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Field evaluation of fungicides and bio-agent against anthracnose of pomegranate caused by *Colletotrichum gloeosporioides* (Penz.) Penz. & Sacc.

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Abstract
Pomegranate (*Punica granatum* L.) is an important fruit crop of Northern districts of Karnataka. It is affected by several diseases which reduces yield and quality this fruit crop. Among fungal diseases anthracnose of pomegranate caused by *Colletotrichum gloeosporioides* is of importance. Field evaluation was carried out to assess the efficacy of fungicides and bio-agents against anthracnose of pomegranate at KVK farm, Vijayapur during 2019-20. Among the tested fungicides and bio-agents, spraying of combi-product pyraclostrobin 5% + metiram 55% at 0.3 percent and difenconazole at 0.1 percent were effective on leaves. Severity of disease on fruits revealed that, combi-product pyraclostrobin 5% + metiram 55%, captan 70% + hexaconazole 5%, hexaconazole and difenconazole were effective and on par. Similarly, higher yield was noticed in treatments having these fungicides.

Keywords: Anthracnose, bio-agents, fungicides, *Colletotrichum gloeosporioides*

Introduction
Pomegranate (*Punica granatum* L.) is an important fruit crop of arid and semi-arid regions around the world. It was domesticated around 2000 BC and was one of the first five fruit crops (date palm, fig, olive, grape and pomegranate) to be cultivated by mankind (Anon., 2014) [1]. The usage of pomegranate is profoundly present in history of mankind. Different parts of pomegranate tree are having significant therapeutic value. This commercial crop has higher demand for its fruits and other processed products. Diseases of the pomegranate are considered to be the major constraint affecting the yield, among fungal diseases, anthracnose caused by *C. gloeosporioides* (Penz.) Penz. & Sacc. is of importance. McRae (1924) [8] for the first time reported anthracnose disease in India. This disease is severe particularly during rainy season or high moisture conditions. Under favorable climatic conditions this disease has caused yield loss of up to 100 percent (Jain and Desai, 2018) [4]. In the present investigation, field evaluation was carried out to assess the efficacy of fungicides and bio-agents against anthracnose of pomegranate at KVK farm Hittinahalli in Vijayapur district during 2019-20 to manage the anthracnose disease of pomegranate. Pomegranate tree were sprayed with different fungicides and bio-agents. The experiment includes best five treatments of *in vitro* studies, one best POP treatment as check and one untreated control with three replications.

Material and Methods
An experiment was conducted at KVK farm Hittinahalli in Vijayapur district during 2019-20 to manage the anthracnose disease of pomegranate. Pomegranate tree (var. Kesar) were sprayed with different fungicides and bio-agents. The experiment includes best five treatments of *in vitro* studies which includes, combi-product pyraclostrobin 5% + metiram 55%, captan 70% + hexaconazole 5%, hexaconazole and tebuconazole 50% + trifloxystrobin 25% one best POP treatment (difenconazole) as check and one untreated control with three replications. Statistical design, Randomized Block Design (RBD) was adopted with three replications and seven treatments. The details of the experiments are given here under.
Variety: Kesar
Spacing: 4.25 m × 3.65 m
Age of the plant: 5 years

Details of treatments

Treatments		Concentration (%)	Quantity/ liter
T1	Hexaconazole 5% EC	0.1	1 ml
T2	Difenconazole 25% EC	0.1	1 ml
T3	Tebuconazole 50% + Trifloxystrobin 25%	0.025	0.25 g
T4	Captan 70% + Hexaconazole 5%	0.2	2 g
T5	Pyraclostrobin 5% + Metiram 55%	0.3	3 g
T6	*Trichoderma harzianum*	1.0	10 ml
T7	Untreated Control	-	-

Statistical design and observation

Design: Randomized Block Design (RBD).
Replications: Three
Treatments: Seven
In total three sprays were given at the intervals of fifteen days, observations on disease severity were scored using 0-5 scale (Wheeler, 1969) [11].

Grade	Area of infection (%)	
	On fruits	On leaf
0	No infection	No infection
1	1-10	Up to 5
2	11-25	6-10
3	26-50	11-20
4	51-75	21-50
5	>75	>50

The percent disease index (PDI) was calculated and angular transformed data used for statistical analysis. Percent disease reduction over the untreated control was worked out. Percent disease index (PDI) was calculated by using following formula proposed by Wheeler (1969) [11].

$$\text{Percent disease index (PDI)} = \frac{\text{Sum of the individual disease ratings}}{\text{Number of leaves assessed} \times \text{Maximum grade}} \times 100$$

Results and Discussion

Severity of anthracnose was uniform before application of treatments. Results of the experiment revealed that (Table 1), after 1st spray least PDI of 15.00 was noticed in T2 (difenconozole 25% EC) which was on par with treatments T1 (hexaconazole 5%EC), T3 (tebuconazole 50% + trifloxystrobin 25%), T4 (captan 70% + hexaconazole 5%), T5 (pyraclostrobin 5% + metiram 55%) and T6 (*T. harzianum*). Maximum PDI was recorded in untreated control (18.75%). After 2nd spray minimum PDI (13.75%) was recorded in treatment T2 (difenconozole 25% EC) and T5 (pyraclostrobin 5% + metiram 55%), which were on par with treatments T1 (hexaconazole 5%EC), T3 (tebuconazole 50% + trifloxystrobin 25%), and T4 (captan 70% + hexaconazole 5%). Maximum PDI was recorded in untreated control (19.17%) followed by T6 (*T. harzianum*) with 16.67 percent. In 3rd spray minimum PDI (10.00%) was recorded in T5 (pyraclostrobin 5% + metiram 55%) followed by T2 (difenconozole 25% EC) with 10.42 percent. T5 (pyraclostrobin 5% + metiram 55%) and T2 (difenconozole 25% EC) are on par with each other and significantly superior to other treatments. Treatments T1 (hexaconazole 5%EC) with 11.67 percent, T3 (tebuconazole 50% + trifloxystrobin 25%) with 12.50 percent and T4 (captan 70% + hexaconazole 5%) with 11.67 percent are on par with each other. Maximum percent disease index was noticed in control T7 (20.00%). T6 treatment (*T. harzianum*) found less effective in controlling anthracnose of pomegranate under field conditions (16.67%).
In case of percent disease control over untreated control, after 3rd spray combi-product pyraclostrobin 5% + metiram 55% showed maximum disease control (64.86%) followed by difenconozole (62.16%). Hexaconazole and combi product captan 70% + hexaconazole 5% showed same level of disease control (54.05%). Least disease control was observed in treatment having *T. harzianum* (21.62%) followed by tebuconazole 50% + trifloxystrobin 25% (48.64%).
Similarly, disease severity on fruit is presented in Table 2 revealed that, after 1st spray minimum PDI of 15.00 percent was recorded on fruit in T5 (pyraclostrobin 5% + metiram 55%) which was on par with T1 (hexaconazole 5%EC), T2 (difenconozole 25% EC), T3 (tebuconazole 50% + trifloxystrobin 25%), T4 (captan 70% + hexaconazole 5%) and T6 (*T. harzianum*). Maximum PDI of 18.75 percent was recorded in untreated control. In 2nd spray least PDI (11.25%) was recorded in treatment T5 (pyraclostrobin 5% + metiram 55%), which was on par with treatments T2 (difenconozole 25% EC) and T4 (captan 70% + hexaconazole 5%). Maximum PDI was noticed in untreated control (20.00%) followed by T6 (*T. harzianum*) with 16.67 percent. In 3rd spray minimum PDI of 8.75 was recorded in T5 (pyraclostrobin 5% + metiram 55%) at 0.3% concentration followed by T4 (captan 70% + hexaconazole 5%), T2 (difenconozole 25% EC), and T1 (hexaconazole 5% EC) which found effective and on par at 0.2, 0.1 and 0.1 percent concentrations respectively. *T. harzianum* was (PDI of 18.33%) was found to be less effective as compared to chemical fungicides.

Table 1: Field evaluation of fungicides and bio-agents against anthracnose of pomegranate during 2019-20

Treatments		Conc. (%)	PDI on leaves			Percent disease control over untreated control		
			No. of sprays			No. of sprays		
			I	II	III	I	II	III
T_1	Hexaconazole	0.1	16.25 (23.76)*	14.17 (22.11)	11.67 (19.97)	17.14	33.33	54.05
T_2	Difenconazole	0.1	15.00 (22.77)	13.75 (21.77)	10.42 (18.82)	25.71	36.11	62.16
T_3	Tebuconazole 50% + Trifloxystrobin 25%	0.025	16.25 (23.76)	14.17 (22.11)	12.50 (20.69)	17.11	33.33	48.64
T_4	Captan 70% + Hexaconazole 5%	0.2	15.42 (23.12)	14.58 (22.43)	11.67 (19.97)	22.85	30.55	54.05
T_5	Pyraclostrobin 5% + Metiram 55%	0.3	15.83 (23.44)	13.75 (21.75)	10.00 (18.41)	20.00	36.11	64.86
T_6	*Trichoderma harzianum*	1.0	16.67	16.67	16.67	14.28	16.66	21.62

			(24.07)	(24.09)	(24.08)			
T 7	Control	-	18.75 (25.65)	19.17 (25.96)	20.00 (26.56)	0.00	0.00	0.00
S. Em. ±			0.55	0.41	0.34			
CD at 5%			1.67	1.25	1.03			

*Arcsine transformed values

Table 2: Field evaluation of fungicides and bio-agents against anthracnose of pomegranate during 2019-20

Treatments		Conc. (%)	PDI on fruits			Percent disease control over untreated control			fruit yield (t/ha)
			No. of sprays			No. of sprays			
			I	II	III	I	II	III	
T 1	Hexaconazole	0.1	15.83 (23.43)*	12.92 (21.06)	10.00 (18.43)	20.00	47.22	78.37	9.94
T 2	Difenconazole	0.1	15.42 (23.10)	12.50 (20.70)	9.58 (18.03)	22.85	50.00	81.08	10.09
T 3	Tebuconazole 50% + Trifloxystrobin 25%	0.025	16.25 (23.76)	12.92 (21.06)	10.42 (18.82)	17.14	47.22	75.67	9.61
T 4	Captan 70% + Hexaconazole 5%	0.2	15.42 (23.12)	12.08 (20.30)	9.17 (17.62)	22.85	52.77	83.78	10.21
T 5	Pyraclostrobin 5% + Metiram 55%	0.3	15.00 (22.77)	11.25 (19.60)	8.75 (17.18)	25.71	58.33	86.48	10.66
T 6	*Trichoderma harzianum*	1.0	16.67 (24.07)	16.67 (24.09)	18.33 (25.35)	14.28	22.22	24.32	8.71
T 7	Control	-	18.75 (25.65)	20.00 (26.56)	22.08 (28.03)	0.00	0.00	0.00	7.79
S. Em. ±			0.58	0.45	0.44				0.28
CD at 5%			1.76	1.37	1.32				0.86

*Arcsine transformed values

Further percent disease reduction over control (PDC) was calculated for all treatments. After 3rd spray among seven treatments highest PDC of 86.48 percent on fruit was recorded in T5 (pyraclostrobin 5% + metiram 55%) at 0.3 percent concentration followed by T4 (captan 70% + hexaconazole 5%) with 83.78 percent, T2 (difenconazole 25% EC) with 81.08 percent and T1 (hexaconazole 5% EC) with 78.37 percent at 0.2, 0.1 and 0.1 percent concentrations respectively. PDC of 75.67 percent was noticed in T3 (tebuconazole 50% + trifloxystrobin 25%) at 0.025 percent concentration. Lowest PDC was observed in T6 (*T. harzianum*) with 24.32 percent at 1 percent concentration.

The findings after three spray indicated that, combi-product pyraclostrobin 5% + metiram 55% and difenconazole 25% EC were on par with each other and significantly superior to other treatments. Hexaconazole 5% EC, combi-products captan 70% + hexaconazole 5% and tebuconazole 50% + trifloxystrobin 25% were on par with each other. *Trichoderma harzianum* found to be least effective. Results on the fruit revealed that combi-product pyraclostrobin 5% + metiram 55%, captan 70% + hexaconazole 5%, hexaconazole 5% EC, difenconazole 25% EC were statistically ion par with each other. The results are in line with report of Hegde (2018) [3]. Madhavan *et al*. (2017) [7] reported about the effectiveness of Cabrio top (pyraclostrobin 5% + metiram 55%) at @ 1750 g/ ha in controlling anthracnose of chilli and increasing yield under field conditions. Jamadar *et al.* (2007) [5] reported the effectiveness of Score 25 EC (difenconazole) in reducing anthracnose of pomegranate by 77.80 to 86.70 percent over untreated control at different concentrations and application of Score 25 EC at 0.25 ml / l and 0.50 ml / l was economical in realizing higher yields. Effectiveness of triazoles is due to their interference in biosynthesis of fungal sterols and ergosterol biosynthesis. Among different fungicides combi-products were significantly superior these results are in agreement with findings of Prashanth *et al*. (2008) [10] and Jayalakshmi (2010) [6]. Strobilurins like pyraclostrobin, trifloxystrobin in combination with tebuconazole, metiram (Cabrio Top) were found highly effective as interfere with the energy production in the fungal cells as it prevents ATP formation by blocking of electron transfer at the site of quinol oxidation in the cytochrome (Devi *et al*., 2020) [2]. Effectiveness of triazoles is attributed to their ability to inhibit sterol biosynthesis pathway in fungi (Nene and Thapliyal, 1973) [9].

Effect of fungicides and bio-agent on yield of pomegranate

Study of effect of fungicides and bio-agent on yield of pomegranate showed that, maximum yield of 10.66 tonnes per ha was recorded in treatment T5 (pyraclostrobin 5% + metiram 55%) at 0.3 percent which was on par with 10.21 tonnes per ha in treatment T4 (captan 70% + hexaconazole 5%), 10.09 tonnes per ha in treatment T2 (difenconazole 25% EC) and 9.94 tonnes per ha in treatment T1 (hexaconazole 5% EC) at 0.3, 0.1 and 0.1 percent concentrations respectively. Treatment T3 (tebuconazole 50% + trifloxystrobin 25%) recorded yield of 9.61 tonnes/ha at 0.025% concentration. Treatment having bioagent *T. harzianum* recorded the yield of 8.71 tonnes per ha. Untreated control recorded the lowest yield of 7.79 tonnes per hectare.

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