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Validation of Different Chemical Fungicides for Management of Downy Mildew in Grapes Caused by *Plasmopara viticola*

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Abstract

Plasmopara viticola (Berk. and M.A. Curtis) Berl. and De Toni is an obligate pathogen that causes grape downy mildew. An experiment was conducted in a farmer's field in Linganahalli village of Bengaluru rural district in 2019 and 2020 in order to validate different fungicides on downy mildew of grapes. Seven treatments with seven different fungicides were used in the current study. The spray with cymoxanil 8 per cent + mancozeb 64 per cent @ 2g/L had the lowest PDI (10.05% in 2019 and 9.75% in 2020) and AUDPC (94.21 in 2019 and 83.97 in 2020), followed by the spray with fluopicolide 4.44 per cent + fosetyl-Al 66.67 per cent WG @ 2g/L. In terms of per cent reduction over control, the cymoxanil 8 per cent + mancozeb 64 per cent @ 2g/L treatment reduced disease severity by 80.49 per cent in 2019 and 82.17 per cent in 2020. During both years, the yield attributes of the chemicals mentioned above had increased.

Keywords : Fungicides, Downy mildew, Per cent disease index, Management

Grape cultivation in India acquires great significance due to its high productivity as compared to many other grape producing countries. The major grape growing states in the country are Maharashtra, Karnataka, Andhra Pradesh and Tamil Nadu (Ramya and Subbarayappa, 2017). Oomycetes pathogens are considered devastating parasites of plants and animals found in almost all ecosystems and show various lifestyles (Thines, 2014). They cause severe infections in their hosts and are responsible for substantial economic losses (Gascuel *et al*., 2015). The oomycete pathogen *P. viticola* is an obligate biotroph that causes the most destructive diseases of grapevines in grape-growing regions of India and the world. It causes various disease symptoms on all the green parts of the plant characterized by the presence of oil spots on the adaxial surface of leaves and white downy growth on the abaxial surface of the leaves, canes and canes bunches in periods of high humidity (Ash, 2005). During the fruiting season, if rainfall occurs during early growth to fruit set stages, crop losses can be expected from 30 per cent to cent per cent. Being a high value commercial crop, any loss could result in significant revenue loss and deprives availability to a large segment of the population (Vilas *et al*., 2011). Infections on clusters can also occur in the absence of rain if dew is formed at night (Sawant *et al*., 2010). Spot infections on rachis or pedicles of young bunch lead to the collapse of berries ahead of the infected area at later stages of development. Hence, the early shoot growth to fruit set stages is a high-risk period for yield losses.

Most of the available *V. vinifera* cultivars in India and the world are highly susceptible to the pathogen. Only recently have sources of resistance been found in the center of origin of viticulture, which is located in Georgia (South Caucasus) (Toffolatti *et al*., 2018). High susceptibility of the available varieties makes chemical control of the pathogen is the most important component of an effective management program for downy mildew to ensure an adequate yield. However, one major problem in managing downy mildew with chemical fungicides is the appearance of fungicide resistance in the pathogen populations (Gisi and Sierotzki, 2008). Since *P. viticola* is a high-risk pathogen with a complex life cycle, which includes sexual and asexual reproduction and polycyclic behaviors (can undergo numerous infection cycles during a single grapevine growing season). Hence, timely application of the effective fungicides at appropriate doses is the key to avoid such problems.

Each year there can be changes to the fungicides recommended as the pathogen develops resistance or new products are registered. Testing the efficacy of available fungicides against the pathogen is essential to recommend it to manage the disease.

Determining the efficacy of individual fungicides was the goal of this experiment. Hence, the experiment was laid out at a farmer's field located at Linganahalli village of Bengaluru Rural District during the two consecutive years.

Material and Methods

Location, Cultivar and Date of Pruning

The present experiment was implemented and carried out in farmer's fields located in Linganahalii village of Bengaluru rural district during 2019 and 2020. The trial was conducted on six-year-old grapevine cultivar Dilkush. The cultivar was planted at 6^1 x 3^1 spacing with a pandal system of training of vines.

During both the year, fruit pruning of vine was carried out on 15^{th} November. The application of different fungicides was initiated after the first appearance of the disease. Three applications of each fungicide were given at the interval of seven days. The present experiment had eight different treatments with three replications, for each treatment, 12 vines were maintained and untreated control was maintained at the border. Details of treatments are given in Table 1.

Observation on Downy Mildew Severity

Observations on downy mildew severity were done on randomly selected four vines of each treatment. From each vine four shoots were selected and labelled, on each shoot 10 leaves were selected for disease scoring. 0-4 grade scale as described by Horsfall and Barratt (1986) was followed for disease observation, where 0 = No powdery growth and downy growth on the leaves, 1 = Trace to 25 per cent of leaf area diseased, 2 = 26 - 50 per cent of leaf area diseased, 3 = 51 - 75 per cent of leaf area diseased, 4 = 76 - 100 per cent of leaf area diseased. Per cent Disease Index (PDI) was calculated using the formula given by McKinney (1923). The data was analysed by RBD (Randomized Block Design) using the R software and OP stat software (Sheoran *et al*., 1998).

Table 1

Details of the different treatments implemented at Linganahalli

Treatments	Description	Concentration*
T1	Captan 50 WP	2.5 g/L
T2	Dithane M-45	2.5 g/L
T3	Metalaxyl-M 4 % + Mancozeb 64 % WP	2.5 g/L
T4	Fosetyl AL 80 WP 2 g/l	2 g/L
T5	Cymoxanil 8% + Mancozeb 64%	2g/L
T6	Iprovalicarb 5.5 % + Propineb 61.25 % WP	2.25g/L
T7	Fluopicolide 4.44 % + Fosetyl - Al 66.67 % WG	2g/L
T8	Untreated control	-

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

Later, PDI values were used to calculate the area under the disease progressive curve (AUDPC) using the following formula given by Wilcoxson *et al.* (1975).

$$\text{AUDPC} = \sum_{i=1}^{k} \left[\frac{1}{2} (Si + Si - 1)\, d \right]$$

S_i = Disease severity at the end of time

S_{i-1} = Number of successive evaluations of downy mildew

d = Interval between two evaluations

Observations on Yield Attributes

At the harvest time, yield attributes like bunch length and an average weight of ten bunches were taken.

For this, from every treatment, ten bunches were randomly selected in each vine. Later length and an average weight of the bunch were recorded.

Results and Discussion

Effect of Different Fungicides in Reducing the Severity of Downy Mildew

All the fungicides used in this experiment to manage downy mildew showed a significant difference over the control during both the years. During 2019, among the different treatments, T_5 and T_7 involving the spray with cymoxanil 8 per cent + mancozeb 64 per cent WP @ 2g/L and fluopicolide 4.44 per cent + fosetyl-Al 66.67 per cent WG 2g/L, respectively have shown the lowest PDI (T_5 - 10.05 per cent and T_7 - 10.56 per cent) as well as the lowest AUDPC (T_5-94.21 and T_7-101.66), which are found on par with each other (Table 1). T_6, involving the spraying with iprovalicarb 5.5 per cent + propineb 61.25 per cent WP 2.25 g/L, has found to be the next best treatment and found statistically different from other treatments (PDI-12.20 per cent and AUDPC-107.33). The highest severity is observed in the treatment involving the captan 50 WP. With respect to the decrease over control, T_5 (80.49 per cent) has shown the highest per cent decrease over the control followed by T_7 (78.19 per cent) (Fig. 1). Other treatments involving iprovalicarb 5.5 per cent + propineb 61.25 per cent WP @ 2.25g/L, fosetyl AL 80 WP @ 2 g/L, metalaxy l-M 4 per cent + mancozeb 64 per cent WP @ 2.5g/L, dithane M-45 @ 2.5 g/L and captan 50 WP @ 2.5 g/L had shown 74.71 per cent, 68.28 per cent, 68.59 per cent, 62.60 per cent and 55.97 per cent decrease over control, respectively (Fig.1).

Table 2

Evaluation of different fungicides on downy mildew of grapes at Linganahalli during 2019

Treatments	1st observation	2nd observation	3rd observation	AUDPC	Bunch length	Average weight of ten bunches
Captan 50 WP 2.5 g/L	2.77 b (9.56) *	14.08 b (22.02)	21.88 b (27.87)	202.82	19.17 d	346.66 f
Dithane M-45 2.5 g/l	3.30 b (10.43)	11.23 c (19.56)	18.10 c (25.16)	168.16	22.90 b	361.66 e
Metalaxyl-M 4 % + Mancozeb 64 % WP 2.5g/L	3.06 b (10.03)	9.61 d (18.36)	15.35 d (23.05)	144.21	20.82 cd	391.66 d
Fosetyl AL 80 WP 2 g/L	2.20 b (8.52)	9.50 d (17.94)	15.02 d (22.78)	138.99	21.75 bc	395.00 d
Cymoxanil 8 % + Mancozeb 64% 2g/L	2.63 b (9.28)	5.70 f (12.86)	10.05 f (18.86)	94.21	26.54 a	446.66 a
Iprovalicarb 5.5 % + Propineb 61.25 % WP 2.25g/L	2.80 b (9.60)	6.60 ef (14.87)	12.01 e (20.26)	107.33	22.90 b	406.66 c
Fluopicolide 4.44 % + Fosetyl-Al 66.67% WG 2g/L	2.80 b (9.62)	6.89 e (15.20)	10.56 f (18.44)	101.66	25.07 a	441.66 b
Untreated control	13.08 a (21.19)	25.75 a (30.47)	48.00 a (43.83)	430.91	15.14 e	230.00 g
S.Em.±	0.48	0.35	0.66		0.95	6.28
C.D. @ 5 %	1.47	1.08	2.04		2.92	19.24

* Angular transformed values. Mean values followed by different letters within the same column indicate significant differences according to Duncan's multiple range test ($p < 0.05$).

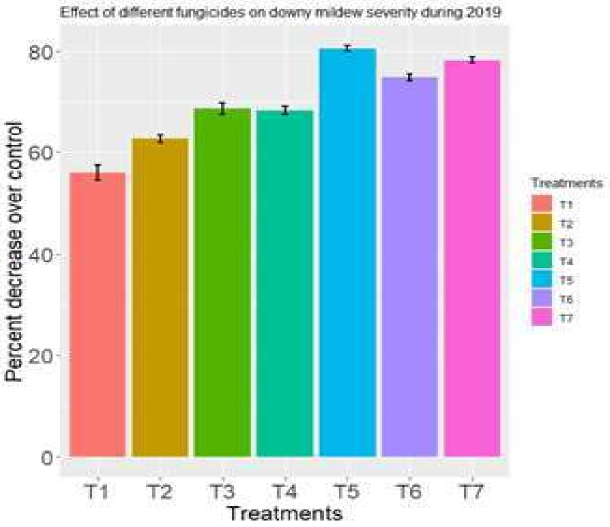

Fig. 1 : Effect of different fungicides on downy mildew severity during 2019

Experiment implemented during 2020 has shown the similar trend *i.e.* lowest severity and highest per cent decrease over control was observed with treatment involving cymoxanil 8 per cent + mancozeb 64 per cent @ 2g/L fallowed by fluopicolide 4.44 per cent + fosetyl-Al 66.67 per cent WG @ 2g/L treatment (Table 2) (Fig. 2). Bhat *et al*., (2017) reported that, minimum disease severity of cucurbit downy mildew was observed upon spraying with metalaxyl + mancozeb (9.59%), metalaxyl M + mancozeb (11.02%), azoxystrobin (13.37%) , curzate M-8 (cymoxanil + mancozeb) (18.99%), dimethomorph) (20.66%), mancozeb (24.85%),

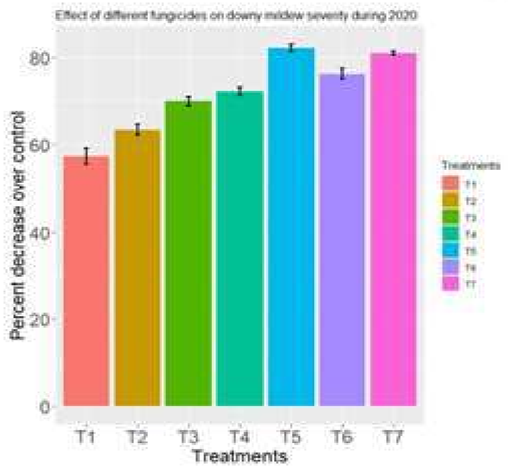

Fig. 2 : Effect of different fungicides on downy mildew severity during 2020

fluopicolide + propamocarb (24.88%), mandi propamid (26.21%), propineb) (26.48%), metiram (28.05%), copper hydroxide (29.86%). Genet and Jaworska (2013) observed that over 60 per cent of the populations were characterized as fully sensitive in a whole-plant assay compared to 10 per cent in the leaf disc assay in Europe to cymoxanil. Cymoxanil is a highly water-soluble compound belonging the chemical class of cyano hydroxyimino acetamides. This fungicide is known to have both protective and curative properties for foliar application; it is especially active against *Peronospora* spp., *Phytophthora* spp. and *Plasmopara* spp. but exact mode of action cymoxanil is unclear (Hillebrand and Zundel, 2010). The partner mancozeb acts by its contact action. The mancozeb is fungitoxic when exposed to air. It is converted to an isothiocyanate, which inactivates the sulphahydral (SH) groups in enzymes of fungi. Sometimes the metals are exchanged between mancozeb and enzymes of fungi, thus causing disturbance in fungal enzyme functioning (https://agro.indofil.com/market-product/mancozeb-cymoxanil-wp).

Effect of different Fungicides on Yield Attributes

Upon spraying with different fungicides, yield attributes like bunch length and an average weight of ten bunches were taken at the harvest time. Among the different treatments, treatment involving the spraying with cymoxanil 8 per cent + mancozeb 64 per cent @ 2g/L (T5) had shown the highest bunch length as well as the highest average weight of ten bunches during both the year, followed by the treatment involving spraying with fluopicolide 4.44 per cent + fosetyl-Al 66.67 per cent WG 2g/L (Table 2 and 3). T5 has shown a 75.33 per cent increase in the bunch length and 94.20 per cent increase in the average weight of ten bunches during 2019 (Fig. 3), whereas, during 2020, 87.09 per cent increase in bunch length and 96.43 per cent increase in the average weight of ten bunches was observed (Fig. 4). Correlation between the yield and severity shows that increased yield is associated with a decreased PDI upon the spraying with

TABLE 3

Evaluation of different fungicides on downy mildew of grapes at Linganahalli during 2020

Treatments	1st observation	2nd observation	3rd observation	AUDPC	Bunch length	Average weight of ten bunches
Captan 50 WP2.5 g/L	1.87 ab (7.85)	14.53 b (22.39)	23.25 b (28.81)	208.56	19.70 f	345.00 f
Dithane M-45 2.5 g/l	1.90 ab (7.91)	13.26 c (21.34)	20.003 c (26.55)	186.15	20.85 e	351.67 e
Metalaxyl-M 4 % + Mancozeb 64 % WP2.5 g/L	2.17 ab (8.47)	10.22 d (18.63)	16.475 d (23.93)	150.22	22.45 cd	365.00 d
Fosetyl AL 80 WP 2 g/l	2.12 ab (8.30)	9.77 d (18.20)	15.155 e (22.89)	141.37	21.67 de	386.67 c
Cymoxanil 8 % + Mancozeb 64% 2 g/L	1.47 b (6.96)	5.31 f (13.29)	9.745 g (18.17)	83.97	26.67 a	458.33 a
Iprovalicarb 5.5 % + Propineb 61.25 % WP2.25g/L	2.10 ab (8.32)	7.76 e (16.16)	12.925 f (21.05)	117.27	23.04 c	400.00 b
Fluopicolide 4.44 % + Fosetyl - Al 66.67% WG2 g/L	2.64 a (9.33)	6.23 f (14.44)	10.392 g (18.79)	97.54	24.66 b	395.00 b
Untreated control	2.65 a (9.32)	28.33 a (32.14)	54.845 a (47.77)	441.14	14.25 g	233.33 g
S.Em.±	0.315	0.35	0.66		0.43	8.75
C.D. @ 5 %	0.931	1.08	2.04		1.31	26.80

* Angular transformed values. Mean values followed by different letters within the same column indicate significant differences according to Duncan's multiple range test ($p < 0.05$)

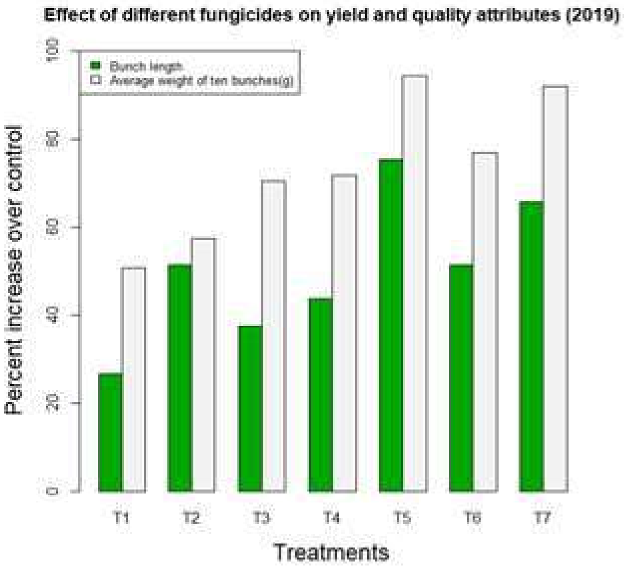

Fig. 3 : Effect of different fungicides on yield attributes during 2019

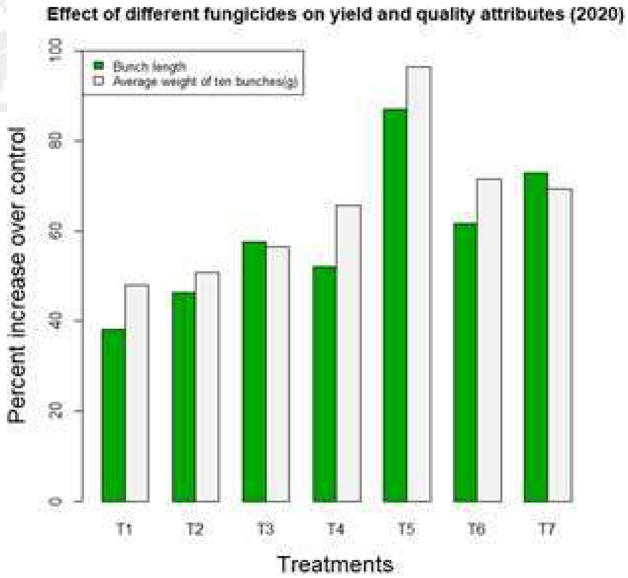

Fig. 4 : Effect of different fungicides on yield attributes during 2020

different fungicides (Fig.5). Bhat *et al*., (2017) reported that an increase in fruit yield is associated with the spraying of different fungicides against the downy mildew of cucurbits caused by *Pseudoperonospora cubensis*. Fungicides used in this experiment have significant results with respect to decreasing the severity and increasing yield attributes over the control when used with appropriate doses.

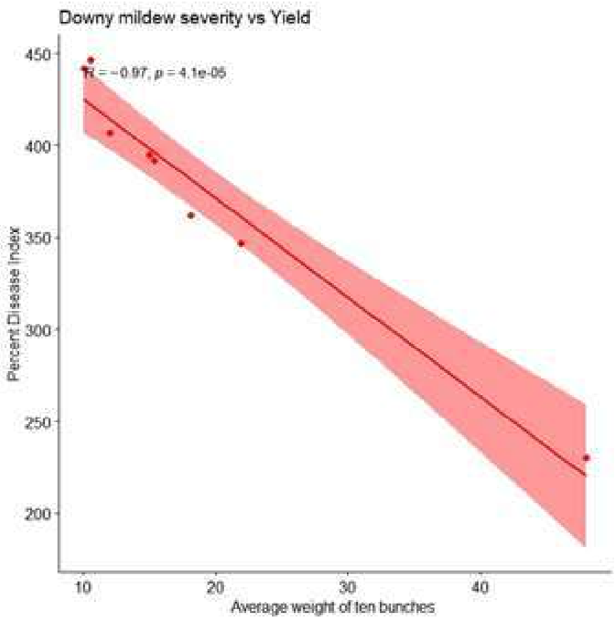

Fig. 5 : Correlation between downy mildew severity and yield

Fungicides are considered as a most important component of an effective management program for downy mildew. The present experiment had shown the effectiveness of individual fungicides on downy mildew grapes caused by *P. viticola*. Using these effective chemicals in integrated management approaches can lead to the better management of the downy mildew with less chances of fungicidal resistance.

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