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Management of Chilli anthracnose/die-back or fruit rot by systemic acquired resistance activators

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ABSTRACT

Chilli is an important spice, vegetable as well as cash crop of Gujarat, mostly cultivated in Kharif season, which is quite remunerative to farmers. Chilli is prone to several diseases, but anthracnose is a most devastating caused by fungus *Colletotrichum capsici* (Sydow) Butler and Bisby and one of the major constraints in chilli cultivation throughout the world. In the present study various systemic acquired resistance activators tested against chilli anthracnose during 2018, 2019 and 2020 at College of Horiculture, S. D. Agricultural University, Jagudan, Mehsana Gujarat. Data clearly revealed that minimum per cent disease intensity and highest green chilli yield was observed in seed soaking + foliar spray of Azoxystrobin 1000 ppm which was at par with seed soaking + foliar spray of Salicylic acid (SA) 100 ppm during individual year and pooled data also. Azoxystrobin and Salicylic acid (SA) induced systemic acquired resistance by increasing defense enzymes peroxidase (PO), polyphenol oxidase (PPO), phenylalanine ammonia lyase (PAL), β-1, 3 glucanase, chitinase, catalase and defense-inducing chemicals (total phenols). Azoxystrobin is also registered in CIBRC for management of chilli anthracnose with PHI 5 days.

Key words: *Capsicum annuum L., Anthracnose, Systemic acquired resistance activators, PDI, Green Chilli fruit yield etc.*

Introduction

Chilli (*Capsicum annuum* L.) belongs to the family *Solanaceae* having Tropical South America as a center of origin mainly cultivated for its green fruits as vegetable and dry chilli as the spice of commerce. It is a rich source of vitamins 'C', 'A' and 'B'. Chilli is valued for pungency which is imparted by an alkaloid, capsaicin and red pigments (Capsorubin and Capxanthin). Green chilli fruit contain 82.6 per cent water, 6.7 per cent fibers, 0.19 per cent mineral matter, 0.06 per cent fat, 111 mg/ 100g vitamin 'C' and vitamin 'A'. Red chilli fruits contain 22.02 per cent dry matter and 6.69 per cent total ash (Muthakrishnan *et al*., 1983). Chilli also used as a stimulator in medicines.

It is one of the most important spices crop for arid and semi-arid region of India. Gujarat, Rajasthan, Tamil Nadu, Maharashtra, Karnataka are the major chilli producer within the country. In India the production during 2019-20 was around 19.31 lakh tones from an area of 6.84 lakh hectares (Anon., 2020-21). In Gujarat, it is grown in an area of 14.14 thousand hectares with the production of 44.19 thousand MT. (Anon., 2020-21).

Low productivity and inability to withstand in international and national market is due to poor quality crop suffered various diseases caused by fungi, bacteria, viruses, nematodes and physiological disorders at different stages of development.

Colletotrichum capsici (Syd.) Butler and Bisbyis is one of the most important plant pathogens worldwide causing the anthracnose in a wide range of hosts including cereals, legumes, vegetables, others crops and in tree fruits also (Bailey and Jeger, 1992). Chilli anthracnose is a major problem which infects the ripened fruits and resulted into fruit rot; occur frequently around the world in chilli growing areas (Poulos, 1992). Yield loss up to 50% in Thailand, 21-47% in Sri lanka, 15% in Korea and 50% in Malaysia have been narrated by various workers in the article of Than *et al*., 2008. Chauhan (2010) noticed 21.12% to 64.41% yield loss due to anthracnose in different districts of North Gujarat. Integrated management namely cultural methods, biological control, application of chemical fungicides and use of resistant cultivars are amongst the effective disease control measures that have been employed to overcome chilli anthracnose (Than *et al.*, 2008). Although the management of anthracnose disease is still being extensively researched, commercial cultivars of *C. annuum* that are resistant to anthracnose yet have not been established. Use of fungicides appears to be the most practical measure for the management of anthracnose. The strobilurin fungicides azoxystrobin (Quadris), trifloxystrobin (Flint) and pyraclostrobin (Cabrio) have been recently recommended for the control of it, but only preliminary reports are available on efficacy of these fungicides against severe form of the disease. Hence, the present investigation was carried out to assess the effect and efficacy of different fungicides with different systemic acquired resistance (SAR) activators to manage disease effectively and economically.

Materials and Methods

An experiment was conducted on 'Gujarat Chilli 3' (GCh 3) at College Farm, College of Horticulture, S. D. Agricultural University, Jagudan-382710, Dist. Mehsana (Gujarat), India during three consecutive year's *viz*., 2018, 2019 and 2020. The experiment was laid out in a randomized block design (RBD) with twelve treatments and three replications which consists 36 treatment plots. Individual plot having a dimension of 5.40 m × 6.00 m with a spacing of 90 cm × 60 cm. Seed were soaked in one liter of water with desired quantity of chemical for half an hour, then air dried and next day the seeds were sown for raising seedlings. Seed sowing was done during last week of June and transplanting will be done at second week of August in all the years. The recommended package of practices was followed during entire period of experimentation. Irrigation was applied by drip irrigation after completion of rainfall. Water was applied through 4 LPH drippers @ one hour every on alternate day. The first foliar sprays were given immediately after first appearance of disease symptoms followed by one spray at 15 days interval. The seed germination was recorded in nursery after 15 days of sowing in per meter row length and converted in the per cent. The observation on the disease intensity was recorded after 10 days of last spray from 20 randomly selected plants from each plots using 0-9 scale formula (Mayee and Datar, 1986). Where, 0 = No infection 1 = 1-10% infection 3 = 11-25% infection 5 = 26-50% infection 7 = 51-75% infection 9 = > 75% infection. Based on these observations, per cent disease intensity (PDI) of the disease was worked out using the formula described by Datar and Mayee (1981). The green chilli fruit yield was recorded from individual plots and converted into hectare basis.

Results and Discussion

Effect of systemic acquired resistance activators on seed germination of chilli were found significant during the period of experimentation and pooled also (Table 1). The maximum germination per cent was observed in T_6, *i.e.* seed soaking + foliar spray of Azoxystrobin 1000 ppm followed by T_2, *i.e.* seed soaking + foliar spray of Salicylic acid (SA) 100 ppm which was at par with T_5, *i.e.* seed soaking of Azoxystrobin 1000 ppm but significantly superior over rest of the treatments during course of investigation and in pooled data also, except 2020. The minimum germination per cent was found in T_{12}, *i.e.* control followed by T_{11}, *i.e.* seed soaking of cow urine 10 % which were at par with T_9, *i.e.* seed soaking of Azoxystrobin 1000 ppm and T_{10}, *i.e.* seed + foliar spray of Copper oxiychloride 3000 ppm in pooled.

Effect of systemic acquired resistance activators on per cent disease intensity of chilliwere found significant during the period of experimentation and pooled also (Table 2). The minimum per cent disease intensity was observed in T_6, *i.e.* seed soaking + foliar spray of Azoxystrobin 1000 ppm which was at par with T_2, *i.e.* seed soaking + foliar spray of Salicylic acid (SA) 100 ppm in pooled as well as individual year also. The maximum percent disease

Table 1. Effect of systemic acquired resistance activators on seed germination of chilli

Treat. No.	Treatment Details	Seed Germination (%)			
		2018	2019	2020	Pooled
T_1	Seed soaking of Salicylic acid (SA) 100 ppm	58.46^{cdef}(72.17)	58.29^{d}(71.90)	59.66^{abc}(74.00)	58.80^{cd}(72.69)
T_2	Seed soaking + Foliar spray of Salicylic acid (SA) 100 ppm	61.21^{ab}(76.33)	62.92^{ab}(78.80)	59.87^{ab}(74.33)	61.33^{b}(76.49)
T_3	Seed soaking of Isonicotinic acid (INA) 100 ppm	58.90^{cde}(72.83)	58.51^{d}(72.25)	58.90^{bc}(72.83)	58.77^{cd}(72.64)
T_4	Seed soaking + Foliar spray of Isonicotinic acid (INA) 100 ppm	60.00^{bc}(74.50)	60.65^{c}(75.50)	58.69^{bc}(72.50)	59.78^{bc}(74.17)
T_5	Seed soaking of Azoxystrobin 1000 ppm	60.54^{bc}(75.33)	61.60^{bc}(76.90)	61.48^{a}(76.73)	61.21^{b}(76.32)
T_6	Seed soaking + Foliar spray of Azoxystrobin 1000 ppm	63.18^{a}(79.17)	64.66^{a}(81.15)	61.71^{a}(77.07)	63.18^{a}(79.13)
T_7	Seed soaking of mancozeb 2000 ppm	57.61^{def}(70.83)	56.99^{de}(69.85)	57.73^{bcd}(71.03)	57.44^{de}(70.57)
T_8	Seed soaking + Foliar spray of mancozeb 2000 ppm	59.55^{bcd}(73.83)	60.08^{c}(74.65)	57.61^{cd}(70.83)	59.08^{c}(73.10)
T_9	Seed soaking of Copper oxychloride3000 ppm	57.08^{efg}(70.00)	56.67^{de}(69.35)	56.15^{d}(68.50)	56.63^{e}(69.28)
T_{10}	Seed + Foliar spray of Copper oxychloride 3000 ppm	57.82^{def}(71.17)	57.50^{de}(70.65)	56.02^{de}(68.30)	57.11^{e}(70.04)
T_{11}	Seed soaking of cow urine 10 %	56.67^{fg}(69.33)	55.65^{ef}(67.70)	55.74^{de}(67.83)	56.01^{e}(68.29)
T_{12}	Control	55.33^{g}(67.17)	54.16^{f}(65.25)	54.11^{e}(65.17)	54.53^{f}(65.86)
	S. Em±	0.64	0.59	0.64	0.62
	$CD_{0.05}$	1.88	1.73	1.87	1.76
	Y X T				1.42
	CV %	5.89	4.73	6.90	5.84

Figures in parentheses are re-transformed values of arc sine transformation treatments mean with the common letter(s) are non-significant by DNMRT at 5 % level of significance

intensity was found in T_{12}, *i.e.* control followed by T_{11}, *i.e.* seed soaking of cow urine 10 %.

Effect of systemic acquired resistance activators on green fruit/pod yield of chilli were found significant during individual years as well as pooled also (Table 3). All the treatments were found effective and producing significantly higher green chilli fruit yield than untreated control. Significantly higher green chilli fruit yield was recorded in treatment T_6, *i.e.* seed soaking + foliar spray of Azoxystrobin 1000 ppm followed by T_2, *i.e.* seed soaking + Foliar spray of Salicylic acid (SA) 100 ppm. Minimum green chilli fruit yield were found in T_{12}, *i.e.* control followed by T_{11}, *i.e.* seed soaking of cow urine 10 %. In the year 2018 and 2020 T_6, *i.e.* seed soaking + foliar spray of Azoxystrobin 1000 ppm was at par with T_2, *i.e.* seed soaking + foliar spray of Salicylic acid (SA) 100 ppm.

Economics in terms of fruit yield and gross realization of different treatments used in the study revealed that seed soaking with Azoxystrobin 1000 ppm and two spray of Azoxystrobin 1000 ppm first at initiation of disease and second spray at 15 days after first spray (T_6) was gave maximum yield and gross realization, followed by seed soaking with Salicylic acid 100 ppm and two spray of salicylic acid first at initiation of disease and second spray at 15 days after first spray (T_2) while maximum net realization and BCR was found in Seed soaking of Salicylic acid 100 ppm and two spray with Salicylic acid first at initiation of disease and second spray at 15 days after first spray (T_2) followed seed soaking of Azoxystrobin 1000 ppm (T_5).

Ahiladevi and Prakasam (2013) revealed that Azoxystrobin 150 g a.i/ha provided the maximum control of the anthracnose disease, followed by Azoxystrobin 125 g a.i/ha. Anand *et al.*, 2010 found that Pf1 at 2.5 kg ha /1 tested in combination with reduced concentration of azoxystrobin @ 250/ ml ha was highly efficient in management of chilli anthracnose. Dale *et al.*, 1999 found that Amistar (Azoxystrobin) at 125-250 mg ai/l provided longer disease protection than benomyl against anthracnose (*Colletotrichum capsici*) of chilli. The strobilurin fungicides represent important class of chemicals for the management of a broad range of fungal diseases in agricultural production systems. Sudaravadana *et al.*, 2007 found that treating

Table 2. Effect of systemic acquired resistance activators on per cent disease intensity of chilli

Treat. No.	Treatment Details	Per cent disease intensity			
		2018	2019	2020	Pooled
T_1	Seed soaking of Salicylic acid (SA) 100 ppm	34.41^{def}(31.47)	33.88^{cd}(30.60)	35.66^{def}(33.52)	34.65^{ef}(31.86)
T_2	Seed soaking + Foliar spray of Salicylic acid (SA) 100 ppm	29.09^{h}(23.20)	27.85^{g}(21.35)	30.86^{hi}(25.87)	29.27^{i}(23.47)
T_3	Seed soaking of Isonicotinic acid (INA) 100 ppm	33.29^{efg}(29.67)	32.82^{cde}(28.90)	34.45^{efg}(31.60)	33.53^{fg}(30.06)
T_4	Seed soaking + Foliar spray of Isonicotinic acid (INA) 100 ppm	31.80^{g}(27.30)	30.94^{ef}(25.95)	33.11^{gh}(29.37)	31.95^{h}(27.54)
T_5	Seed soaking of Azoxystrobin 1000 ppm	31.25^{g}(26.43)	30.17^{f}(24.80)	32.62^{gh}(28.58)	31.34^{h}(26.60)
T_6	Seed soaking + Foliar spray of Azoxystrobin 1000 ppm	28.90^{h}(22.92)	27.25^{g}(20.50)	30.13^{i}(24.75)	28.76^{i}(22.72)
T_7	Seed soaking of mancozeb 2000 ppm	36.21^{cd}(34.43)	35.01^{c}(32.45)	37.54^{cd}(36.67)	36.25^{d}(34.52)
T_8	Seed soaking + Foliar spray of mancozeb 2000 ppm	33.04^{fg}(29.27)	32.28^{def}(28.05)	34.05^{fg}(30.90)	33.12^{g}(29.41)
T_9	Seed soaking of Copper oxychloride3000 ppm	38.25^{bc}(37.87)	37.47^{b}(36.55)	38.25^{bc}(37.87)	37.99^{c}(37.43)
T_{10}	Seed + Foliar spray of Copper oxychloride3000 ppm	35.37^{de}(33.03)	34.65^{c}(31.85)	36.65^{cde}(35.17)	35.55^{de}(33.35)
T_{11}	Seed soaking of cow urine 10 %	39.16^{b}(39.40)	38.45^{b}(38.20)	40.36^{b}(41.47)	39.32^{b}(39.69)
T_{12}	Control	43.49^{a}(46.90)	42.02^{a}(44.35)	44.35^{a}(48.40)	43.29^{a}(46.55)
	S.Em±	0.68	0.69	0.72	0.36
	$CD_{0.05}$	1.98	2.03	2.10	1.01
	Y X T				NS
	CV %	3.39	3.57	3.47	3.48

Figures in parentheses are re-transformed values of arc sine transformation treatments mean with the common letter(s) are non-significant by DNMRT at 5 % level of significanc

trees with these *viz.,* 1, 2 and 4 ml/l. concentrations provided 100 and more than 60 per cent reduction of panicle and leaf anthracnose compared to untreated mango trees for which disease incidences were 27.73 and 53.68 PDI were noticed. This controlling effect was mainly due to translaminar and systemic movement of azoxystrobin, inside the tissues, which is widely distributed from the site application through diffusion (Vincelli, 2002). Anand *et al.* (2007) evaluated Azoxystrobin at three different concentrations, namely, 31.25, 62.50 and 125 g a.i. ha^{-1} along with mancozeb (1 kg ha^{-1}) and *Pseudomonas fluorescens* (10 kg ha^{-1}) for their efficacy in inducing defense enzymes in tomato against *Alternaria solani* and *Septoria lycopersici*. The activity of defense enzymes peroxidase (PO), polyphenol oxidase (PPO), phenylalanine ammonia lyase (PAL), β-1, 3 glucanase, chitinase, catalase and defense-inducing chemicals (total phenols) was found to be increased in azoxystrobin and *P. fluorescens*-treated tomato plants. The activity of these defense enzymes and chemicals was higher in azoxystrobin (125 g *a.i.* ha^{-1}) and *P. fluorescens*-treated tomato plants compared to other treatments. Increased expression of specific isoforms of PO and PPO was also observed due to ISR induction. These results are in conformity with the findings of Sendhil vel *et al.* (2003), who reported that the activity of PO, PPO, PAL, b-1, 3 glucanase, chitinase and total phenols were higher in azoxystrobin treated grapevine plants due to SAR induction. Salicylic acid (SA) 100 ppm also found effective for management of this disease. Gao *et al.* (2015) reported that Salicylic acid (SA) is an important phytohormone that plays a vital role in a number of physiological responses, including plant defense and provide systemic acquired resistance. Systemic resistance mechanisms are induced in crop plants by treatment with chemical inducers, such as isonicotinic acid (INA), benzothiadiazole (BTH), probenazole and salicylic acid (Sakamoto *et al*., 1999). Hence, azoxystrobin and salicylic acid play an important role as SAR inducers.

Authors' Contributions: All authors equally contributed

Declaration: All authors read, reviewed, agreed and approved the final manuscript

Table 3. Effect of systemic acquired resistance activators on green fruit/pod yield of chilli

Treat. No.	Treatment Details	Green Chilli Yield (kg/ha)			
		2018	2019	2020	Pooled
T_1	Seed soaking of Salicylic acid (SA) 100 ppm	11766.67^{fg}	11967.33^{g}	11258.33^{ef}	11664.11^{f}
T_2	Seed soaking + Foliar spray of Salicylic acid (SA) 100 ppm	12785.00^{ab}	13005.67^{b}	12265.00^{ab}	12685.22^{b}
T_3	Seed soaking of Isonicotinic acid (INA) 100 ppm	11916.67^{ef}	12086.50^{f}	11403.33^{e}	11802.17^{f}
T_4	Seed soaking + Foliar spray of Isonicotinic acid (INA) 100 ppm	12287.33^{cd}	12538.67^{d}	11782.00^{cd}	12202.67^{d}
T_5	Seed soaking of Azoxystrobin 1000 ppm	12516.67^{bc}	12835.33^{c}	12006.67^{bc}	12452.89^{c}
T_6	Seed soaking + Foliar spray of Azoxystrobin 1000 ppm	12994.67^{a}	13213.33^{a}	12462.67^{a}	12890.22^{a}
T_7	Seed soaking of mancozeb 2000 ppm	11423.33^{h}	11564.50^{i}	10914.33^{g}	11300.72^{h}
T_8	Seed soaking + Foliar spray of mancozeb 2000 ppm	12083.33^{de}	12287.00^{e}	11573.33^{de}	11981.22^{e}
T_9	Seed soaking of Copper oxiychloride 3000 ppm	11053.33^{i}	11256.75^{j}	10537.67^{h}	10949.25^{i}
T_{10}	Seed + Foliar spray of Copper oxiychloride 3000 ppm	11550.00^{gh}	11729.00^{h}	11045.33^{fg}	11440.11^{g}
T_{11}	Seed soaking of cow urine 10 %	10996.67^{i}	11008.25^{k}	10491.00^{h}	10831.17^{i}
T_{12}	Control	10353.33^{j}	10515.65^{l}	9718.67^{i}	10195.88^{j}
	S.Em±	94	33	105	44
	$CD_{0.05}$	277	98	307	123
	Y X T				NS
	CV %	10.38	8.48	8.60	9.24

Treatments mean with the common letter(s) are non significant by DNMRT at 5 % level of significance

Table 4. Economics of different treatments

Sr. No	Treatment details	Yield (Kg/ha)	Gross Realization (Rs.)	Cost of Inputs (Rs.)	Net Realization (Rs.)	BCR
T_1	Seed soaking of Salicylic acid (SA) 100 ppm	11664	116641	50005	66636	2.33
T2	Seed soaking + Foliar spray of Salicylic acid (SA) 100 ppm	12685	126852	50220	76632	2.53
T_3	Seed soaking of Isonicotinic acid (INA) 100 ppm	11802	118022	50010	68012	2.36
T_4	Seed soaking + Foliar spray of Isonicotinic acid (INA) 100 ppm	12203	122027	50640	71387	2.41
T_5	Seed soaking of Azoxystrobin 1000 ppm	12453	124529	50010	74519	2.49
T_6	Seed soaking + Foliar spray of Azoxystrobin 1000 ppm	12890	128902	55510	73392	2.32
T_7	Seed soaking of mancozeb 2000 ppm	11301	113007	50005	63002	2.26
T_8	Seed soaking + Foliar spray of mancozeb 2000 ppm	11981	119812	50500	69312	2.37
T_9	Seed soaking of Copper oxiychloride 3000 ppm	10949	109493	50005	59488	2.19
T_{10}	Seed + Foliar spray of Copper oxiychloride 3000 ppm	11440	114401	52100	62301	2.20
T_{11}	Seed soaking of cow urine 10 %	10831	108312	50010	58302	2.17
T_{12}	Control	10196	101959	50000	51959	2.04

Cost of Inputs

Sr.No.	Item	Price Rs. (kg /l)
1	Average Green Chilli rate	10 / kg
2	Salicylic Acid	2200/ kg
3	Isonicotinic Acid	6400/ kg
4	Azoxystrobin	5510/ lit
5	Mancozeb	250/ kg
6	Copper oxiychloride	700/ kg
7	Cow urine	5/l

Table 5. Information regarding pesticide recommended according CIBRC

Crop	Common name of the disease	Dosage per ha			Waiting period from last application to harvest (in days)
		a. i. (g)	Formulation (g/ml)/%	Dilution in water (L)	
Azoxystrobin 23% SC					
Chilli	Fruit rot, Powdery mildew	125 g	500 ml	500-750	5

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