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Assessment of Bioefficacy of Potential Fungicides and Biocontrol agents for Efficient Management of Blackgram Powdery Mildew

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ABSTRACT: Though the plant disease management starts with cultural, mechanical, physical and biological methods but practically the chemical methods and use of biocontrol agents are in predominant practice to reduce the outbreak of diseases. Hence, to know the field efficacy of any new fungicide molecules, there is need to test chemical under laboratory condition which provides useful and preliminary information regarding efficacy of fungicides against pathogen within a shortest period of time. A experiment was conducted to evaluate the bioefficacy of fungicides and bioagents against *Erysiphe polygoni* causing powdery mildew in blackgram at Deparment of Plant Pathology, UAS Raichur. Among ten systemic fungicides, seven non systemic fungicides, nine combi fungicides and seven bioagents evaluated against *E. polygoni*, maximum mean inhibition of conidial germination was observed in tebuconazole 25 EC (98.67%), mancozeb 75 WP (88.62%), carbendazim 12 % + mancozeb 63 % WP (85.06%) and *P. fluorescens* (Dharwad) (96.51%) respectively. Based on the results of *in vitro* evaluation the effective fungicides and bioagents were selected for their bioefficacy in field conditions. Two sprays of difenconazole at 0.1 per cent found best fungicide in management of powdery mildew of blackgram followed by propiconazole, tebuconazole and hexaconazole treatments.

Keywords: Blackgram, Powdery mildew, Fungicides, Bioagents, Per cent disease index.

INTRODUCTION

Blackgram (*Vigna mungo* L.) is popularly known as Urd bean, Urid or mash is an important pulse crop in India. India is the largest producer and consumer of blackgram in the world. Blackgram is a rich source of protein food and it contains 26.2 per cent crude protein, 1.2 per cent fat and 56.6 per cent carbohydrates (Raju, 2019). Blackgram crop is mini-fertiliser factory as it restores soil fertility by fixing atmospheric nitrogen and thus producing nitrogen equivalent of around 22 kg per hectare (Rachie and Roberts, 1974). It is also cultivated in many tropical and subtropical countries of Asia, Africa and Central America. Although, India, Pakistan, Bangladesh, Burma and Sri Lanka are the principal countries contributing to the world production (Raju, 2019). In India, blackgram is grown in an area of 56.02 Lakh ha with the production of 30.60 lakh tonnes and productivity of 546 kg per ha. More than 80 per cent of blackgram production comes from 10 states, of which Madhya Pradesh (39%), Rajasthan (12%), Uttar Pradesh (11%) and Andhra Pradesh (10%) (Anon., 2018). In Karnataka blackgram grown in area of 0.72 lakh ha with the production of 0.33 Lakh tonnes and productivity of 495 kg/ha (Anon., 2020).

Blackgram suffers from many biotic and abiotic stresses. Among the biotic stresses, diseases such as *Cercospora* leaf spot (*Cercospora canescens*), powdery mildew (*Erysiphe polygoni*) and *Mung bean yellow mosaic virus* diseases which attack blackgram are considered as an economically important diseases. Powdery mildew is distributed in India and Southeast Asian countries and becomes severe in dry season causing 9.0-50.0 per cent yield loss (Reddy *et al.*, 2008).

Among foliar fungal diseases, powdery mildew caused by *Erysiphe polygoni* is one of the economically important disease in blackgram which occurs at later stages of crop growth causing a yield loss of 20 per cent. Yield loss is much high when the pathogen infects the crop before flowering, however it results in complete loss of the crop if disease occurs at seedling stage (Jayasekhar and Ebenezar, 2016). The powdery mildew of blackgram appears on all the above ground parts of the plant. The infected leaf surface, petioles, stem and pods exhibits as small, round, whitish, powder-like spots. Symptoms first appear on crown leaves on shaded lower leaves and on under leaf surface. These white powdery colonies grow in size and cover both sides of the leaf, petioles and young stems. When disease progressed, lower leaves showed chlorosis, distortion and premature leaf fall due to infection of *E. Polygoni*. Severe infection of inflorescence is found to affect pod setting where as severe infection at later stages show shrivelled and dried appearance to immature pods (Korra and Kumar, 2018).

In Karnataka blackgram is economically importanat pulse crop cultivated in Bidar, Kalaburgi, Vijayapur, Ballari, Raichur and other districts mainly in black soil during *Kharif* and *Rabi* seasons both as main crop as well as intercrop. The crop is severely infected by powdery mildew during *Rabi* season causing considerable yield loss. An attempt was made to identify potential fungicides and bioagents for management of powdery mildew disease in both *in vitro* and *in vivo* conditions.

MATERIAL AND METHODS

A. In vitro evaluation of fungicides and bioagents against E. polygoni

The bioefficacy of systemic, non-systemic, combi fungicides and bioagents were evaluated against *Erysiphe polygoni* under *in vitro* by spore germination technique. Required doubled concentrations of fungicides and bioagent culture filtrate were prepared in sterile water separately under aseptic conditions. The oidial suspension was prepared separately in sterile distilled water and adjusted to 4 $\times 10^3$ oidia / ml using haemocytometer. Then a drop of oidial suspension was separately mixed with one drop of doubled concentration of fungicidal and bioagent cultural filtrate solution in a cavity slides to achieve the required concentrations of systemic fungicides (0.05, 0.1 and 0.15 %), non-systemic, combi fungicides (0.1, 0.2 and 0.3 %) and bioagents (5, 10, 15, 20%). In each treatment four replications were maintained. Treated cavity slides were kept in moist chamber created in Petri plates for incubation. Effect of fungicide and their concentrations on the germination of oidia was observed after 24 h, under microscope at 40 X magnification. A control treatment was maintained with distilled water. In each microscopic field number of spores germinated out of total spores were observed. Per cent inhibition over the control was calculated by using the formula given by Vincent (1947).

$$I = \frac{(C - T)}{C} \times 100$$

where, I = Per cent inhibition.

C = Germination of oidia in control.

T = Germination of oidia in treatment.

Details of fungicides and biocontrol agents are mentioned in the tables (1, 2, 3, 4). Statistical analysis were carried out as per the procedures given by Panse and Sukhatme (1985). Actual data in percentage were converted to arc sine values, before analysis according to the table given by Snedecor and Cochran (1994). The software SPSS (Statistical Package for Social Sciences) was also used for analysis, developed by IBM corporation.

B. Management of blackgram powdery mildew under field conditions

The experiment was carried out at research plot of Plant Pathology, Main Agricultural Research Station (MARS), Raichur. Based on the results of *in vitro* evaluation, the effective fungicides such as Difenconazole 25% EC (0.1%), Propiconazole 25% EC (0.1%), Myclobutanil 10% WP (0.1%), Tebuconazole 25.9% EC (0.05%), Hexaconazole 5% EC (0.15), Mancozeb 75% WP (0.3%), Carbendazim 12% + Mancozeb 63% WP (0.2%) and bioagents *Pseudomonas fluorescens* (Raichur) (0.5%) and *Bacillus subtilis* (0.5%) were selected for their bioefficacy in field conditions. The experiment was laid out in randomized block design using susceptible variety TAU-1 having 10 treatments with three replications, the seeds were sown in 30 × 10 cm spacing in 3 × 3 m^2 plot size and followed recommended package of practices except for powdery mildew disease management. Before appearance of disease five plants were selected randomly in each treatment and tagged. Soon after the appearance of disease, treatments were imposed. First spray of different treatments were imposed at 60 DAS followed by second spray at 75 DAS at 15 days interval. Disease severity was recorded before the spray and after 10 days of each spray by using scale of 0-9 developed by Mayee and Datar (1986). Per cent disease index and per disease reduction over control was calculated. In addition to this yield per plot was also recorded and converted in yield per hectare, further benefit cost ratio was calculated.

Disease scale

Score	Description
0	No symptom of powdery mildew on leaves.
1	Small scattered powdery mildew specks covering 1 % or less leaf area.
3	Small powdery lesions covering 1-10 % of leaf area.
5	Powdery lesions enlarged covering 11-25 % of leaf area.
7	Powdery lesions coalesce to form big patches covering 26-50 % leaf area.
9	Big powdery patches covering 51 % or more of leaf area and defoliation occur

$$PDI = \frac{\text{Sum of individual disease ratings}}{\text{Total no. of plants observed} \times \text{Maximum disease scale}} \times 100$$

RESULTS AND DISCUSSION

A. In vitro evaluation of systemic fungicides against E. polygoni

The results revealed that, all the fungicides were significantly superior over the control (Table 1). Among the ten systemic fungicides, tebuconazole was found to be most effective at all the three concentrations and with highest spore inhibition of 98.10, 98.62 and 99.30 per cent at 0.05, 0.1 and 0.15 per cent respectively with mean spore germination inhibition of 98.67 per cent found significantly superior when compared to other systemic fungicides. It is also known as a DMI (demethylation inhibiting fungicide). Tebuconazole acts by affecting the cell walls of fungi by suppressing spore germination and fungus growth. It also interferes with the production of ergosterol, a molecule essential to the formation of fungus (Annon, 2020). The best treatment was on par with propiconazole with spore germination inhibition of 88.00, 97.00 and 99.30 per cent with mean spore germination inhibition of 94.77 per cent. It is triazoles group of fungicide which interfere with biosynthesis of sterols *i.e*., inhibits the biosynthesis of ergosterol which is essential for structure of cell wall and its absence causes irreversible damage to cell wall and ultimately fungus dies (Haribhai *et al.,* 2020), which was followed by difenconazole (88.60, 97.40 and 97.43%) with mean spore germination inhibition of 94.48 per cent which is on par with hexaconazole (90.00, 95.00 and 95.32%) with mean spore germination inhibition of 93.44 per cent. Whereas least spore germination inhibition was documented in azoxystrobin 40, 62 and 75 per cent at 0.05, 0.1 and 0.15 per cent concentrations respectively with mean spore inhibition of 59 per cent.

Table 1: *In vitro* efficacy of systemic fungicides against *E. polygoni* by spore germination technique.

Sr. No.	Fungicide	Inhibition of spore germination over control (%)			
		Concentration (%)			Mean
		0.05	0.1	0.15	
1.	Azoxystrobin 23% SC	40.00 (39.22)[f]	62.00 (51.92)[e]	75.00 (59.98)[h]	59.00
2.	Carbendazim 50% WP	71.83 (57.92)[e]	72.00 (58.03)[d]	79.16 (62.81)[gh]	74.33
3.	Difenconazole 25% EC	88.60 (70.24)[b]	97.40 (80.69)[ab]	97.43 (80.74)[bc]	94.48
4.	Hexaconazole 5% EC	90.00 (71.54)[b]	95.00 (77.05)[b]	95.32 (77.48)[cd]	93.44
5.	Myclobutanil 10% WP	77.00 (61.32)[d]	84.00 (66.40)[c]	88.00 (69.70)[ef]	83.00
6.	Penconazole 100% EC	81.00 (64.13)[c]	89.00 (70.60)[c]	91.62 (73.14)[de]	87.21
7.	Propiconazole 25% EC	88.00 (69.70)[b]	97.00 (79.99)[ab]	99.30 (85.17)[a]	94.77
8.	Tebuconazole 25.9% EC	98.10 (82.04)[a]	98.62 (83.22)[a]	99.30 (85.17)[ab]	98.67
9.	Thiophanate methyl 41.7% SC	70.00 (56.77)[e]	76.00 (60.64)[d]	89.18 (70.77)[ef]	78.39
10.	Tolfenpyrad 15% EC	70.00 (56.77)[e]	84.00 (66.40)[c]	85.00 (67.19)[fg]	79.67
	Mean	77.45	85.50	89.93	
		S. Em (±)		C.D at 1%	
	Fungicide (F)	0.62		1.74	
	Concentration (C)	0.34		0.95	
	F × C	1.07		3.02	

*Mean of three replications **The values in the parentheses are arc sine values

Across the different concentrations, systemic fungicides tested at 0.15 per cent concentration found highly effective in spore germination inhibition and significantly superior over 0.05 per cent concentration. Fungicides at 0.15 per cent found significantly superior over other fungicides at 0.1 per cent concentration except with difenconazole, hexaconazole and tebuconazole which are statistically on par with each other between these two concentrations.

Among the ten systemic fungicides tested, four fungicides *viz.,* tebuconazole, difenconazole, propiconzole and hexaconazole were the most effective with maximum spore germination inhibition. Praveenkumar, (2013) reported that, maximum inhibition of spore germination of *E. polygoni* was observed in propiconzole (89.61%) followed by hexaconazole (87.56 %) and least in carbendazim (65.71%). Amaresh *et al*., (2013) who reported that, maximum inhibition of conidial germination of *Erysiphe cichoracearum* was noticed in difenconazole (99.78 %), penconazole (98.81 %), propiconazole (98.36 %) and triadimefon (97.94 %). Sheetal, (2020) reported that, difenconazole (88.98%), penconzole (87.74%) and propiconazole (86.80%) were the most effective with maximum spore germination inhibition of *L. taurica* of chilli. Kumar and Chandel (2018) reported that, difenoconazole was most effective in its efficacy as no conidia of rose powdery mildew were germinated and it was followed by the trifloxystrobin + tebuconazole (96.38%), tebuconazole (95.65%) and propiconzole (86.23%). Kavyashree *et al.,* (2017) reported that, triazole fungicides namely propiconzole (78.39%), hexaconazole (70.25%) and difenconazole (64.23%) were highly effective in spore germination inhibition of *L. taurica* in cluster bean.

In general, the treatments comprising of triazole fungicides performed more consistently than other fungicides. These fungicides interfere with biosynthesis of sterols *i.e.* inhibits the biosynthesis of ergosterol which is essential for structure of cell wall and its absence leads to irreversible injury to cell wall and ultimately fungus dies. In addition, they are also known to impede conidial and haustorial formation. They change the sterol content and saturation of the polar fatty acids leading to alterations in membrane permeability and behaviour of membrane bound enzymes (Nene and Thapliyal, 1993).

B. In vitro evaluation of non systemic fungicides against E. polygoni

In the present study, evaluated seven different non systemic fungicides at three different concentration (0.1, 0.2 and 0.3 %) with respect to inhibition of conidial germination of *E. polygoni* DC. under *in vitro* conditions.

All the fungicides were tested statistically significant in inhibiting the conidial germination. The per cent spore germination inhibition over control was calculated.

The observations on spore germination and spore germination inhibition revealed that, all the seven non systemic fungicides were found significantly superior over the control in inhibiting the spore germination of *E. polygoni* (Table 2). Among these mancozeb was most effective at 0.3 per cent concentration with highest spore inhibition of 92.53 per cent and mean spore germination inhibition of 88.62 per cent, which was significantly superior over other treatments because it reacts and inactivates the sulfhydryl groups of amino acids and enzymes within fungal cells resulting in disruption of lipid metabolism, respiration and production of adenosine phosphate and it is classified by the Fungicide Resistance Action Committee (FRAC) in mode-of-action group M (Multi Site Action) (Gullino *et al*., 2010). The best chemical was on par with wettable sulphur with spore germination inhibition of 89.22 per cent with mean spore inhibition of 88.32 per cent, which creates a protective coating on the surface of a plant that prevents the spore germination.

Table 2: *In vitro* efficacy of non systemic fungicides against *E. polygoni* by spore germination technique.

Sr. No.	Fungicide	Inhibition of spore germination over control (%)			
		Concentration (%)			Mean
		0.1	0.2	0.3	
1.	Copper hydroxide 53.8% (36.32) WP	72.90 (58.61)[c]	75.80 (60.51)[c]	80.50 (63.77)[c]	76.40
2.	Dinocap 48% EC	71.60 (57.77)[c]	73.00 (58.67)[c]	81.00 (64.13)[bc]	75.20
3.	Mancozeb 75% WP	85.53 (67.61)[ab]	87.79 (69.52)[a]	92.53 (74.11)[a]	88.62
4.	Propineb 70%WP	64.13 (53.19)[d]	83.31 (65.86)[b]	87.16 (68.97)[abc]	78.20
5.	Wettable sulphur 80% WDG	87.82 (69.55)[a]	87.92 (69.63)[a]	89.22 (70.80)[a]	88.32
6.	Zineb 75 WP	70.05 (56.80)[c]	76.52 (60.99)[c]	82.53 (65.27)[bc]	76.37
7.	Captan 70 WP	84.50 (66.79)[b]	85.50 (67.59)[ab]	87.70 (69.44)[ab]	85.90
	Mean	76.65	81.41	85.81	
			S. Em (±)		C.D at 1%
	Fungicide (F)		0.51		1.45
	Concentration (C)		0.33		0.94
	F × C		0.88		2.51

*Mean of three replications; **The values in the parentheses are arc sine values

Next best fungicide was captan with spore germination inhibition of 87.70 per cent with mean spore inhibition of 85.90 per cent. Captan is a multisite activity fungicide, inhibit spore germination by blocking the activity of thiol containing enzymes involved in mitochondrial respiration in fungal spores (Yang *et al*., 2011). The fungicides with low spore germination inhibition were noticed in dinocap (81%) with mean spore inhibition of 75.20 per cent which acts as uncoupler of oxidative phosphorylation, upsetting the electrochemical balance of the fungal cell and preventing the formation of energy rich ATP, affects the respiration and cell wall formation of fungi (Yang *et al*., 2011). Which is on par with zineb (82.53%) with mean spore inhibition of 76.37 per cent. Least mean spore germination inhibition was documented in copper hydroxide 76.40 per cent.

At 0.1 and 0.2 per cent concentration wettable sulphur showed highest spore inhibition of 87.82 and 87.92 per cent which was on par with mancozeb with spore inhibition of 85.53 and 87.79 per cent. Irrespective of the non systemic fungicides, across the different concentrations the fungicides performed well in spore germination inhibition at 0.3 per cent and found significantly superior over the 0.1 and 0.2 concentrations.

The results obtained in the present investigation are in accordance with the findings of Aswathanarayana (2003) who reported karathane and wettable sulphur were effective in complete inhibition of conidial germination at 0.3 per cent against *Uncinula necator* causing grape powdery mildew. Praveenkumar (2013) observed that, maximum inhibition of spore germination of *E. polygoni* in wettable sulphur (91.21%) followed by mancozeb (88.43 %) whereas copper oxychloride (39.93 %) was found to be the least effective. Amaresh *et al.* (2013) reported that, mancozeb and wettable sulphur inhibited conidial germination of *E. cichoracearum* of 95.55 and 91.53 per cent, respectively. Similarly wettable sulphur 80 WDG showed maximum inhibition of conidial germination (84.60 %) followed by mancozeb (80.65 %) and propineb (76.60 %) at 0.3 per cent concentration, whereas the least per cent inhibition was documented in copper hydroxide (27.44 %) at 0.1 per cent (Sheetal, 2020).

C. In vitro evaluation of combi fungicides against E. polygoni

All the combi fungicides were found effective at all concentrations. Among the nine combi products tested against *E. polygoni,* highest spore germination inhibition was documented in combi product carbendazim 12 % + mancozeb 63 % WP (Saaf) (77.23, 84.29 and 93.65 %) with mean per cent inhibition of 85.06 per cent. It was followed by trifloxystrobin 25 % + tebuconazole 50 % (nativo) (73.15, 81.80 and 89.00 %) at 0.1, 0.2 and 0.3 per cent concentrations respectively with mean spore germination inhibition of 81.32 per cent. The next best fungicides were azoxystrobin 18.2 % + difenconazole 11.4 % SC (72.00, 75.00 and 85.00%) followed by fluopyram 17.7 % + tebuconazole 17.7 % w/w SC (71.60, 79.70 and 79.90 %) and which was found on par with hexaconazole 5 % + captan 70 % WP (71.00, 77.00 and 83.00%) and azoxystrobin 4% + tebuconazole 18.3% (71.20, 75.50 and 82.60%) and with mean spore germination inhibition of 77.33, 77.07, 77.00 and 76.43 per cent respectively (Table 3).

Table 3: *In vitro* efficacy of combi fungicides against *E. polygoni* by spore germination technique.

Sr. No.	Fungicide	Inhibition of spore germination over control (%)			
		Concentration (%)			Mean
		0.1	0.2	0.3	
1.	Azaoxystrobin 11 % + tebuconozole 18.3 %	71.20 (57.52)^{bcd}	75.50 (60.31)^{d}	82.60 (65.32)^{c}	76.43
2.	Azoxystrobin 18.2 % + difenoconazole 11.4 % SC	72.00 (58.03)^{bc}	75.00 (59.98)^{de}	85.00 (67.19)^{bc}	77.33
3.	Carbendazim 12 % + mancozeb 63 % WP	77.23 (61.47)^{a}	84.29 (66.62)^{a}	93.65 (75.37)^{a}	85.06
4.	Carboxin 37.5 % + thiram 37.5 % WP.	70.00 (56.77)^{cd}	71.23 (57.54)^{ef}	73.00 (58.67)^{d}	71.41
5.	Copper oxy chloride 14% + copper hydroxide 14%	69.19 (56.26)^{d}	70.16 (56.87)^{f}	72.00 (58.03)^{d}	70.45
6.	Fluopyram17.7 % + tebuconazole 17.7 % w/w SC	71.60 (57.77)^{bcd}	79.70 (63.20)^{bc}	79.90 (63.34)^{c}	77.07
7.	Hexaconazole 5 % + captan 70 % WP	71.00 (57.39)^{bcd}	77.00 (61.32)^{cd}	83.00 (65.62)^{c}	77.00
8.	Hexaconazole 4 % + zineb 68 % WP	70.16 (56.87)^{cd}	73.50 (58.99)^{def}	80.00 (63.41)^{c}	74.55
9.	Trifloxystrobin 25 % + tebuconazole 50%	73.15 (58.77)^{b}	81.80 (64.72)^{ab}	89.00 (70.60)^{b}	81.32
	Mean	71.73	76.46	82.02	
			S. Em (±)	**C.D at 1%**	
	Fungicide (F)		0.41	1.17	
	Concentration (C)		0.24	0.68	
	F × C		0.72	2.04	

*Mean of three replications; **The values in the parentheses are arc sine values

The low spore germination inhibition was observed in copper oxy chloride 14% + copper hydroxide 14% (airone) (72.00%) followed by carboxin 37.5 % + thiram 37.5 % WP (vitavax power) (73.00%) at the concentration of 0.3 per cent with mean spore germination inhibition of 70.45 and 71.41 per cent, respectively. However, all the fungicides showed same trend of spore germination inhibition at lower concentrations (0.1 and 0.2 %). In all the tested fungicides maximum inhibition was documented in higher concentration compared to lower concentration.

The results obtained in the present investigation are on per with the findings of Hebasur *et al.* (2018), who observed the 100 per cent inhibition of spore germination of *L. taurica* in chickpea at 0.3 per cent concentrations in combi products such as Saaf (carbendazim 12% + mancozeb 63%), taqat (captan 70 % + hexaconazole 5% 75WP) and avtar (hexaconazole 4% + zineb 68%) with mean spore inhibition of 96.81, 97.45 and 97.18 per cent respectively. Haribhai *et al.,* (2020) documented maximum spore inhibition of *E. polygoni* in tebuconazole 50% + trifloxystrobin 25% WG (70.10%) followed by tebuconazole 10% + sulphur 65% WG with 66.57 per cent. Similarly trifloxystrobin 25 % + tebuconazole 50 % (91.61 %) showed maximum inhibition of conidial germination followed by fluopyram 17.7 % + tebuconazole 17.7 % SC (87.37 %) and azoxystrobin 11 % + tebuconazole 18.3 % (85.58 %) at 0.3 per cent concentration, whereas the least per cent inhibition was documented in carbendazim 12 % + mancozeb 63 % (59.79 %) at 0.01 per cent (Sheetal, 2020).

D. In vitro evaluation of bioagents against E. polygoni by spore germination technique

In vitro evaluation of bioagents was conducted with respect to inhibition of conidial germination of *E. polygoni* at different (5, 10, 15 and 20%) concentrations as explained in "Material and Methods". The outcomes are presented in the Table 4.

Table 4: *In vitro* efficacy of bioagents against *E. polygoni* by spore germination technique.

Sr. No.	Bioagent	Inhibition of spore germination over control (%)				
		Concentration (%)				Mean
		5	10	15	20	
1.	*Trichoderma harzianum* (Dharwad)	38.21 (38.17)[f]	50.65 (45.35)[d]	71.64 (57.80)[d]	86.81 (68.68)[c]	61.83
2.	*Trichoderma harzianum* (Raichur)	61.20 (51.45)[e]	75.20 (60.11)[c]	83.02 (65.64)[c]	87.31 (69.10)[c]	76.68
3.	*Trichoderma viride* (Raichur)	82.09 (64.94)[c]	82.24 (65.05)[bc]	90.63 (72.15)[b]	91.63 (73.15)[bc]	86.65
4.	*Bacillus subtilis* (Raichur)	85.07 (67.24)[b]	86.19 (68.16)[b]	87.37 (69.15)[bc]	88.62 (70.26)[c]	86.81
5.	*Pseudomonas fluorescens* (Dharwad)	95.80 (78.14)[a]	96.15 (78.65)[a]	96.58 (79.31)[a]	97.50 (80.87)[a]	96.51
6.	*Pseudomonas fluorescens* (Raichur)	94.90 (76.92)[a]	95.08 (77.15)[a]	96.66 (79.44)[a]	96.80 (79.66)[ab]	95.86
7.	*Ampelomyces quisqualis*	75.00 (59.98)[d]	83.00 (65.62)[bc]	86.20 (68.17)[bc]	92.05 (73.59)[bc]	84.06
	Mean	76.04	81.22	87.44	91.53	
			S. Em (±)		C.D at 1%	
	Fungicide (F)		0.65		1.85	
	Concentration (C)		0.49		1.40	
	F × C		1.31		3.70	

*Mean of three replications; **The values in the parentheses are arc sine values

Seven bioagents had statistically significant effect on inhibition of conidial germination of *E. polygoni.* Highest spore germination inhibition was documented in *P. fluorescens* (Dharwad) (95.80, 96.15, 96.58 and 97.50%) and was significantly superior over rest of the treatments with mean spore inhibition of 96.51 per cent, but it was on par with *Pseudomonas fluorescens* (Raichur) (94.90, 95.08, 96.66 and 96.80%) at 5, 10, 15 and 20 per cent concentrations respectively with mean per cent inhibition of 95.86 per cent. *P. fluorescens* produce volatile organic compounds (VOCs) and metabolites which might inhibited the spore germination of *E. polygoni.*

Next best biocontrol agents were *Bacillus subtilis* (Raichur) (85.07, 86.19, 87.37 and 88.62%) followed by *T. viride* (Raichur) (82.09, 82.24, 90.63 and 91.63%) and *Ampelomyces quisqualis* (75.00, 83.00, 86.20 and 92.05%) with mean spore inhibition of 86.81, 86.65 and 84.06 per cent respectively.

Least conidial germination was observed in *T. harzianum* (Dharwad) (38.21, 50.65, 71.64 and 86.81%) and *T. harzianum* (Raichur) (61.20, 75.20, 83.02 and 87.31 %) at concentrations of 5, 10, 15 and 20 per cent cultural filtrates respectively with mean spore inhibition of 61.83 and 76.68 per cent respectively.

The results obtained in the present investigation are similar to the findings of (Praveenkumar, 2013) who reported that, maximum inhibition of conidial germination was in *P. fluorescens* (51.79%) followed by *T. viride* (32.89%) each at 1.0 per cent concentration. Siddappa, (2012) observed that, maximum inhibition of conidial germination was in *P. fluorescens* (93.16%) which was followed by *T. viride* (82.72%) and least in *Pseudomonas putida* (53.15%) at 10 per cent concentration. But these results are in contradictory, with Biju (2003) observed least inhibition of conidial germination of *E. polygoni* in *P. fluorescens* (8.26%) at 0.1 per cent concentration but *T. harzianum* was showed maximum spore inhibition of 48.77 per cent.

E. Management of blackgram powdery mildew under field conditions

In the present study two sprays of difenconazole (0.1%) at 75 and 85 DAS was most effective in reducing the disease severity with least PDI of 26.33 and 31.11 per cent with 57.35 and 66.57 per cent reduction in disease over control. It was followed by two sprays of propiconzole (0.1%) at 75 and 85 DAS was effective fungicide with 29.38 and 34.81 per cent disease severity and 52.41 and 62.58 per cent reduction in disease over control was documented. Next best fungicide was tebuconazole at 0.1 per cent with 30.86 and 35.85 per cent disease severity and 50.01 and 61.47 per cent reduction in disease over control at 75 and 80 DAS which was on par with hexaconazole (0.1%) with 31.10 and 36.54 per cent disease severity and 49.61 and 60.73 per cent disease reduction over control was documented . Whereas *B. subtilis* (0.5%) and *P. fluorescens* (0.5%) were least effective in controlling the disease with 46.17 and 42.96 per cent disease severity with 50.38 and 53.83 per cent reduction of disease respectively at 85 DAS over control. All other treatments were also effective in reducing the severity of the disease, significantly. Whereas maximum PDI of 93.05 was noticed with untreated control indicating the sufficient disease pressure for drawing the meaningful conclusions.

The yield data revealed that, the plots treated with fungicides gave significantly higher yield over control

(Table 5). The mean yield of the plot treated with difenconazole was found to be superior to all the treatments and resulted in maximum yield (12.66 q/ha) followed by propiconzole (11.98 q/ha). The field treated with tebuconazole (11.76 q/ha) which was on par with hexaconazole (11.71q/ha). *B. subtilis* and *P. fluorescens* showed yield performance up to 10.06 and 10.54 q/ha respectively, which were least as compared to other fungicidal treatments. Whereas yield per plant was also maximum in difenconazole (8.97 g/plant), followed by propiconzole (8.93g/plant) and yield per plant was least in plots treated with *B. subtilis* and *P. fluorescens* (6.27 and 6.73 g/plant) respectively.

Table 5: Management of blackgram powdery mildew during *rabi* 2020-21.

Treatments	60DAS	75DAS		85DAS		Yield per plant (g)	Yield (q/ha)*	BC Ratio
	PDI	PDI	Per cent disease reduction over control	PDI	Per cent disease reduction over control			
T_1: Difenconazole 25% EC	20.86 (27.17)	26.33 (30.86)^{a}	57.35	31.11 (33.89)^{a}	66.57	8.97	12.66	2.26
T_2: Propiconazole 25% EC	26.17 (30.76)	29.38 (32.81)^{b}	52.41	34.81 (36.15)^{b}	62.58	8.93	11.98	2.42
T_3: Myclobutanil 10% WP	23.70 (29.12)	34.32 (35.85)^{de}	44.40	40.25 (39.36)^{d}	56.75	7.37	10.43	2.13
T_4: Tebuconazole 25.9 % EC	23.45 (28.96)	30.86 (33.74)^{bc}	50.01	35.85 (36.77)^{b}	61.47	8.55	11.76	2.22
T_5: Hexaconazole 5%EC	22.09 (28.03)	31.10 (33.38)^{bc}	49.61	36.54 (37.18)^{b}	60.73	7.95	11.71	2.39
T_6: Mancozeb 75% WP	21.97 (27.94)	36.54 (37.18)^{e}	40.81	39.34 (38.83)^{cd}	57.72	7.38	11.52	2.31
T_7: Carbendazim12% + Mancozeb 63% WP	22.83 (28.54)	32.59 (34.80)^{cd}	47.21	37.28 (37.62)^{bc}	59.93	7.13	11.36	1.71
T_8: *P. fluorescens* (Raichur)	25.55 (30.35)	43.70 (41.37)^{f}	29.21	42.96 (40.94)^{e}	53.83	6.73	10.54	2.01
T_9: *B. subtilis* (Raichur)	21.72 (27.77)	42.96 (40.94)^{f}	30.41	46.17 (42.79)^{f}	50.38	6.27	10.06	1.90
T_{10}: Control (Check)	25.18 (30.11)	61.73 (51.76)^{g}	–	93.05 (74.68)^{g}	–	5.75	5.98	1.26
S. Em (±)	0.56	0.54		0.64		0.70	0.35	
CD (P≤0.05)	1.68	1.62		1.93		2.10	1.05	

* Means of three replications; Figures in parentheses are arcsine transformed value, PDI: Per cent disease index

Economics of management of blackgram powdery mildew was worked out. Based on the cost benefit ratios, propiconzole, hexaconazole, mancozeb and difenconazole were found to be the best fungicides as these credited highest cost benefit ratio of 1:2.42, 1:2.39, 1:2.31 and 1:2.26 respectively, while tebuconazole, myclobutanil and carbendazim 12% + mancozeb 63% (Saaf) has, 1:2.22, 1:2.13 and 1:1.71 respectively. Bioagents, *P. fluorescens* and *B. subtilis* had cost: benefit ratio 1:2.01 and 1:1.90 respectively.

Propiconazole and hexaconazole belongs to triazoles group. These fungicides interfere with biosynthesis of sterols *i.e.* inhibits the biosynthesis of ergosterol which is essential for structure of cell wall and its absence causes irreversible damage to cell wall and ultimately fungus dies. In addition, they are known to impede conidial and haustorial formation. They change the sterol content and saturation of the polar fatty acids leading to alterations in membrane permeability and behaviour of membrane bound enzymes (Nene and Thapliyal, 1993).

However, the maximum cost benefit ratio was obtained in two sprays of propiconzole (1:2.42) treated plots followed by two sprays of hexaconazole (1:2.39) and mancozeb (1:2.31) and least cost benefit ratio was found in two spray of *B. subtilis* (1:1.90). These results were similar to the findings obtained by Ushamalini and Nakkeeran (2017) who reported that two sprays of propiconzole (0.15%) at 30 and 45 DAS was highly effective in reducing the powdery mildew incidence (4.7%), while in control the incidence was 87.37 per cent. The same treatment also documented higher seed yield of 774.5 kg/ha as against 638.9 kg in control. Khunt *et al.,* (2017) found that, propiconzole (0.025%) was most effective fungicide with mean disease intensity of 4.43 per cent and maximum disease control of 79.28 per cent followed by wettable sulphur (0.2%). The highest yield of 798 kg/ha was obtained in the treatment of propiconzole closely followed by wettable sulphur with 701 kg/ha. Deshmukh *et al.* (2018) studied the efficacy of fungicides against powdery mildew of pea caused by *E. polygoni* DC. The minimum severity of 20.33 per cent was documented in the plots protected with hexaconazole which was followed by propiconzole (25.81%) and wettable sulphur (26.89%). While maximum disease severity of 80.86 per cent was documented in control plot.

CONCLUSION

From the present study it was concluded that, among ten systemic fungicides, seven non systemic fungicides, nine combi fungicides and seven bioagents evaluated against *E. polygoni* under *in vitro* condition, maximum mean inhibition of conidial germination was observed in tebuconazole 25 EC, mancozeb 75 WP, carbendazim 12 % + mancozeb 63 % WP and *P. fluorescens* (Dharwad) respectively. Whereas in field condition two sprays of difenconazole at 0.1 per cent found best fungicide in management of powdery mildew of blackgram followed by propiconazole, tebuconazole and hexaconazole treatments.

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