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In vitro efficacy of non systemic, systemic and ready-mix fungicides against *Colletotrichum sorghi* (Cesati.) Wilson causing anthracnose of sorghum

NS Chavda and KK Kanzaria

Abstract
The efficacy of different non systemic, systemic and ready-mix fungicides were tested under *in vitro* condition against *Colletotrichum sorghi* (Cesati.)Wilson causing anthracnose of sorghum using poisoned food technique. All the fungicides tested were capable of inhibiting the mycelial growth of *C. sorghi* at various concentrations as compared to control. Mancozeb 75% WP among non systemic fungicides exhibited mean mycelial growth inhibition of 80.44 per cent. Wettable sulphur 80% WP was the least effective fungicide with mean mycelial growth inhibition of 48.24 per cent. Carbendazim 50% WP, thiophanate methyl 70% WP and benomyl 50% WP among systemic fungicides found best effective and recorded maximum mean mycelial growth inhibition of 99.98, 99.47 and 99.00 per cent, respectively. Whereas, the least effective fungicide was picoxystrobin 22.52% SC with mean mycelial growth inhibition of 77.32 per cent and was found statistically at par with fosetyl-Al 80% WP with mean mycelial growth inhibition of 79.88 per cent. Among ready-mix fungicides, carbendazim 12% + mancozeb 63% WP and carboxin 37.5% + thiram 37.5% WS found equally effective giving 99.98 per cent mean mycelial growth inhibition. While, cymoxanil 8% + mancozeb 64% WP exhibited 64.19 per cent mycelial growth inhibition and remain less effective under laboratory condition.

Keywords: sorghum, anthracnose, *C. sorghi*, fungicides, mycelial growth inhibition

Introduction
Sorghum (*Sorghum bicolour* (L.) Moench) is one of the leading cereal crops in the world. It is used for food, fodder and the production of alcoholic beverages. Sorghum crop is reported to affect by several diseases around the world *viz*., cercospora leaf spot (*Cercospora sorghi*), anthracnose-foliar, head, root and stalk rot (*Colletotrichum graminicola*) and leaf blight (*Drechslera turcicum*). Among them, anthracnose of sorghum caused by *Colletotrichum sorghi* has become serious problem in Gujarat during recent years and deteriorated the quality of fodder and reduce the yield. Looking to its importance of this disease in Saurashtra region experiment was conducted to find out the most effective fungicides in inhibiting the mycelial growth at different concentration under *in vitro* condition.

Material and Methods
Evaluation of Fungicides
In vitro evaluation of different fungicides against anthracnose of sorghum caused by *C. sorghi* was carried out in Factorial Completely Randomized design with three repetitions. Mycelial growth inhibition activities of seven non-systemic fungicides *viz*; chlorothalonil 75% WP, copper hydroxide 77% WP, copper oxychloride 50% WP, mancozeb 75% WP, propineb 70% WP, thiram 75% SD, wettable sulphur 80% WP at 500. 1000, 1500 and 2000 ppm concentrations; seven systemic fungicides *viz;* benomyl 50% WP, carbendazim 50% WP, fosetyl-Al 80% WP, metalaxyl MZ 35% WP, picoxystrobin 22.52% SC, propiconazole 25% EC, thiophanate methyl 70% WP at 50, 100, 250 and 500 ppm concentrations and seven ready-mix fungicides *viz;* azoxystrobin 11% + tebuconazole 18.30% SC, carbendazim 12% + mancozeb 63% WP, cymoxanil 8% + mancozeb 64% WP, hexaconazole 4% + zineb 68% WP, carboxin 37.5% + thiram 37.5% WS, tebuconazole 50% + trifloxystrobin 25% WG, tricyclazole 18 % + mancozeb 62 % WP at 100, 250, 500 and 1000 ppm concentrations were tested against *C. sorghi in vitro* by employing poisoned food technique of Bagchi and Das

(1968) [1] using Potato Dextrose Agar (PDA) as a germinating medium. The quantity of each fungicides required was incorporated into autoclaved PDA medium before solidification using micropipette and then medium poured into sterilized Petri dishes (90 mm dia.) in equal quantity (20 ml per Petri dish) to form a uniform layer.

An actively growing mycelial bit of 4 mm diameter was transferred under aseptic conditions over the solidified PDA medium in an inverted position and then Petri dishes were incubated at room temperature (28 $\pm$ 2^0 C) for 7 days. Observations was recorded on linear mycelial growth in treated and control plates. Inoculated Petri dishes containing PDA medium without fungicides were served as control.

The radial growth of fungal colonies were measured from two different angles in millimeter (mm) and the average values were calculated. The per cent mycelial growth inhibition of fungus in each treatment was calculated by using following formula (Vincent, 1947) [2].

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

Where, I = Percent inhibition of mycelial growth
C = Colony diameter in control (mm)
T = Colony diameter in respective treatment (mm)

Results and discussion

In vitro evaluation of non systemic fungicides against *C. sorghi*

The relative efficacy of different seven non systemic fungicides were tested at concentrations of 500, 1000, 1500 and 2000 ppm using poison food technique. The data on per cent mycelial growth inhibition are presented in Table 1 and depicted in Fig. 1.

Data presented in Table 1 revealed that mancozeb 75% WP was the most effective fungicide with 80.44 per cent mean mycelial growth inhibition and significantly superior over rest of the treatments. Copper oxychloride 50% WP and copper hydroxide 77% WP found equally effective with mean mycelial growth inhibition of 78.61 and 77.98 per cent, respectively. This was followed by thiram 75% SD with mean mycelial growth inhibition of 78.05 per cent. Whereas, propineb 70% WP and chlorothalonil 75% WP found moderately effective and remained statistically at par with mean mycelial growth inhibition of 61.93 and 60.32 per cent, respectively. Wettable sulphur 80% WP was the least effective fungicide with mean mycelial growth inhibition of 48.24 per cent.

Effect of different concentration of non-systemic fungicides indicated that increase in fungicidal concentration results in increase in mycelial growth inhibition against given pathogen. Among different non-systemic fungicides, mancozeb 75% WP recorded the maximum mycelial growth inhibition of 92.52 per cent at 2000 ppm concentration and was found significantly superior over rest of the treatments. Copper hydroxide 77% WP found next best effective fungicide with mycelial growth inhibition of 89.47 per cent and found at par with copper oxychloride 50% WP (88.55 per cent) followed by thiram 75% SD (86.25) per cent at 2000 ppm concentration.

The fungicide mancozeb 75% WP exhibited 83.78 per cent mycelial growth inhibition and found at par with thiram 75% SD (83.81) and copper hydroxide 77% WP (80.44) at 1500 ppm concentration. Whereas, wettable sulphur 80% WP found the least effective fungicide with mycelial growth inhibition of 45.62, 46.86 and 48.90 per cent at 500, 1000 and 1500 ppm concentration, respectively.

Table 1: *in vitro* evaluation of non-systemic fungicides against *C. sorghi*

Non systemic fungicides	Concentration (ppm)				Mean inhibition (%)
	500	1000	1500	2000	
Chlorothinol 75% WP	45.42 (50.64)*	49.18 (57.16)	52.95 (63.70)	56.66 (69.78)	51.06 (60.32)
Copper hydroxide 77% WP	55.76 (68.33)	59.13 (73.66)	63.82 (80.44)	70.83 (89.47)	62.39 (77.98)
Copper oxychloride 50% WP	58.79 (73.14)	59.61 (74.40)	62.33 (78.35)	70.92 (88.55)	62.91 (78.61)
Mancozeb 75% WP	57.09 (70.47)	60.00 (74.79)	66.40 (83.78)	74.30 (92.52)	64.45 (80.44)
Propineb 70% WP	49.19 (57.28)	50.45 (59.46)	52.51 (62.96)	55.58 (68.03)	51.93 (61.93)
Thiram 75% SD	60.19 (60.32)	62.29 (81.80)	66.06 (83.81)	69.45 (86.25)	60.19 (78.05)
Wettable Sulphur 80%WP	42.49 (45.62)	43.20 (46.86)	44.37 (48.90)	45.91 (51.59)	43.99 (48.24)
	Fungicides (F)		Concentration (C)		F x C
S.Em.±	0.51		0.38		1.02
C.D. at 5 %	1.44		1.09		2.89
C.V. %	3.08				

Data were arcsine transformed before analysis.
* Numerals in parentheses are re-transformed value

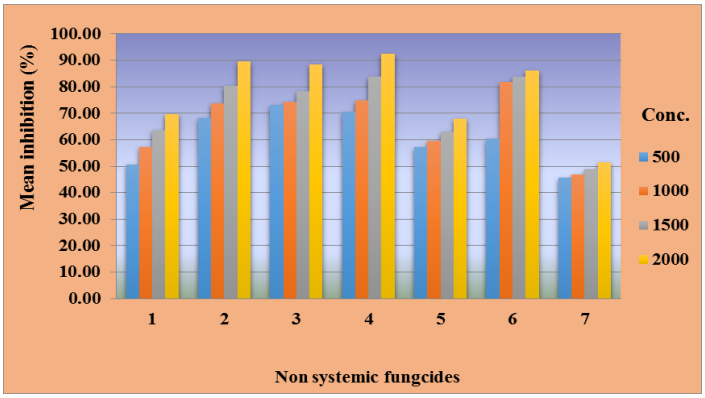

Fig 1: *In vitro* evaluation of non-systemic fungicides against *C. sorghi*

1.	Chlorothalonil 75% WP
2.	Copper hydroxide 77% WP
3.	Copper oxychloride 50% WP
4.	Mancozeb 75% WP
5.	Propineb 70% WP
6.	Thiram 75% SD
7.	Wettable sulphur 80% WP

Similar type of results were also observed by Narendra (2012) [3] and Ravindranath (1978) [4]. They reported that among non-systemic fungicide most effective fungicide with highest average mycelial growth inhibition was observed in mancozeb (75.94%) and copper oxychloride (72.26%) at 0.3 and 0.4 per cent. While, Ravindranath showed that thiram and mancozeb were the best effective fungicide exhibiting complete mycelial growth inhibition at 1000 and 2000 ppm, respectively against *C. graminicola*.

In vitro* evaluation of systemic fungicides against *C. sorghi

The relative efficacy of different seven systemic fungicides were tested at concentrations of 50, 100, 250 and 500 ppm using poison food technique. The data on per cent mycelial growth inhibition are presented in Table 2 and depicted in Fig. 2.

Table 2: *in vitro* evaluation of systemic fungicides against *C. sorghi*

Systemic fungicides	Concentration (ppm)				Mean inhibition (%)
	50	100	250	500	
Benomyl 50% WP	79.11 (96.07)*	89.19(99.98)	89.19 (99.98)	89.19(99.98)	86.67(99.00)
Carbendazim 50% WP	89.19(99.98)	89.19(99.98)	89.19(99.98)	89.19(99.98)	89.19(99.98)
Fosetyl-Al 80% WP	57.74(71.51)	60.50(75.63)	66.69(84.33)	69.88(88.04)	63.70(79.88)
Metalaxyl MZ 35% WP	59.92(74.80)	65.34(82.58)	70.43(88.42)	83.14(98.52)	69.71(86.08)
Picoxystrobin 22.52% SC	53.29(64.26)	57.91(71.66)	66.96(84.67)	70.41(88.68)	62.15(77.32)
Propiconazole 25% EC	71.35(89.75)	76.40(94.27)	82.51(98.13)	89.19(99.98)	79.86(95.93)
Thiophanate methyl 70% WP	82.05(97.96)	89.19(99.98)	89.19(99.98)	89.19(99.98)	87.41(99.47)
Concentration mean (%)	37.89(45.71)	40.59(48.00)	42.62(50.42)	44.63(51.93)	41.44(49.02)
	Fungicides (F)		Concentration (C)		F x C
S.Em.±	0.60		0.45		1.21
C.D. at 5 %	1.71		1.29		3.43
C.V. %	2.73				

Data were arcsine transformed before analysis.
* Numerals in parentheses are re-transformed value

Data presented in Table 2 revealed that carbendazim 50% WP was the most effective with 99.98 per cent mean mycelial growth inhibition and found significantly superior over rest of the treatments. Thiophanate methyl 70% WP and benomyl 50% WP recorded next best and found equally effective with mean mycelial growth inhibition of 99.47 and 99.00 per cent, respectively. This was followed by propiconazole 25% EC with mean mycelia growth inhibition of 95.93 per cent. Whereas, picoxystrobin 22.52% SC was the least effective fungicide with mean mycelial growth inhibition of 77.32 per cent which remained at par with fosetyl-Al 80% WP and recorded mean mycelial growth inhibition of 79.88 per cent.

Effect of different concentration of systemic fungicides indicated that increase in fungicidal concentration results in increase in mycelial growth inhibition against given pathogen. Among different systemic fungicides, carbendazim 50% WP recorded the maximum mycelia growth inhibition of 99.98 per cent at all concentrations (50, 100, 250, 500 ppm) and was found statistically at par with thiophanate methyl 70% WP and benomyl 50% WP at 100, 250 and 500 ppm followed by propiconazole 25% EC at 500 ppm concentration. Whereas, metalaxyl MZ 35% WP (98.52) at 500 ppm followed by propiconazole 25% EC (98.13) and thiophanate methyl 70% WP (97.96) found moderately effective in inhibiting the mycelial growth at 250 and 50 ppm concentration, respectively.

The least effective systemic fungicide found was picoxystrobin 22.52% SC with mycelial growth inhibition of 64.26 per cent at 50 ppm concentration.

More or less similar result also reported by Rekha (2013) [6] and Narendra (2012). They recorded 100 per cent growth inhibition with carbendazim, propiconazole at 50, 100, 200 and 400 ppm concentration. While, Singh *et. al.* found 100 per cent inhibition at 250 and 500 ppm concentrations in thiophanate methyl against *C. graminicola*.

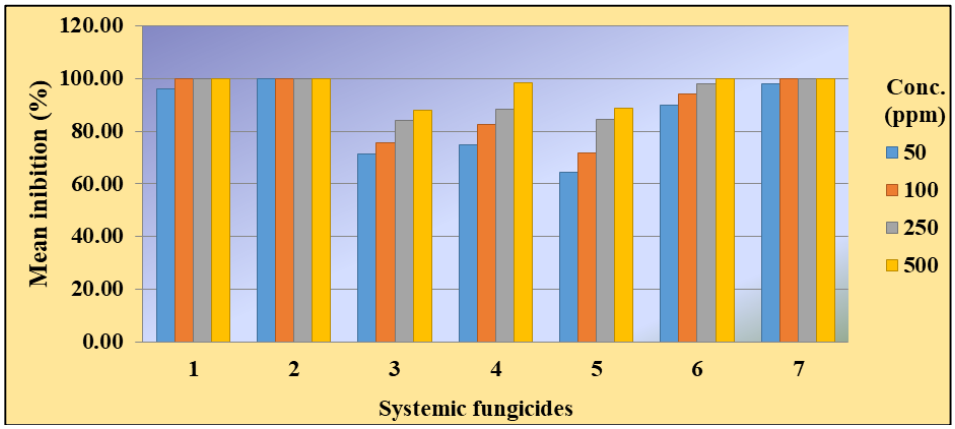

Fig 2: *in vitro* evaluation of systemic fungicides against *C. sorghi*

1.	Benomyl 50% WP
2.	Carbendazim 50% WP
3.	Fosetyl-Al 80% WP
4.	Metalaxyl MZ 35% WP
5.	Picoxystrobin 22.52% SC
6.	Propiconazole 25% EC
7.	Thiophanate methyl 70% WP

In vitro* evaluation of ready-mix fungicides against *C. sorghi

The relative efficacy of different seven ready-mix fungicides were tested at concentrations of 100, 250, 500 and 1000 ppm using poison food technique. The data on per cent mycelial growth inhibition are presented in Table 3 and depicted in Fig. 3.

Table 3: *in vitro* evaluation of ready-mix fungicides against *C. sorghi*

Ready-mix fungicides	Concentration (ppm)				Mean inhibition (%)
	100	250	500	1000	
Azoxystrobin 11% + Tebuconazole 18.30% SC	64.48(81.43)*	66.56(84.16)	68.88(87.02)	71.91(90.24)	67.96(85.71)
Carbendazim 12% + Mancozeb 63% WP	89.19(99.98)	89.19(99.98)	89.19(99.98)	89.19(99.98)	89.19(99.98)
Cymoxanil 8% + Mancozeb 64% WP	44.26(48.71)	51.47(60.70)	57.61(71.30)	60.74(76.03)	53.52(64.19)
Hexaconazole 4% + Zineb 68% WP	51.39(60.96)	57.57(71.25)	60.46(75.57)	66.38(83.88)	58.95(72.92)
Carboxin 37.5% + Thiram 37.5% WS	89.19(99.98)	89.19(99.98)	89.19(99.98)	89.19(99.98)	89.19(99.98)
Tebuconazole 50% + Trifloxystrobin 25 WG	66.77(84.42)	70.59(88.95)	73.21(91.65)	77.76(95.21)	72.08(90.06)
Tricyclazole 18% + Mancozeb 62% WP	53.70(64.91)	58.71 (73.02)	63.12(79.31)	78.00(95.62)	63.38(78.22)
Concentration mean (%)	35.30(41.56)	37.17(44.46)	38.58(46.52)	41.01(49.30)	38.02(45.47)
	Fungicides (F)		Concentration (C)		F x C
S.Em.±	0.61		0.46		1.22
C.D. at 5 %	1.73		1.31		3.47
C.V. %	3.01				

Data were arcsine transformed before analysis.
*Numerals in parentheses are re-transformed value

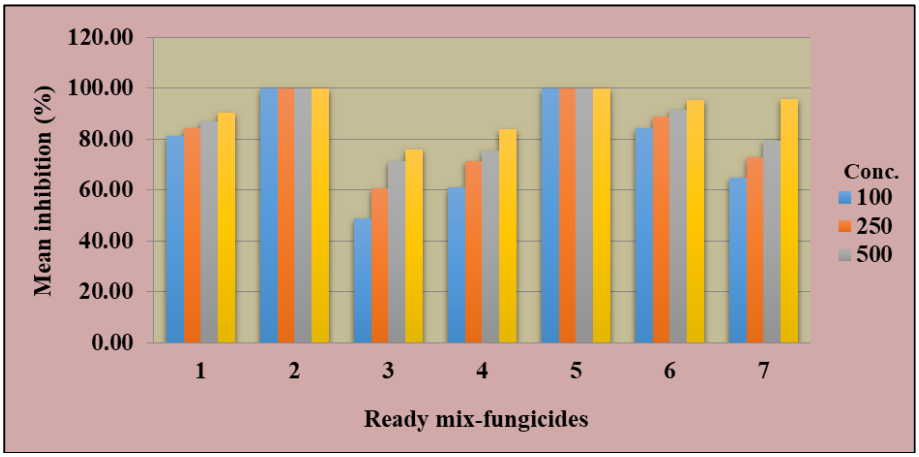

Fig 3: *in vitro* evaluation of ready-mix fungicides against *C. sorghi*

1.	Azoxystrobin 11% + Tebuconazole 18.30% SC
2.	Carbendazim 12% + Mancozeb 63% WP
3.	Cymoxanil 8% + Mancozeb 64% WP
4.	Hexaconazole 4% + Zineb 68% WP
5.	Carboxin 37.5% + Thiram 37.5% WS
6.	Tebuconazole 50% + Trifloxystrobin 25% WG
7.	Tricyclazole 18% + Mancozeb 62% WP

Data presented in Table 3 revealed that carbendazim 12% + mancozeb 63% WP and carboxin 37.5% + thiram 37.5% WS were found equally effective with 99.98 per cent mean mycelial growth inhibition and remained superior over rest of the treatments. Tebuconazole 50% + trifloxystrobin 25% WG recorded next best with mean mycelial growth inhibition of 90.06 per cent. Cymoxanil 8% + mancozeb 64% WP was found the least effective fungicide with mean mycelial growth inhibition of 64.19 per cent.

Effect of different concentration of ready-mix fungicides indicated that increase in fungicidal concentration results in increase in mycelial growth inhibition against given pathogen. Among different ready-mix fungicides, carbendazim 12% + mancozeb 63% WP and carboxin 37.5% + thiram 37.5% WS recorded the maximum mycelia growth inhibition of 99.98 per cent at all concentrations (100, 250, 500, 1000) tried. Tricyclazole 18% + mancozeb 62% WP and tebuconazole 50% + trifloxystrobin 25% WG found equally effective at 1000 ppm concentration with mycelial growth inhibition of 95.62 and 95.21 per cent, respectively. The least effective fungicide in inhibiting mean mycelial growth was cymoxanil 8% + mancozeb 64% WP with 48.71 per cent at 100 ppm concentration.

The more or less similar trend was also observed by Rekha (2013) [6] and found 100 per cent growth inhibition with carbendazim + mancozeb at 50, 100, 200 and 400 ppm concentration *in vitro*.

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