2%), Indofil Z-78 (0.2%), Chlorothalonil (0.2%), and Bavistin (0.1%) resulted in disease control by 62.3%, 57.5%, 58.0%, 58.7% respectively (Kumar et al., 2013).In the study on damping-off and wilt diseases of watermelon caused by *Fusarium oxysporum* f. sp. *niveum*, reported that the fungicide thiophanate-methyl (Topsin-M) reduced pre-emergence damping-off and wilt incidence by 44.4% and 72.9%, respectively, under greenhouse conditions. Under field conditions, application of thiophanate-methyl resulted in a reduction of pre-emergence damping-off and wilt by 73.7% and 67.7%, respectively (Sallam, 2009).

A two-year study on white mold disease of snap bean, caused by *Sclerotinia sclerotiorum* was conducted, in the 2015 growing season, disease incidences of 26.9%, 25.2%, and 14.2% were recorded following applications of boscalid (126.2 g/ha), fluazinam (162.8 mL/ha), and thiophanate-methyl (35.9 mL/ha), respectively. In 2016, the same treatments resulted in substantially lower incidences of 1.9%, 0.6%, and 7.6%, respectively (Lehner et al., 2017). The management of black scurf disease in potato, caused by *Rhizoctonia solani* was demonstrated that the application of a fungicidal combination of thiophanate-methyl 45% + pyraclostrobin 5% FS at a rate of 20.0 mL/100 kg of seed was highly effective. This treatment led to a significant reduction in disease incidence, 83.7% in the 2012–13 season and 67.5% in 2013–14; as well as disease severity, which was reduced by 82.6% and 60.4% during the respective seasons (Lal et al., 2017). In the experiment of cumin wilt caused by *Fusarium oxysporum* f. sp. *cumini*, the efficacy of various fungicides applied as foliar sprays at a concentration of 2000 ppm. The treatments included carbendazim (50% WP), tebuconazole 50% + trifloxystrobin 25% (75 WG), pyraclostrobin 5% + metiram 55% WG, carbendazim 12% + mancozeb 63%, and thiophanate-methyl (70% WP). Disease control efficiencies were recorded as 80.51%, 67.84%, 64.63%, 76.80%, and 67.93%, respectively, indicating significant suppression of the wilt pathogen (Jangir et al., 2022). The efficacy of fungicides against wilt diseases in pepper under both greenhouse and field conditions was demonstrated, under greenhouse trials, thiophanate-methyl (0.10%) achieved the highest disease control (83.10%) against *Verticillium* wilt caused by *Verticillium dahliae*, compared to untreated controls. In field experiments of *Fusarium* wilt caused by *Fusarium oxysporum*, the highest disease control was observed with captan (at 0.30% concentration) (95.60%), while thiophanate-methyl, applied at a 0.10% concentration, resulted in the lowest control efficacy (54.40%) (Mihajloviæ et al., 2021).

The application of fungicides remains a widely accepted practice for crop disease management. The continuous use of a single fungicide may lead to the development of pathogen resistance. Utilizing fungicides with different modes of action may help overcome this resistance and reduce the infection percentage. Consequently, this study aims to investigate the development of resistance to thiophanate-methyl in *A. alternata* and explore strategies to overcome this resistance by using fungicides with distinct mechanisms of action.

Passage effect in the establishment of resistance to thiophanate-methyl in Alternaria alternata

Experimental site:

The experiment was conducted from August 2023 to May 2024 at Lakhanapur village, Tehsil Nipani, District Belgaum, State of Karnataka, India (Pin code: 591 237). The village is situated at 16.4332° N latitude and 74.4013° E longitude. The location lies within the Northern Transition Agro-climatic Zone of Karnataka. The average annual rainfall is 1000mm to 1300mm. The soil type at the site is classified as deep black, silt-loamy soil.

In vivo studies:

The spore suspension (30ml, 1×10^6 conidia/ml) of pathogen *A. alternata* was introduced on 30 days old tobacco plants sprayed with thiophanate-methyl (70% WP) (@200ppm) continuously, alternately, and in a mixture with other fungicides (@200ppm). The fungicides like chlorothalonil (75%WP), mancozeb (75%WP), carbendazim (50%WP) and copper oxychloride (50% WP) were used. The concentrations of spore suspension and all fungicides, age of test plant, were kept constant for every passage. Ten plants for each fungicidal treatment were used. The experiment was carried out in triplicate at above mentioned location. The percentage of infection over untreated control plants was calculated.

Continuous, Alternate and Mixture passage

To investigate the impact of continuous passage in the establishment of thiophanate-methyl resistance in *A. alternata*, 30 ml (1×10^6 conidia/ml)of a spore suspension from a single culture plate of isolate (Aa-18) was prepared and applied to 30days old tobacco plants which had been administered with thiophanate-methyl (@200ppm) before 24hours. After 15 days, 30 ml (1×106 conidia/ml) of spore suspension from the diseased area was prepared and sprayed in triplicate on 30 days old tobacco plants treated with thiophanate-methyl 24 hours earlier. A similar procedure was followed up to the 8thpassage to develop fungicide resistance. For each passage the observations were taken after 15 days.

To study alternate and mixture passage, 30ml (1×10^6 conidia/ml) spore suspension of *A. alternata* isolate (Aa-18) was introduced on 30days oldtobacco plants which had been treated with thiophanate-methylat a concentration of 200 ppm before 24 hours. After 15 days,30ml (1×10^6 conidia/ml) spore suspension from such an infected portion was prepared and sprayed on 30 days old healthy tobacco plantsthat hadbeen sprayed with other individual fungicides in alternate and the fungicides in a mixture with thiophanate-methyl (all @ 200ppm) before 24 hours. The same procedure was continued until pathogen growth was completely inhibited. The experimental plants were kept under observation. Readings were taken at 15-day intervals and the percentage of infection (%) was calculated by formula-

Percentage of infection (%) = (No. of plants infected/ Total number plants treated) x 100

Result and Discussion

The development of thiophanate-methyl resistance in *A. alternata* through continuous treatment and the evaluation of alternate and mixed treatments using two fungicides was investigated *in vivo*. Fungicides, including copper oxychloride, mancozeb, carbendazim, and chlorothalonil, were used in the study. The percentage of infected tobacco plants was compared to that of untreated control plants to determine the efficacy of the treatments.

In the continuous passage experiment, the *A. alternata* isolate (Aa-18) was inoculated onto tobacco plants previously treated with thiophanate-methyl. As a result of prolonged exposure to the same fungicide, resistance in the pathogen developed progressively, reaching a significant level by the 8th passage and showed increased infection percentage by 70% (Table 1, Fig. 1 & Fig.3).

In the alternate passage, when thiophanate-methyl was used alternately with chlorothalonil and copper oxychloride (both applied at 200 ppm) separately, a significant reduction in infection percentage was observed at the 2nd passage by 10% and 20 % respectively. In contrast, when thiophanate-methyl was alternated with carbendazim and mancozeb (both applied at 200 ppm) separately, pathogen growth was completely inhibited at the 1st passage by reducing the thiophanate-methyl resistance (Table 1, Fig. 1 & Fig.4). Similar results were found by Mishrakoti (2015), reported that the alternate

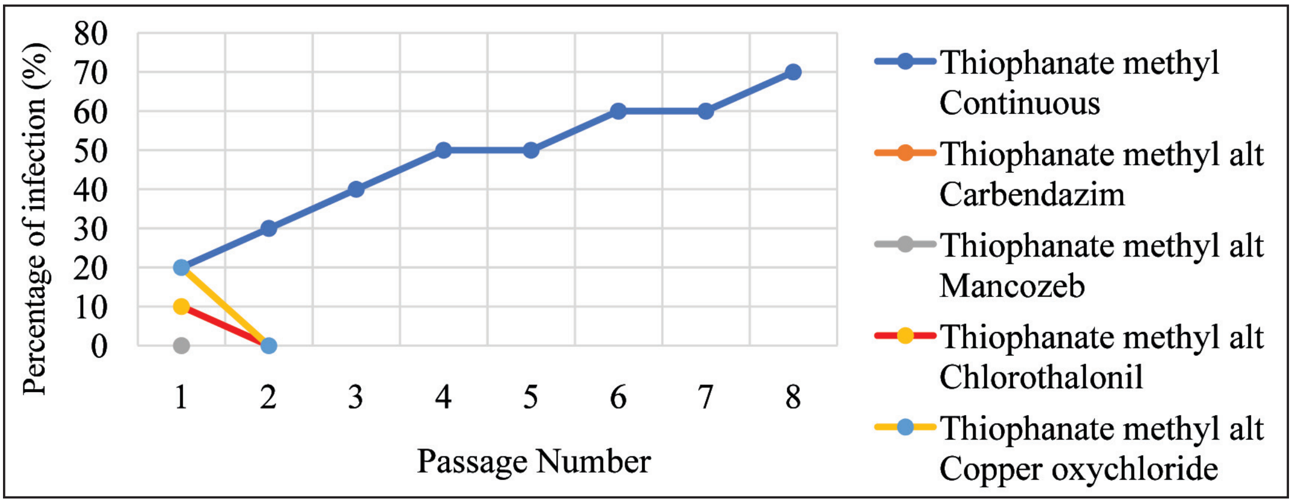

Figure 1. Dose response curve of *Alternaria alternata* to Thiophanate-methyl used continuously and alternately with different fungicides in developing the resistance till eight successive passages.

Table 1. Exposure of *Alternaria alternata* to thiophanate-methyl continuously and alternately with various fungicides(*In vivo)*

Fungicides (200ppm)	Passage Number and Percentage of infection (%)							
	1	2	3	4	5	6	7	8
Thiophanate-methyl (70% WP) continuous	20.00	30.00	40.00	50.00	50.00	60.00	60.00	70.00
Thiophanate-methyl (70% WP) alt. Carbendazim (50% WP)	00.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00
Thiophanate-methyl (70% WP) alt. Mancozeb (75% WP)	00.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00
Thiophanate-methyl (70% WP) alt. Chlorothalonil (75% WP)	10.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00
Thiophanate-methyl (70% WP) alt. Copper oxychloride (50% WP)	20.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00

Table 2. Exposure of *Alternaria alternata* to Thiophanate-methyl continuously and in a mixture with various fungicides(*In vivo)*

Fungicides (200ppm)	Passage Number and Percentage of infection (%)							
	1	2	3	4	5	6	7	8
Thiophanate-methyl (70% WP) continuous	20.00	30.00	40.00	50.00	50.00	60.00	60.00	70.00
Thiophanate-methyl(70% WP) + Chlorothalonil (75% WP)	00.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00
Thiophanate-methyl (70% WP) + Mancozeb (75% WP)	00.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00
Thiophanate-methyl (70% WP) + Carbendazim 50%	10.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00
Thiophanate-methyl (70% WP) + Copper oxychloride (50% WP)	20.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00

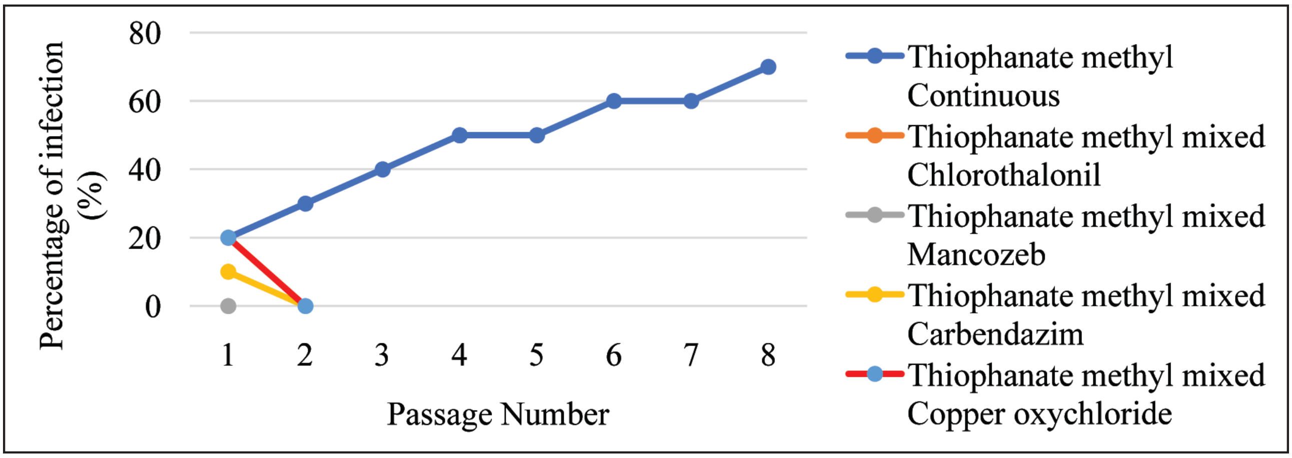

Figure 2. Dose response curve of *Alternaria alternata* to Thiophanate-methyl used continuously and in a mixture with different fungicides in developing the resistance till eight successive passages.

application of carbendazim with Ridomil, Dhanuka, and Kocide resulted in complete inhibition of the pathogen's growth by the second passage in an *in vivo* experiment. Vihol et al. (2009) evaluated the efficacy of various fungicides under field conditions and found that mancozeb (0.2%) was the most effective in controlling blight of cumin caused by *Alternariaburnsii* followed by copper oxychloride (0.25%) and thiophanate-methyl (0.03%). Desai et al. (2015) reported that the management of pigeon pea wilt caused by *Fusarium udum* was highly effective when benomyl was alternated

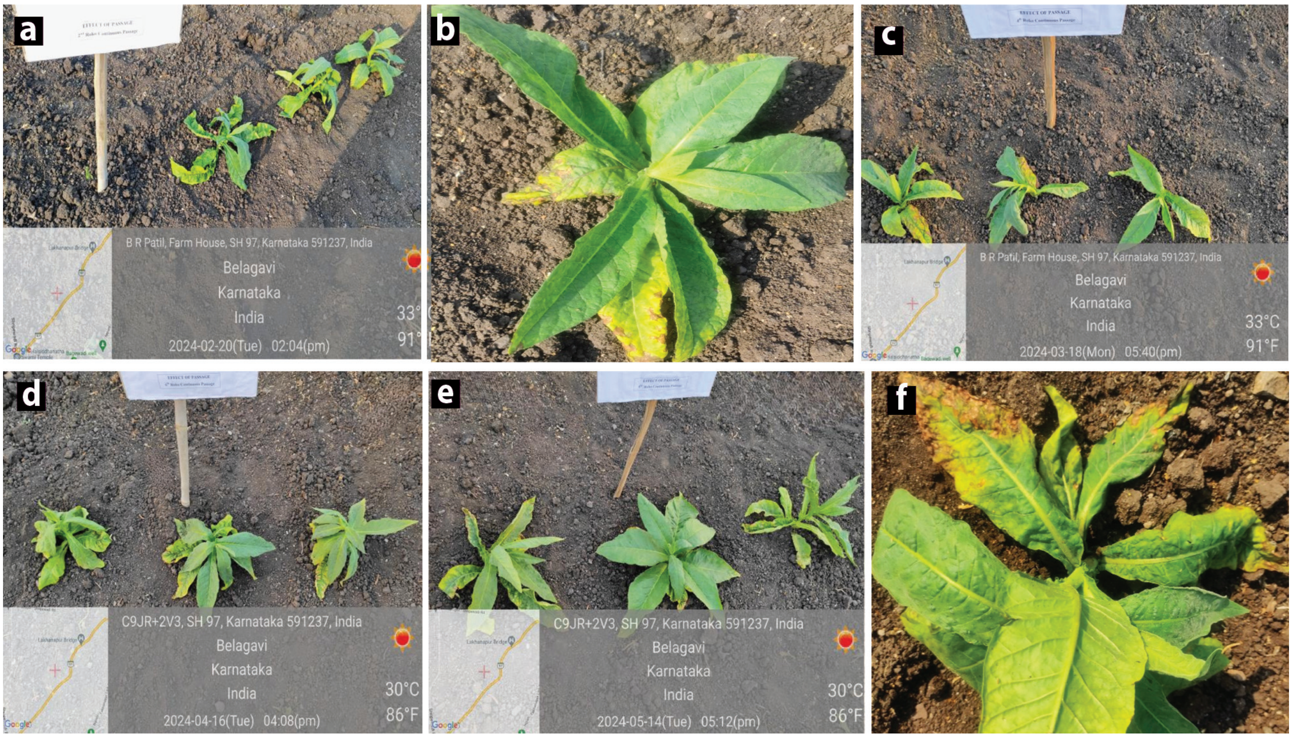

Figure 3. Effect of continuous passage on the development of thiophanate-methyl resistance in Alternaria alternata. **a.** 2nd Passage, Thiophanate-methyl continuous, **b.** 2nd Passage, Thiophanate-methyl continuous (plant showing symptoms), **c.** 4th Passage, Thiophanate-methyl continuous **d.** 6th Passage, Thiophanate-methyl continuous **e.** 8th Passage, Thiophanate-methyl continuous **f.** 8th Passage, Thiophanate-methyl continuous (plant showing symptoms)

with Roko (thiophanate-methyl), leading to complete elimination of infection (100%) by the third passage.

In the mixture passage, when thiophanate-methyl was combined with chlorothalonil and copper oxychloride (both applied at 200 ppm) separately, and subsequently applied to the plants, a significant inhibition of pathogen growth was observed after the 2nd passage, resulting in reduction of infection percentage by 10% and 20%, respectively. In contrast, when thiophanate-methyl was mixed with

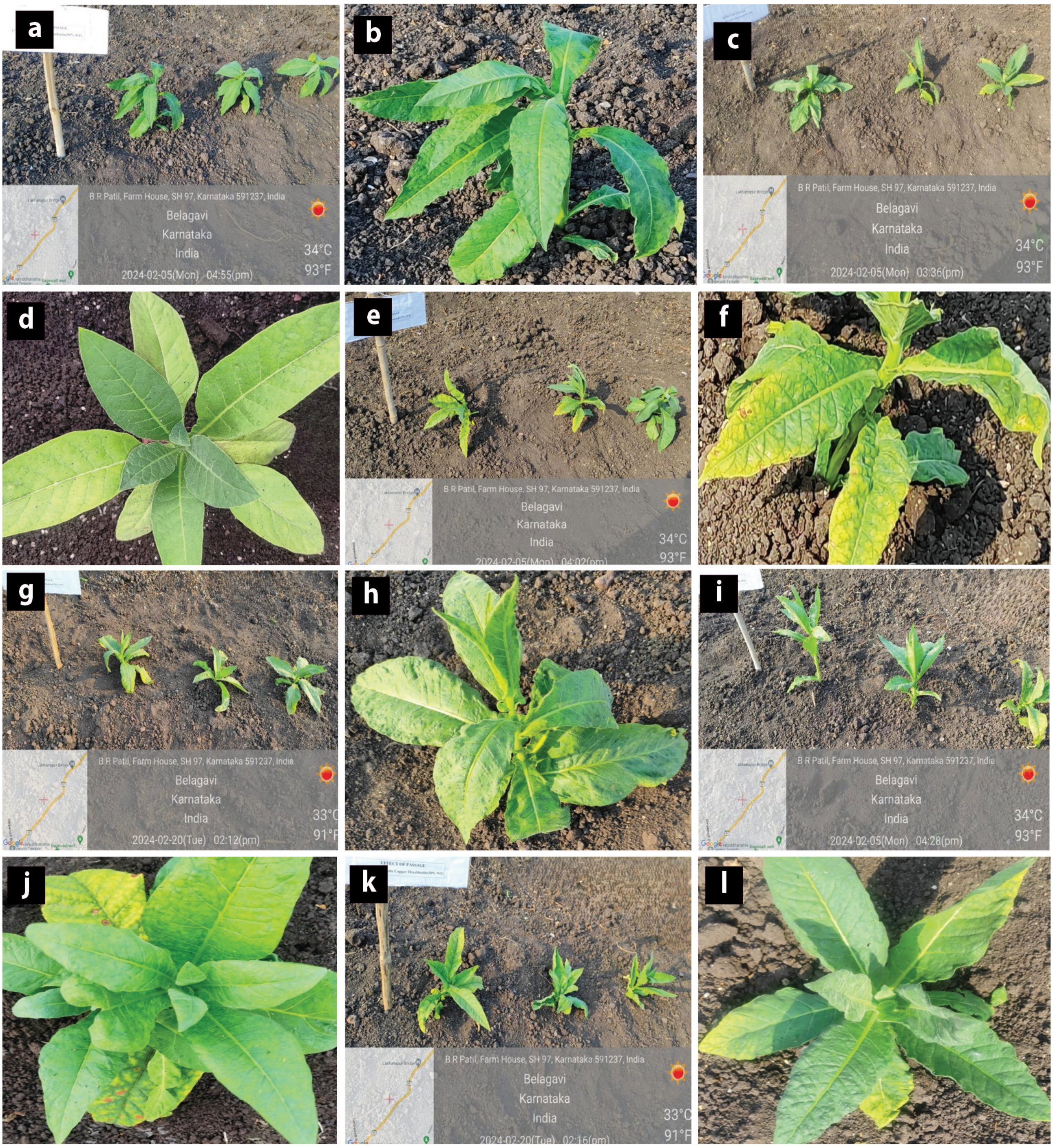

Figure 4. Effect of alternate passage on the development of Thiophanate-methyl resistance in *Alternaria alternata.* **a.** 1st Passage, Thiophanate-methyl alternate Carbendazim **b.** 1st Passage, Thiophanate- methyl alternate Carbendazim (plant without symptoms) **c.** 1st Passage, Thiophanate-methyl alternate Mancozeb **d.** 1st Passage, Thiophanate-methyl alternate Mancozeb (plant without symptoms) **e.** 1st Passage, Thiophanate-methyl alternate Chlorothalonil **f.** 1st Passage, Thiophanate-methyl alternate Chlorothalonil (plant showing symptoms) **g.** 2nd Passage, Thiophanate-methyl alternate Chlorothalonil **h.** 2nd Passage, Thiophanate-methyl alternate Chlorothalonil (plant without symptoms) **i.** 1st Passage, Thiophanate-methyl alternate Copper oxychloride **j.** 1st Passage, Thiophanate-methyl alternate Copper oxychloride (plant with symptoms) **k.** 2nd Passage, Thiophanate-methyl alternate Copper oxychloride (plant without symptoms) **l.** 2nd Passage, Thiophanate-methyl alternate Copper oxychloride

mancozeb and carbendazim (both applied at 200 ppm) separately and sprayed on plants, disease infection was completely inhibited at the 1st passage by delaying the thiophanate-methyl resistance in pathogen (Table 2, Fig. 2 & Fig.5).

Alternaria alternata (Fr.) Keissl. is the etiological agent of brown spot disease, which affects a wide range of crops, leading to both qualitative and quantitative yield losses. Due to severe disease conditions, farmers use various fungicides to manage its spread. The present study was conducted to evaluate the effect of different fungicides, applied in

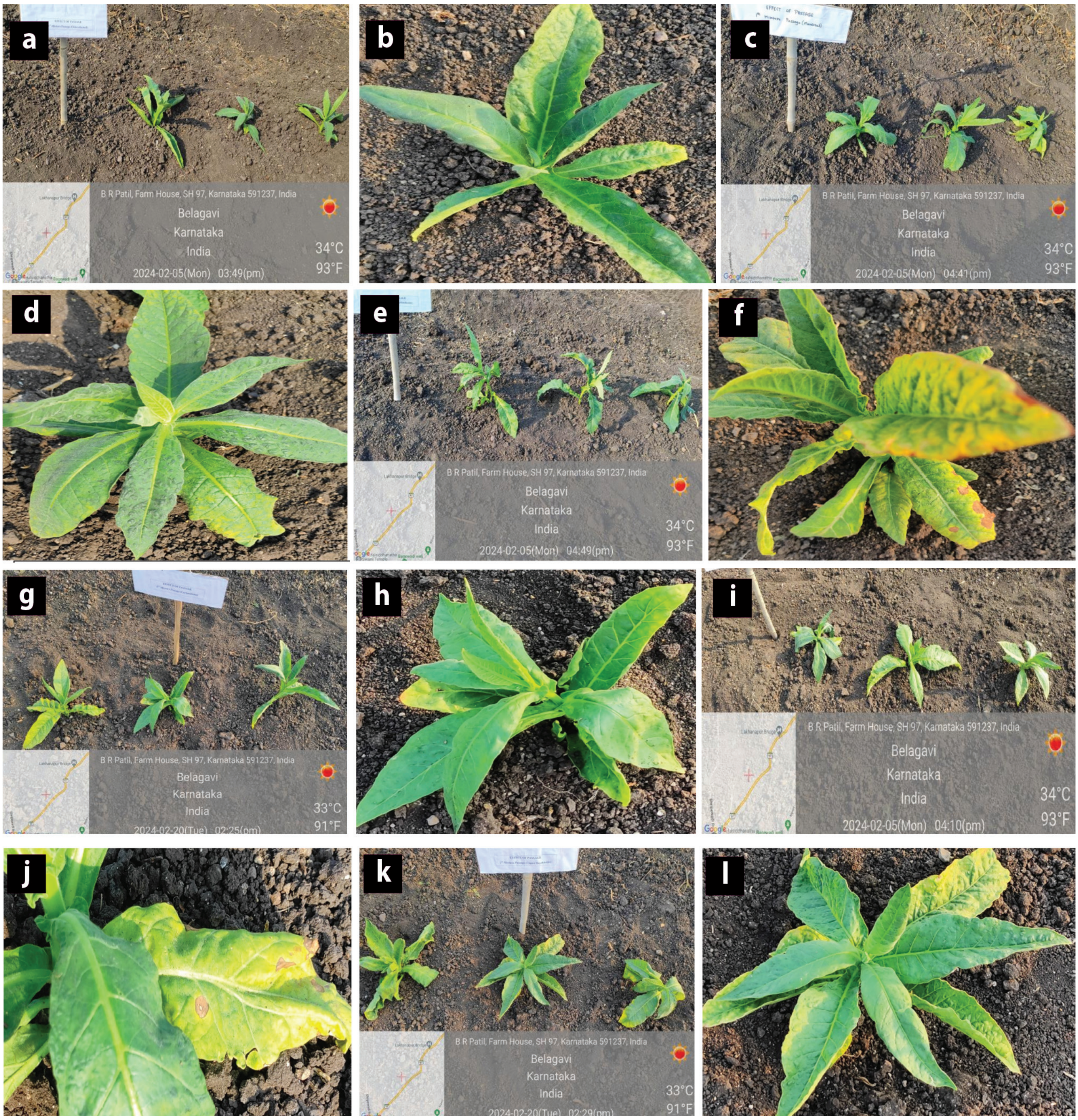

Figure 5. Effect of Mixture passage on the development of Thiophanate-methyl resistance in *Alternaria alternata* **a.** 1st Mixture Passage, Thiophanate-methyl + Chlorothalonil **b.** 1st Mixture Passage, Thiophanate-methyl + Chlorothalonil (plant without symptoms) **c.** 1st Mixture Passage, Thiophanate-methyl + Mancozeb **d.** 1st Mixture Passage, Thiophanate-methyl + Mancozeb (plant without symptoms) **e.** 1st Mixture Passage, Thiophanate-methyl + Carbendazim **f.** 1st Mixture Passage, Thiophanate-methyl + Carbendazim (plant with symptoms) **g.** 2nd Mixture Passage, Thiophanate-methyl + Carbendazim **h.** 2nd Mixture Passage, Thiophanate-methyl + Carbendazim (plants without symptoms) **i.** 1st Mixture Passage, Thiophanate-methyl + Copper oxychloride **j.** 1st Mixture Passage, Thiophanate-methyl + Copper oxychloride (plant showing symptoms) **k.** 2nd Mixture Passage, Thiophanate-methyl + Copper oxychloride l. 2 nd Mixture Passage, Thiophanate-methyl + Copper oxychloride (plant without symptoms)

continuous, alternate, and mixed forms, in inhibiting the development of *A. alternata* resistance to thiophanate-methyl and in reducing both disease infection and pathogen growth. Current investigation revealed the successful establishment of resistance in the pathogen by continuous application of thiophanate-methyl and the use of other fungicides like carbendazim, mancozeb, chlorothalonil, and copper oxychloride alternately and in a mixture with thiophanate methyl helped to slow down the thiophanate-methyl resistance in *A. alternata* and reduced pathogen growth. These findings are consistent with the observations of Dekker (1981), Mathivanan and Prabavathy (2007), Sable and Gangawane (2012), who stated that the use of fungicide combinations is an effective strategy for managing the development of fungicide-resistance in pathogens.

The disease resistance in *A. alternata* was decreased by using carbendazim (0.5%) in mixed and in alternate form with thiophanate-methyl, Dithane M-45, ridomil and curzate, and has been proven best to control root rot of fenugreek, investigated by Khandare (2014). Khilare and Gangawane (1998) reported the development of resistance by continuous application of thiophanate-methyl and then the use of thiophanate-methyl alternately and in mixed form with Captan and Dithane M-45 was found to reduce the resistance in *Penicillium digitatum* and proved effective in the management of green mold disease.

Field experiments were conducted by Romana et al. (2019) for three-years period to control *C. manginecans*, the pathogen responsible for mango quick decline. The application of Bavistin (carbendazim) in combination with thiophanate-methyl at a concentration of 750 ppm resulted in a significant reduction in disease incidence by 40% in 2014, 36% in 2015, and 39% in 2016. Baviskar and Rathod (2023) conducted an experimental study to control blue mold disease in pear. Thiophanate-methyl, when applied in combination with Polyram (Metiram 70% WG), Dithane Z-78, Kocide, and Acrobat, resulted in a significant reduction in the resistance of *Penicillium expansum* at 5thpassage. The effect of mixture passage of carbendazim with fungicides such difenoconazole, myclobutanil and propiconazole on *Gloeosporium ampelophagum*, the causative agent of grape anthracnose, was studied by Khilare and Chavan (2011) and reported that the disease incidence was reduced at 5th passage treatment by decreasing the resistance in the pathogen. Mueller et al. (2004) reported that the application of thiophanate-methyl at rates of 0.56 kg a.i./ha and 1.12 kg a.i./ha during the reproductive growth stage of soybean significantly reduced the incidence of stem rot caused by *Sclerotinia sclerotiorum*, and also resulted in increased crop yield.Gowdar et al. (2021) evaluated the bio-efficacy of thiophanate-methyl ranging from 857 to 1143 g/ha, these doses were found to be effective in controlling blast disease, sheath rot, and paddy grain discoloration in rice, resulting higher yield of rice.Malathi et al. (2004) demonstrated that pre-planting treatment of sugarcane setts in a 0.25% thiophanate-methyl suspension for a duration of 24 hours was significantly more effective in reducing debris-borne infections by *Colletotrichum falcatum* compared to 1 hour treatment at higher concentrations. Moreover, thiophanate-methyl treatment is better than the use of carbendazim in controlling red rot disease of sugarcane. Mathivanan and Prabavathy (2007) conducted an *in vivo* study demonstrating that a mixture of carbendazim and mancozeb at a concentration of 2.0 g/L was highly effective in reducing leaf blight of sunflower caused by *Alternaria helianthi*. Across three separate experiments, this treatment resulted in disease reductions of 55.7%, 32.7%, and 48.6%, respectively, compared to other fungicidal treatments and the unsprayed control.

This experiment demonstrated that the use of fungicides in alternating form or combinations of different fungicides at low concentrations was more effective than the application of individual fungicides in suppressing pathogen growth and reducing disease infection in the host plant. Moreover, the use of thiophanate methyl with carbendazim, mancozeb, chlorothalonil and copper oxychloride in different mode of actions yielded better results. Additionally, lower application rates in such mixtures can enhance crop safety and improve economic efficiency, making this approach a sustainable strategy within integrated disease management programs.

Conclusion

The present study demonstrated that continuous application of thiophanate-methyl (70% WP) resulted in increased fungicide resistance in the pathogen which was indicated by increased percentage of infection upto the 8th passage. In contrast, alternating thiophanate-methyl with each fungicide such as, chlorothalonil, mancozeb, carbendazim and copper oxychloride and applying each individual fungicide separately in combination with thiophanate-methyl, effectively reduced the developed resistance, significantly inhibited pathogen infection and pathogen growth in infected tobacco plants.

References

Baviskar, R. and Rathod, L. 2023. Effect of passage on the development of thiophanate-methyl resistance in *Penicillium expansum* causing blue mold of pear. Res. Jr. Agril. Sci.,14(6): 2019-2022.

Choudhary, S., Ghasolia, R. P., Yadav, A.L., Kakraliya, G. L. and Nasanwa, R. 2017. Management of *Alternaria alternata* of blond Psyllium (*Plantago ovata* L.) through fungicides *in vitro* and natural condition. Int. J. Chem. Stud.,5(3): 473-476.

Dekker, J. 1981. Counter measures for avoiding fungicide resistance. In: Dekkar, J and Georgopoulos, S. G., (eds.). Fungicide resistance in crop protection (CAPD Wageningen, Netherlands. 128-138.

Desai, U. A., Andoji, Y. S., and Kamble, S. S. 2015. Effect of passage on the development of Benomyl resistance in *Fusarium udum* (Butler) causing wilt in pigeon pea. Int. J. Res. Bot. 5(2): 27-30

Ginoya, C. M. and Gohel, N. M. 2015. Evaluation of newer fungicides against *Alternaria alternata* (Fr.) Keissler causing fruit rot disease of chili. Int. J. Plant Prot., 8(1): 169-173.

Gowdar, S. B., Hurali, S., Mastan, A. R., Reddy, B. G. and Mahanthashivayogayya, H. 2021. Bio-efficacy of thiophanate-methyl 70% WP against blast, sheath rot and grain discoloration diseases of Paddy. Biol. Forum – An Int. J., 13(4): 728-732.

Jangir, H., Dama, R., and Choudhary, A. 2022. Management of wilt disease of cumin caused by *F. oxysporum* f. sp. *cumini* with fungicides *in vitro* and *in vivo*. The J. Res. PJTSAU50(1): 101-107.

Kamanna, B. C., Shankarappa, T. H. and Arunkumar, G. S. 2010. Evaluation of fungicides for the management of *Chrysanthemum* leaf blight caused by *Alternaria alternata* (Fr.) Keissler. Plant Arch.,10(2): 595-597.

Khandare, N. K. 2014. Efficacy of carbendazim and other fungicides on the development of resistance during passage in *Alternaria alternata* causing root rot to fenugreek. Int. J. Sci. Res., 3(10): 2115-2119.

Khilare, V. C and Chavan, S. S. 2011. Effect of passage on the development of carbendazim resistance in *Gloeosporium ampelophagum* causing anthracnose of grapes. Biosci. Biotechnol. Res. Asia. 8(2): 505-508.

Khilare, V. C. and Gangawane, L. V. 1998. Effect of passage on the development of thiophanate-methyl resistance in *Penicillium digitatum.* J. Indian Bot. Soc.,77(1-4): 237-238; ref: 7.

Kumar, M., Bhadauria, V., Singh, K., Singh, C. and Yadav, A.K. 2013. Evaluation of fungicide efficacy for the management of *Alternaria* leaf spot disease on chill. Plant Pathol. J., 12(1): 32-35

Kumar,A. and Singh, H. K. 2020. Management of *Alternaria* leaf spot [*Alternaria alternata* (Fr.) Keissler] of Ber (*Zizyphus mauritiana* Lamk.). J. Pharmacogn. Phytochem.,9(5): 1552-1555.

Kumar,V., Singh, G. and Tyagi, A.2017. Evaluation of different fungicides against *Alternaria* leaf blight of tomato (*Alternaria solani*). Int. J. Curr. Microbiol. Appl. Sci., 6(5): 2343-2350.

Lal, M., Yadav, S. and Chand, S. 2017. Thiophanate methyl 45% + Pyraclostrobin 5% FS: A new molecule for potato tubers treatment against black scurf disease caused by *Rhizoctonia solani*. Indian J. of Plant Prot. 45 (2): 177-180.

Lehner, M. S., Del, P. E. M., Gugino, B. K., Kikkert, J. R., and Pethybridge, S. J. 2017. Sensitivity and Efficacy of Boscalid, Fluazinam, and Thiophanate-Methyl for White Mold Control in Snap Bean in New York. Plant Dis. 101(7): 1253-1258.

Malathi, P., Padmanaban, P., Viswanathan, R., Mohanraj, D., and Sundar, R. A. 2004. Efficacy of thiophanate methyl against red rot of sugarcane. Acta Phytopathol. Entomol. Hung.39(1-3): 39-47.

Mathivanan, N. and Prabavathy, V. K. 2007. Effect of Carbendazim and mancozeb combination on *Alternaria* leaf blight and seed yield of sunflower. Phytopathol and Plant Prot. 40 (2): 90-96.

Meena, S., Ghasolia, R. P. and Sharma J. 2020. Efficacy of fungicides against *Alternaria alternata* causing *Alternaria* blight of fennel. Int. J. Chem. Stud. 8(2): 723-726.

Mihajloviæ, M., Rekanoviæ, E., Hrustiæ, J., Grahovac, M., and Tanoviæ, B. 2021. *In vitro* and *in vivo* toxicity of fungicides and biofungicides for the control of *Verticillium* and *Fusarium* wilt of pepper. Pestic. Phytomed. (Belgrade), 36(1): 23–34.

Ministry of Commerce and Industry, Government of India. 2023. Tobacco Board, Andhra Pradesh. Published on the Internet. https://tobaccoboard.com/indexeng.php (continuously updating).

Mishrakoti, M. S. 2015. Studies on leaf blight management of carrot. Ph.D. Thesis, Shivaji University, Kolhapur, Maharashtra.

Mueller, D. S., Bradleyb, C. A.,Grauc, C.R., Gaskad, J.M.,Kurlee, J.E. and Pedersena, W.L. 2004. Application of thiophanate-methyl at different host growth stages for management of *Sclerotinia* stem rot in soybean. Crop Prot., 23: 983–988.

Nagrale, D. T., Gaikwad, A. P., Goswami, S. and Sharma, L. 2012. Fungicidal management of *Alternaria alternata* (Fr.) Keissler causing blight of gerbera (*Gerbera jamesonii* H. Bolus ex J.D. Hook). J. Appl. & Nat. Sci., 4 (2): 220-227.

Romana, A., Talib,S. S. and Khan, I. A. 2019. Efficacy of systemic fungicides against *Ceratocystis manginecans*; the cause of mango quick decline. Int. J. Agric. Biol., 22(5): 1065-1070; ref. 31

Sable, P. and Gangawane, L. V. 2012. Effect of Passage on the Development of Carbendazim Resistance. J. Adv. Lab. Res. Biol. 3(4): 290-292

Sallam, N. M. A. 2009. Efficacy of integrating plant growth-promoting rhizo bacteria and the fungicide thiophanate-methyl for controlling watermelon dampingoff and wilt diseases caused by *Fusarium oxysporum* f. sp. *niveum*. Assiut J. of Agric. Sci., 40 (1): 93-104

Sindhamathar, A., Narasimhan, V. and Ramaswamy, R. 1976. Control of rust and *Alternaria* blight of sunflower. Madras Agric. J. 78: 152 -153.

Valvi, H. T., Saykar, A. D and Bangar, V. R. 2019. *In vitro* and *in vivo* field efficacy of different fungicides against *Alternaria brassicae* (Berk.) sacc. causing *Alternaria* leaf spot of cauliflower. J. Pharmacogn Phytochem., 8(2): 1333-1337.

Vihol, J.B., Patel, K.D. Jaiman, R.K. and Patel, N.R. 2009. Efficacy of plant extracts, biological agents and fungicides against *Alternaria* blight of cumin, J. Mycol. Pl. Patho. 39:156