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MANAGEMENT OF DOWNY MILDEW OF GRAPES BY NEW COMBINATION FUNGICIDE OXATHIAPIPROLIN 0.6% + MANCOZEB 60% WG IN INDIA

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Abstract– Downy mildew of grapes caused by *Plasmopara viticola* is the most important disease of grapes which is observed in all grape growing regions of India. A new fungicide Oxathiapiprolin (piperidinylthiazoleisoxazoline class) along with Mancozeb (ethylene-bis-dithiocarbamate) was evaluated against downy mildew of grapes in the year 2018-19 and 2019-20 under field conditions at Maharashtra. Three concentrations of Oxathiapiprolin 0.6% + Mancozeb 60% WG, i.e. 1666, 2500 and 3333 g/ha were checked in the experiment. Pooled data revealed that the test fungicide@ 3333 g/ha manifested lowest PDI of 11.25 with a corresponding yield of 22.99 t/ha and it was at par with @2500 g/ha which had a PDI of 12.13 and yield of 22.31 t/ha. Hence the treatment Oxathiapiprolin 0.6% + Mancozeb 60% WG @ 3333 g/ha may be recommended against downy mildew of grapes.

INTRODUCTION

Grape (*Vitis vinifera* L.) is an important commercial fruit crop in sub-tropical regions of the world. India had a production of 3.2×10^5 MT from an approximate acerage of 1.5×10^5 ha in 2020-21 (Anonymous, 2021). Maharashtra, Karnataka, Tamil Nadu and Andhra Pradeshare the major grape growing states of India (Dethe, 2000). Grapes are mainly consumed as fresh berries and also processed for making wine, juice, jelly/jam and raisins. Grape has many nutritional properties like high vitamins, minerals, lipids and fiber content along with antioxidant, antimicrobial, anti-inflammatory, and anti-carcinogenic activities. India exported 2.6 $\times10^5$ MT of fresh grapes in 2021-2022 with a contribution of Rs. 2.3×10^5 lakh in the national exchequer (Anonymous, 2021-22). Grapevine downy mildew caused by *Plasmopara viticola* Berk. & Curt. (Berl. and de Toni) (Fig. 1) is considered to have a high destructive potential causing 60-70% of crop loss. (Sawant *et al.* 2010). The pathogen can infect all green tissue of the plant including leaves, young stems, flowers and young developing berries. The initial symptom starts as yellowing water-soaked lesions on the upper side of leaves and after 5-10 days "downy" (white cottony growth) patches appear on the underside of these leaves under conditions of high relative humidity. Several fungicides of all groups like Propineb, Mancozeb, Fosetyl Al, Dimethomorph, Mandipropamid and Cyazofamid are reported to control the disease. The repeated use of solo fungicides with a single-site mode of action is associated with a higher risk of resistance evolution when compared to a more diversified approach, e.g., multiple fungicide classes in mixtures or in alternation. The present investigation was carried out using a new formulation of a combination of Oxathiapiprolin 0.6% + Mancozeb 60% WG against the downy mildew disease. Oxathiapiprolin (FRAC 49) affects the oomycetous fungi by inhibiting an oxysterol binding protein (OSBP) homologue (Pasteris *et al.*, 2016) which may disrupt other processes in the fungal cell, such as signaling, maintaining cell membranes, and the formation of more complex lipids that are essential for the cell to survive (Weber-Boyvat *et al.*, 2013). Mancozeb [(FRAC code M 03) ethylene-bis-dithiocarbamate (EBDC)] is an extensively used fungicide that controls a wide

variety of plant diseases and has not developed resistance to fungal diseases due to its multisite mode of action (Saha *et al.*, 2022). For broad-spectrum disease management, mancozeb is often premixed with various systemic fungicides that have been reported to have developed resistance to *Plasmopara viticola*. The efficacy of the combined action might be more effective against the pathogens with no risk of development of resistance against fungicides. Hence in the present study the ready-mix fungicide Oxathiapiprolin 0.6% + Mancozeb 60% WG was evaluated against *Plasmopara viticola* under field conditions.

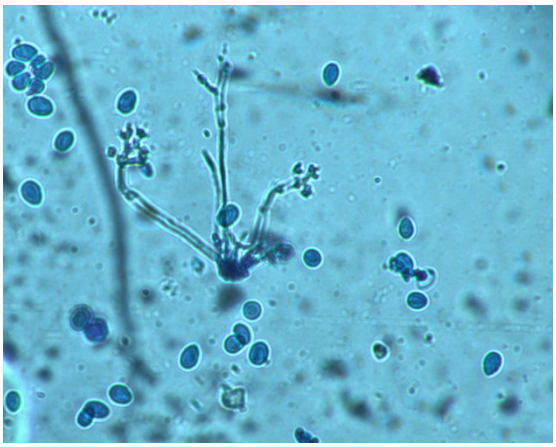

Fig. 1. Sporangia of *Plasmopara viticola*

MATERIALS AND METHODS

The bio efficacy of combined fungicide viz. Oxathiapiprolin 0.6% + Mancozeb 60% WG@ 1666 g/ha, 2500 g/ha and 3333 g/ha was evaluated against downy mildew infection on grape leaves along with its solo components Oxathiapiprolin 10.1%w/w @400 ml/ha and Mancozeb 75% WP @2000 g/ha. Mandipropamid 23.4 % SC @ 800 ml/ha was the standard check fungicide and water sprayed untreated control was maintained as well. The field trial was conducted in a vineyard of Thompson Seedless located at, Nashik (latitude: 20°14′55′′N, longitude: 73°53′40′′E, elevation: 571 msl) for two consecutive seasons (2018-2019 & 2019-2020) after fruit pruning. The test chemical Oxathiapiprolin 0.6% + Mancozeb 60% WGwas supplied by Corteva Agriscience India Pvt. Ltd, Hyderabad, India. The experiment was laid out in Randomized Block Design (RBD) with four replications in 8 grape vines with a spacing of 10 ft. x 6 ft. on Y- trellises. Fungicide application was started with the visibility of initial symptoms (30 and 35 days after fruit pruning in 2018-19 and 2019-20 respectively) with knapsack sprayer. Total 4 sprays including one preventive spray were given at an interval of 10 days to vines. Water volume used for spray was calculated based on requirement of 1000 l/ha at full canopy. Downy mildew incidence on leaves was recorded visually adopting the 0-4 scale, where 0 = nil, 1 = trace to 25, 2 = 26 to 50, 3 = 51 to 75 and 4 = more than 75 leaf area infected (Horsfall and Heuberger 1942). Percent Disease Index (PDI) was calculated by using following formulae.

$$\text{PDI} = \frac{\text{Sum of numerical ratings} \times 100}{\text{Number of leaves observed} \times \text{Maximum of rating scale}}$$

The ratings on ten leaves were recorded on randomly selected canes. Ten such canes per vine were observed and 100 disease observations were recorded per replicate. Four replications for each treatment were considered. Only actively growing downy mildew lesions were considered for recording ratings. The marketable yield from all the treatments was recorded at harvest and expressed in kg/vine and further extrapolated to yield/ha basis.

The mean of PDI of both the seasons was calculated and percent disease control was tabulated using following formula:

I= C-T/C ×100

Where,

I=percent disease control; C=PDI in untreated control; T= PDI in fungicide treatment

Statistical analysis

The data were analyzed using SAS (ver. 9.3; SAS Institute Inc., Cary, North Carolina, USA).

Phytotoxicity

Phytotoxicity experiment was conducted at the same plot and the vines treated with sprays of different doses of Oxathiapiprolin 0.6% + Mancozeb 60% WG@2500 g/ha and 5000 g/ha. Vineyards were critically observed for presence of phytotoxic effects such as chlorosis, tip burning, necrosis, epinasty, vein clearing and hyponasty on leaves and necrosis, russeting on berries after each spray of the fungicide. Observations were recorded at 0, 1, 3, 5, 7 and 10 days after spray of fungicides in the form of visual ratings in 0-10 scale where, 0=No Phytotoxicity, 1=0-10%, 2=11 – 20%, 3=21-30%, 4=31-40%, 5=41-50%, 6=51-60%, 7=61-70%, 8=71-80%, 9=81-90%, 10=91-100%.

RESULTS

Field bio-efficacy and yield of test fungicide against downy mildew

The two doses of Oxathiapiprolin 0.6% + Mancozeb 60% WG, i.e. 3333 g/ha and 2500 g/ha gave a significant disease control of downy mildew of grapes with significant increase in yield over its solo doses as well as the untreated control (Table 1). All treatments were significantly superior over untreated control for PDI on leaves and enhanced marketable yield/vine. The test fungicide Oxathiapiprolin 0.6% + Mancozeb 60% WG@ 3333g/ha, manifested the lowest PDI values i.e. 10.63 and 11.83 with PDC of 67.68 in both seasons respectively and both the treatments were at par with each other. It was followed by its lower dose, i.e. 2500g/ha where the PDI values were 11.50 and 12.75 respectively with a mean PDC of 64.87. Solo fungicides viz; Oxathiapiprolin 10.1 % w/w@ 400 ml/ha and Mancozeb 75% WP@ 2000 g/ha recorded a PDC of 49.53 and 47.67 respectively. Standard check fungicide, Mandipropamid @ 800ml/ha exhibited a PDC of 52.05. The untreated control had the maximum PDI of 33.88 and 35.63 in the two consecutive seasons respectively under study. The reduction in disease by Oxathiapiprolin 0.6% + Mancozeb 60% WGwas also reflected in the yield of the crop at the dose 3333g/ha and 2500 g/ha which recorded 22.12 and 21.46 t/ha yield respectively. The untreated control exhibiteda low yield of 13.12 t/ha. There was no occurrence of any phytotoxicity symptoms, i.e. chlorosis, wilting, vein clearing, epinasty, hyponasty, necrosis and scorching on leaves up to 10 days after spray.

DISCUSSION

The test fungicide Oxathiapiprolin 0.6% + Mancozeb 60% WG @ 3333 g/ha, manifested the lowest PDI values, i.e. 10.63 and 11.83 with PDC of 67.68 in both seasons, i.e. 2018-19 and 2019–20 respectively. According to Pasteris *et al.* (2016) and Miao, *et al*. (2018)

Table 1. Bio-efficacy and Yield of Oxathiapiprolin 0.6% + Mancozeb 60% WG against downy mildew in grapes after fruit pruning

Tr. No	Treatments	Dose/ha Formulation (ml)	2018-19	2019-20	Pooled Data	Percent Reduction over control	Yield (t/ha) 2018-19	Yield (t/ha) 2019-20	Yield (t/ha) Pooled Data	Percent Increase over control
T_1	Oxathiapiprolin 0.6% + Mancozeb 60% WG	1666	24.31 (29.51)** c*	25.56 (30.33) c	24.94 (29.93) c	27.78 (31.43) c	16.00c	15.25 c	15.62 c (20.44)c	14.88
T_2	Oxathiapiprolin 0.6% + Mancozeb 60% WG	2500	11.50 (19.82) a	12.75 (20.91) a	12.13 (20.38) a	64.87 (53.67) a	21.59 a	21.33 a	21.46 a (38.74)ab	38.76
T_3	Oxathiapiprolin 0.6% + Mancozeb 60% WG	3333	10.63 (19.02)a	11.88 (20.16) a	11.25c (19.60) a	67.38 (55.19) a	22.51 a	21.73 a	22.12 a (39.61)a	40.68
T_4	Mandipropamid 23.4 % SC	800	15.88 b (23.47)	17.13b (24.44)	16.50 b (23.97)	52.05 (46.18) b	18.27 b	18.01 b	18.14 b	27.67 (31.70)ab
T_5	Oxathiapiprolin 10.1 % w/w	400	16.75 (24.15) b	18.00 (25.10) b	17.38 (24.64) b	49.53 (44.73) b	18.05 b	17.79 b	17.92 b	26.85 (31.18)ab
T_6	Mancozeb 75% WP	2000	17.44 (24.68)b	18.69 (25.60)b	18.06 (25.15)b	47.67 (43.66) b	17.88 bc	17.46 b	17.67 b	25.39 (30.00)b
T_7	Untreated Control	-	33.88 (35.56)d	35.63 (36.62)d	34.75 (36.10)d	-	13.66 d	12.57 d	13.12 d	-
	CD (P = 0.05)	-	1.64	1.82	1.73	3.98	1.07	0.91	0.94	8.91

*Figure with same letter in a column are not significantly different from each other.
** Figures in parentheses indicate arcsine transformed averages.

Oxathiapiprolin solo was used to control the major oomycetes diseases i.e. downy mildew of grapes, late blight of potato and tomato, and vegetables. Rubin *et al.* (2018), reported that oxathiapiprolin demonstrated outstanding preventative and curative control of potato late blight. Cohen *et al.* (2015) analysed that oxathiapiprolin was effectively inhibiting all the developmental stages in the asexual life cycle of *Pseudoperonos poracubensis*, which is the pathogen of downy mildew of cucurbits. Oxathiapiprolin acts at multiple stages of the pathogen's asexual life cycle at extremely low concentrations. Preventatively, it inhibited zoospore release, zoospore motility and sporangia germination. Curatively, it stopped mycelial growth within the host plant before visible lesions occurred, thereby offering protection at one- and two-days post-infection. It also stopped mycelial growth and inhibited further lesion expansion, and finally inhibited spore production. It phenotypically showed translaminar and acropetally systemic movement, protecting treated leaves and new leaves as they emerged and grew. Mancozeb is known to control downy mildew and anthracnose diseases of grapes (Saha *et al*., 2021). Although the non-systemic fungicides viz., Mancozeb, Captan and Ziram exhibited statistically inferior efficacy as compared to systemic ones (Khilari *et al*., 2010) they were the best for ready mix fungicides to mitigate resistance issues. From a resistance management perspective, a larger number of applications and/or a higher dose are expected to increase therate of selection for fungicide resistance (van den Bosch *et al*., 2014). According to FRAC Anonymous (2021) resistance risk of OXTP (Oxathiapiprolin) assumed to bemedium to high (single site inhibitor) and

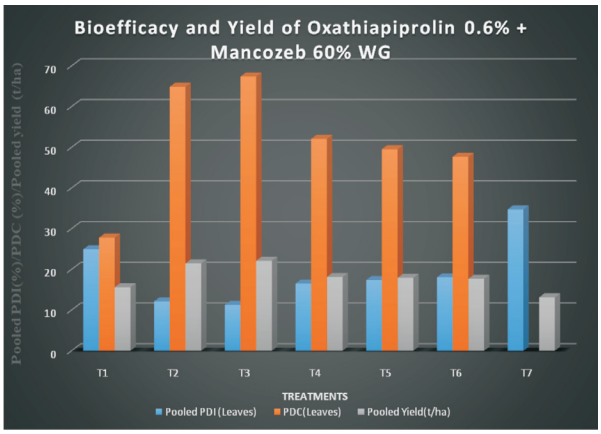

Fig. 2. Bioefficacy and Yield of Oxathiapiprolin 0.6% + Mancozeb 60% WG

therefore resistance management is required. Thereare several principal recommendations to delay the buildup of fungicide-resistant sub-populations in the field using mixtures with another fungicide having a different mode of action is a key strategy to mitigate resistance. Numerous studies showed the usefulness of dual or triple mixtures in suppressing the buildup of resistance in oomycete foliar pathogens against, e.g., phenyl amide fungicides in the field (Gisi and Cohen, 1996). Hence, the ready of Oxathiapiprolin 0.6% + Mancozeb 60% used be a total solution for the management of downy mildew of grapes.

CONCLUSION

Oxathiapiprolin 0.6% + Mancozeb 60% WG @ 3333g/haas a foliar spray manifested significantly higher disease control of downy mildew in grapes over its solo doses, increased the yield and were devoid of any phytotoxic effects on grapes. Thus, these combinations at above doses may be recommended for the management of downy mildew of grapes.

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FRAC Code List ©*2021: Fungal control agents sorted by cross resistance pattern and mode of action (including coding for FRAC Groups on product labels).https://www.frac.info/docs/defaultsource/publications/frac-code-list/frac-code-list-2021—final.pdfsfvrsn=f7ec499a_2.

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