J. Mycopathol. Res. **52(2)** : *217-225, 2014;* (ISSN 0971-3719)

Search for new fungicides against Stem rot of jute (*Corchorus olitorius* L. and *C.capsularis* L.) caused by *Macrophomina phaseolina* (Tassi) Goid

RAJIB KUMAR DE

Division of Crop Protection, Central Research Institute for Jute and Allied Fibres, Indian Council of Agricultural Research, Barrackpore, Kolkata 700120

Received : 09.12.2013 RMS Accepted : 10.09.2014 Published : 27.10.2014

Search for new fungicides for management of Stem rot of jute (*Corchorus olitorius* L. and *C. capsularis* L.), caused by *Macrophomina phaseolina*, revealed that pre-sowing seed treatment followed by foliar spraying of tebuconazole one month after sowing resulted in lowest Stem rot incidence of 25 % and it was statistically at par with carbendazim (28.5%) and hexaconazole (28.6%) compared to 45.2 % in check. These were best fungicides against jute stem rot pathogen as also observed in *in vitro* tests. These were followed by tricyclazole, copper oxychloride and mancozeb, respectively, with 33.4, 33.5 and 35.9 % of Stem rot incidence. Among the fungicides tested, thiophanate methyl was least effective against Stem rot of jute with 38.7 % disease. The progress of stem rot was slowest in tebuconazole and carbendazim in all the dates of crop growth from 30 to 90 days after sowing. Chemicals and fungicides causing complete inhibition of *M. phaseolina* under *in vitro* tests were propiconazole 25% EC (10 μg/ml), turmeric oil (10 μg/ml), carbendazim 50 WP (25 μg/ml), copper oxychloride 50 WP (50 μg/ml), tebuconazole 25.9% EC (50 μg/ml), hexaconazole 5% EC (100 μg/ml), curcumin mixture (100 μg/ml) and tricyclazole 75% WP (10000 μg/ml).

Key words: Jute, Stem rot, fungicides, *Macrophomina phaseolina*

INTRODUCTION

Jute (*Corchorus olitorius* L. and *C. capsularis* L.), often called 'golden fibre', is one of the important commercial fibre crops of India and grown mostly in its eastern region with an area of 0.91 million hectares and production 11.82 million bales (one bale = 180 kgs) dry fibres with fibre productivity of 2349 kg per hectare. It is cultivated as pre-*kharif* crop mainly in the states of West Bengal, Bihar and Assam with percentage contributions to National production jute fibres are 79.54, 10.80 and 6.22, respectively (Anonymous, 2012). Recently jute has emerged with stronger attributes due to its eco-friendliness with more oxygen producing, carbon dioxide absorbing and higher fuel wood producing capabilities, apart from its biodegradable diversified products.

Jute crop is infected with many fungal, bacterial, viral and nematode diseases. Out of these, Stem rot of jute caused by *Macrophomina phaseolina* (Tassi) Goid. is economically the most important disease affecting both yield and quality of fibre in both cultivated species, namely, *C. olitorius* L. and *C. capsularis* L. Stem rot is the common name but the pathogen attacks any part of the plant at any stage of growth right from germination to harvest producing various symptoms, like, damping-off, seedling blight, leaf blight, stem rot, collar rot, root rot and spot on pod especially in seed crop. The disease is seed, soil as well as air borne and continues to damage the crop in all jute growing areas in India and other countries starting from germination to maturity in both seed and fibre crops. Hence, management of jute stem rot targets manipulation of soil, pre-sowing seed treatment and foliar spraying of fungicides or judicious combination of all. Development of Stem rot in jute is dependent on environmental and soil factors, namely, soil moisture, relative humidity and air temperature. Jute crop in acid soils with pH 6.0 and below is more readily attacked by stem rot than a crop at neutral soil (Roy *et al.,* 2008).

Tossa jute being most widely cultivated in all the jute growing areas, this investigation has been undertaken to determine the effect of old as well as new fungicides on Stem rot disease of jute in the field.

MATERIALS AND METHODS

In order to search for new fungicides for management Stem rot of jute caused by *M. phaseolina in vitro* and in field, experiments were carried out with few new fungicides along with old. Using standard food poisoned technique, the efficacy of fungicides was tested *in vitro* against two isolates (Barrackpore in West Bengal and Sorbhog in Assam) of *M. phaseolina* from stem rot infected jute plants using potato dextrose agar medium on active ingredient basis in completely randomized design using formula $V_1S_1= V_2S_2$ (where V_1 S_1 and V_2 S_2 were initial and final volumes and concentrations, respectively) to determine final concentrations with minor modifications (De and Mukhopadhyay, 1994). In field, fungicides were applied as pre-sowing seed treatment and followed by a foliar spraying @ 0.1 % active ingredient at 30 days later as per different treatments in randomized block design with three replications on a new jute variety, JRO 8432 at main farm of CRIJAF, Nilganj, Barrackpore, India during normal cropping season of 2010 - 12. The soil in the experimental field was sandy loam and neutral in nature (pH 6.5 - 7.5). The inoculum density of *M. phaseolina* was 2.6×10^2 colony forming units at the surface up to 5 cm depth, gradually decreasing with the depth. Standard agronomic practices for commercial jute crop were followed except application of fungicides as required for different treatments. Percentage incidence of stem rot was noted at fortnightly intervals starting from 30 days after sowing (DAS) and after final thinning of crop. No other plant protection chemical was applied.

RESULTS AND DISCUSSION

Testing efficacy of fungicides in vitro against Macrophomina phaseolina : Effect of hexaconazole 5% EC on M. phaseolina

At the concentration of 5, 10, 50 µg/ml of hexaconazole (Contaf 5 EC), the radial growths were almost same for both the isolates (Barrackpore and Sorbhog) of *M. phaseolina*. When the dosage of hexaconazole was further enhanced from 100 to 1000 µg/ml, the radial growth of the pathogen was completely checked and no growth was observed. On the contrary, the mycelial growth of both isolates of the pathogen was full of 90 mm Perti plates in the untreated check plots.

The inhibition percentage of 83 – 98 % were observed in the concentrations of 5, 10, 50 µg/ml of hexaconazole in case of two isolates (Barrackpore and Sorbhog) of *M. phaseolina.* But with higher concentrations of hexaconazole, i.e., 100 -1000 µg/ml, cent per cent inhibition of growth of both isolates (Barrackpore and Sorbhog) of *M. phaseolina* was noticed (Table 1). Among the two isolates of *M. phaseolina* from jute, no significant difference in the sensitivity to various concentrations of hexaconazole was observed.

Effect of tebuconazole 25.9 % EC on M. phaseolina

The radial growths of 15.25, 7.0 mm and 14.0, 6.75 mm were noted, respectively, in case of two isolates (Barrackpore and Sorbhog) of *M. phaseolina* at the concentrations of 5 and 10 µg/ml of tebuconazole 25.9% m/m EC (Folicur 250 EC). The radial growth of the both isolates of pathogen was completely checked and no growth was observed when the dosage of tebuconazole was further enhanced from 50 to 1000 µg/ml. The mycelial growth of both isolates of the pathogen was 90 mm in Perti plates in the untreated check plots.

The inhibition percentage of 83 – 92 % was observed in the concentrations of 5 – 10 µg/ml of tebuconazole in both the isolates of *M. phaseolina.* But cent per cent inhibition of growth of both isolates (Barrackpore and Sorbhog) was noticed with higher concentrations of tebuconazole, i.e., 50 - 1000 µg/ml. Tebuconazole inhibited growth of two isolates of *M. phaseolina* by 83 – 100 % at 5 – 1000 ppm concentrations (Table 1). There was no

Table 1 : Effect of hexaconazole 5% EC and tebuconazole 25.9 % EC on two isolates of *Macrophomina phaseolina in vitro*

Dosage in µg/ml	Hexaconazole 5% EC				Tebuconazole 25.9 % EC			
	Barrackpore isolate		Sorbhog isolate		Barrackpore isolate		Sorbhog isolate	
	Radial growth (mm)	Inhibition % age	Radial growth (mm)	Inhibition % age	Radial growth (mm)	Inhibition % age	Radial growth (mm)	Inhibition % age
Check	90	-	90	-	90	-	90	-
5.0	14.75	83.61	14.75	83.61	15.25	83.05	14	84.44
10.0	9.75	89.16	9.25	89.72	7	92.22	6.75	92.5
50.0	1.25	98.61	1.5	98.33	0	100	0	100
100.0	0	100	0	100	0	100	0	100
500.0	0	100	0	100	0	100	0	100
1000.0	0	100	0	100	0	100	0	100
CD (P=0.05)	0.66	-	0.50	-	1.89	-	2.33	
SEm±	0.31	-	0.24	-	0.90	-	1.12	

Table 2 : Effect of different doses of propiconazole 25 % EC, tricyclazole 75 % WP, turmeric oil and curcumin mixture on *Macrophomia phaseolina in vitro*

Propiconazole 25 % EC			Tricyclazole 75 % WP			Turmeric oil			Curcumin mixture		
Treatments (Dosage in µg/ml)	Radial growth (mm)	Inhibition %	Treatments (Dosage in µg/ml)	Radial growth mm	% Inhibition	Treatments (Dosage in µg/ml)	Radial growth mm	% Inhibition	Treatments (Dosage in µg/ml)	Radial growth mm	% Inhibition
Check	90.00	-	Check	90.00	-	Check	90.00		Check	90.00	
1	6.00	93.33	0.25	71.50	20.56	1	6	93.33	1	12.00	86.66
2	2.75	96.94	0.50	61.25	31.94	2	2.75	96.94	2	7.75	91.38
5	1	98.88	1.00	51.00	43.33	5	1	98.88	5	4.5	95.00
10	0	100	5.00	43.75	51.39	10	0	100	10	0	97.08
25	0	100	10.00	34.75	61.39	25	0	100	25	1.5	98.33
50	0	100	50.00	25.50	71.67	50	0	100	50	0.5	99.44
100	0	100	100.00	20.50	77.22	100	0	100	100	0	100
250	0	100	250.00	17.00	81.11	250	0	100	250	0	100
500	0	100	500.00	14.75	83.61	500	0	100	500	0	100
1000	0	100	1000.00	7.50	91.67	1000	0	100	1000	0	100
2500	0	100	2500.00	3.50	96.11	2500	0	100	2500	0	100
5000	0	100	5000.00	2.00	97.78	5000	0	100	5000	0	100
10000	0	100	10000.00	0.00	100.00	10000	0	100	10000	0	100
CD (P=0.05)	0.52	-	-	0.43	-	-	1.47	-	-	1.43	-
SEm+	0.26	-	-	0.38	-	-	0.73	-	-	1.02	-

significant difference in the sensitivity to various dilutions of tebuconazole among the isolates (Barrackpore and Sorbhog) of *M. phaseolina* from jute.

Effect of propiconazole on M. phaseolina in vitro

Propiconazole 25 % EC was very effective in reducing growth of *M. phaseolina*. Complete inhibition of growth was observed at concentration of 1 µg/ml onwards whereas in check with no fungicide added radial growth of 90 mm was observed (Table 2).

Effect of tricyclazole on M. phaseolina in vitro

Tricyclazole 75 % WP at a concentration of 5 µg/ml inhibited growth of *M. phaseolina* by 50 % only. Growth was checked completely at concentration as high as 10000 µg/ml (Table 2).

Effect of turmeric oil on M. phaseolina in vitro

Turmeric oil was also found to be very effective against *M. phaseolina in vitro.* Cent per cent growth was inhibited at a low concentration of 10 µg/ml

Table 3 : Effect of fungicides on Stem rot of jute variety JRO 8432 caused by *Macrophomina phaseolina* in the field during 2010.

Treatment	% stem rot infected plant at different DAS*			
	45	75	110	% reduction over check
Thiophanate methyl 70 WP	4.10 (11.56)	7.15 (15.40)	16.07 (23.56)	13.97
Mancozeb 75 WP	3.42 (10.65)	5.60 (13.65)	15.67 (23.31)	16.11
Tricyclazole 75 % WP	2.98 (9.91)	5.55 (13.34)	11.18 (19.36)	40.14
Tebuconazole 25.9 %EC	3.01 (9.98)	4.61 (12.38)	8.06 (16.48)	56.85
Hexaconazole 5 % EC	4.02 (11.47)	5.69 (13.63)	10.11 (18.53)	45.87
Copper oxychloride 50WP	2.92 (9.84)	4.77 (12.62)	12.79 (20.87)	31.53
Carbendazim 50WP	2.67 (9.16)	5.72 (13.81)	9.25 (17.70)	50.48
Untreated Check	4.82 (12.59)	9.86 (18.19)	18.68 (25.59)	-
CD (P= 0.05)	(2.98)	(3.74)	(3.43)	-
SEm±	(1.42)	(1.78)	(1.63)	

* Figures in the parentheses indicate Arc Sine transformed values

Table 4 : The effect of fungicides on stem rot of jute variety JRO 8432 caused by *Macrophomina phaseolina* in the field during 2011.

Treatments*	Per cent stem rot incidence**					% reduction in stem rot over check
	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	
Thiophanate methyl 70 WP	2.93 (9.44)	12.66 (20.02)	21.00 (26.72)	29.89 (32.92)	36.82 (37.12)	25.10
Mancozeb 75 WP	2.90 (9.70)	10.89 (19.19)	20.09 (26.51)	26.93 (31.25)	33.78 (35.53)	31.28
Tricyclazole 75 % WP	3.25 (10.29)	14.77 (22.47)	26.47 (30.69)	26.95 (31.26)	34.12 (35.72)	30.59
Tebuconazole 25.9 % EC	1.66 (7.05)	3.98 (11.47)	7.83 (16.25)	13.86 (21.54)	19.84 (26.05)	60.37
Hexaconazole 5 % EC	2.34 (8.42)	11.09 (19.08)	16.25 (23.70)	16.43 (23.89)	24.68 (29.79)	49.79
Copper oxychloride 50 WP	3.00 (9.95)	7.24 (14.93)	12.04 (20.25)	26.87 (31.19)	31.66 (34.20)	35.59
Carbendazim 50 WP	4.44 (11.96)	13.95 (21.73)	19.48 (26.18)	24.04 (29.35)	26.47 (30.95)	46.15
Untreated Check	7.43 (15.78)	18.88 (25.75)	28.68 (32.35)	31.62 (34.16)	49.16 (44.52)	-
CD (P=0.05)	(4.24)	(8.11)	(7.53)	(5.66)	(8.13)	-
SEm±	(2.02)	(3.86)	(3.58)	(2.69)	(3.87)	-

* Fungicides applied as pre-sowing seed treatment @ 0.1 % active ingredient followed by single foliar spray @ 0.1 % active ingredient at 30 DAS. ** Figures in the parenthesis indicate arc sin transformed values.

onwards. Radial growth of 90 mm was observed in check where no fungicide was added (Table 2).

Effect of curcumin mixture on M. phaseolina in vitro

Curcumin mixture was also effective against *M. phaseolina* with 100 % growth inhibition at 100 µg/ml and above and no growth was observed. But radial growth of 90 mm was noted in check with no fungicide added (Table 2).

Field efficacy of new fungicides against Stem rot of jute :

Effect of fungicides against Stem rot of jute during 2010

Among the new fungicides, tebuconazole 25.9 EC

Table 5 : Effect of new fungicides on the incidence of stem rot of jute variety JRO 8432 caused by *Macrophomina phaseolina* during 2012.

Treatments*	% Mean stem rot**					%reduction in stem rot over check
	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	
Thiophanate methyl 70 WP	0.34 (3.28)	1.63 (7.22)	3.50 (10.72)	16.56 (18.30)	40.58 (23.83)	16.24
Mancozeb 75 WP	0.25 (2.23)	3.76 (10.27)	8.11 (16.12)	23.59 (19.48)	38.08 (28.78)	7.68
Tricyclazole 75 % WP	0.54 (3.88)	1.92 (7.33)	4.97 (11.57)	17.76 (15.45)	32.69 (24.92)	20.75
Tebuconazole 25.9 % EC	0.57 (4.15)	2.02 (8.05)	4.66 (12.43)	17.40 (19.07)	30.31 (24.63)	26.52
Hexaconazole 5 % EC	0.18 (1.94)	1.95 (7.86)	3.97 (11.19)	17.99 (20.81)	32.65 (25.10)	20.84
Copper oxychloride 50 WP	0.31 (2.59)	1.57 (7.20)	5.37 (13.39)	16.57 (18.79)	35.38 (23.92)	14.23
Carbendazim 50 WP	0.63 (4.39)	1.87 (7.610	3.89 (11.30)	14.20 (17.59)	30.68 (22.06)	25.62
Untreated Check	1.62 (7.07)	1.73 (7.41)	5.03 (12.83)	20.75 (18.06)	41.25 (27.03)	-
CD (P=0.05)	(3.22)	(4.470	(5.37	(5.89)	(5.66)	-
SEm+	(1.53)	(2.13)	(2.55)	(2.80)	(2.69)	-

*Two applications: (1) seed treatment before sowing @ 0.1 % a.i. and (2) one foliar spraying at one month after sowing. **Figures in the parentheses represent angular conversion values.

Table 6 : Pooled mean effect of new fungicides on the incidence of stem rot of jute variety JRO 8432 during 2010, 2011 and 2012.

Treatments	Pooled mean stem rot incidence**					% reduction in stem rot over check
	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	
Thiophanate methyl 70 WP	1.64 (7.11)	6.13 (13.94)	12.25 (20.10)	17.87 (24.87)	38.70 (38.43)	14.38
Mancozeb 75 WP	1.57 (7.10)	6.02 (14.13)	14.10 (21.95)	18.71 (25.56)	35.93 (36.83)	20.50
Tricyclazole 75 % WP	1.89 (7.88)	6.56 (14.71)	15.72 (22.95)	16.75 (24.16)	33.40 (35.30)	26.10
Tebuconazole 25.9 % EC	1.11 (5.79)	3.01 (9.96)	6.24 (14.47)	11.96 (20.21)	25.07 (29.99)	44.53
Hexaconazole 5 % EC	1.26 (6.25)	5.68 (13.68)	10.11 (18.47)	13.37 (21.44)	28.66 (32.37)	36.59
Copper oxychloride 50 WP	1.65 (7.38)	3.91 (11.22)	8.71 (17.13)	16.07 (23.59)	33.52 (35.36)	25.48
Carbendazim 50 WP	2.53 (9.01)	6.16 (14.30)	11.69 (19.99)	14.65 (22.50)	28.58 (32.31)	36.76
Untreated check	4.53 (12.22)	8.48 (16.92)	16.85 (24.20)	20.75 (27.08)	45.20 (42.24)	-
CD (P=0.05)	(3.09)	(4.31)	(5.56)	(3.21)	(3.78)	-
SEm+	(1.47)	(2.05)	(2.65)	(1.53)	(1.80)	-

**Figures in the parentheses represent angular conversionvalues.

superseded carbendazim 50 WP. Tebuconazole 25.9 EC reduced stem rot to 8 % from 18.6 % in untreated control resulting in 56.8 % control of stem rot. It was followed by carbendazim 50 WP, hexaconazole 5 % EC, tricyclazole 75 WP and copper oxychloride 50 WP with 9.2, 10.1, 11.1 and 12.7 % stem rot incidence which respectively caused 50.4, 45.8, 40.1 and 31.5 % reduction in disease incidence over untreated check at maturity of the crop.

Initial data at 45 DAS indicated that carbendazim 50 WP was the best in managing stem rot and it was followed by copper oxychloride 50 WP, tricyclazole 75 WP and tebuconazole 25.9 EC with 2.6, 2.9, 2.9 and 3.0 % stem rot, respectively. However, at 75 DAS the efficacy of the different fungicides in terms of incidence of stem rot was almost similar to that of at final stage of the crop. Tebuconazole 25.9 EC was most effective against stem rot with 4.6 % disease incidence, followed by

Table 7 : Effectiveness of different fungicides on *Macrophomina phaseolina*, stem rot pathogen of jute *in vitro*

Crop	Disease	Pathogen	Fungicide	Maximum dosage (µg/ml*) tested	Dosage (µg/ml*) causing 100 % inhibition	Remarks	May be recommended (Yes / No)
Jute	Stem rot	*Macrophomina phaseolina*	Thiram	5000	2000	Good	Yes
			Carbendazim 50 WP	5000	25	*Excellent*	***Yes***
			Copper oxychloride 50 WP	5000	50	Very good	Yes
			Mancozeb 75 WP	5000	-	-	No
			Hexaconazole EC	1000	100	Good	Yes
			Tebuconazole EC	1000	50	Very good	Yes
			Propiconazole 25 % EC	*10000*	*10*	*Excellent*	***Yes***
			Tricyclazole 75 % WP	10000	10000	Poor	No
			Turmeric oil	*10000*	*10*	*Excellent*	***Yes***
			Curcumin mixture	10000	100	Very good	Yes
			Bleaching powder [$Ca(OCl)_2$]	5000	5000	Excellent	Yes

copper oxychloride 50 WP, tricyclazole 75 WP, mancozeb 75 WP, hexaconazole 5 % EC, and carbendazim 50 WP, respectively, with 4.7, 5.5, 5.6, 5.6 and 5.7 % jute stem rot at 75 DAS.

Among all the fungicides tested, thiophanate methyl 70 WP was least effective against stem rot of jute caused by *M. phaseolina* with 4.1, 7.1 and 16% incidence, respectively, at 45, 75 and 110 DAS as compared to 4.8, 9.8 and 18.6 % in untreated check (Table 3).

1) Dynamics of Stem rot of jute with fungicides

The incidence of Stem rot of jute varied among all treatments including untreated check with a low range of 2 – 4 % initially at 45 DAS. When the progress of disease over time was considered, it was observed that in untreated check plot the stem rot increased very rapidly from initial 4.8 to 9.8 in 30 days from 45 DAS and finally to 18.6 % during the maturity of the crop. But in all the fungicide treated plots the growth of stem rot disease was arrested showing high efficacy of these fungicides, except thiophanate methyl 70 WP and mancozeb 75 WP. The progress of disease over time was slowest in case of tebuconazole 25.9 EC and carbendazim 50 WP, where it rose from initial 2 -3 % at 45 DAS to 4 – 5 % at 75 DAS and finally to 8 – 9 % at the harvest of the crop. So, tebuconazole 25.9 EC and carbendazim 50 WP not only managed the stem rot of jute effectively but also decreased the build up of disease over the crop growth period drastically. At the harvest of the crop, the variation in incidence of stem rot was great ranging from lowest of 8 % to a highest of 18.6 % in untreated check (Table 3).

Effect of fungicides against Stem rot of jute during 2011

Tebuconazole was best in reducing the stem rot incidence compared to check in all the dates of observations. It decreased stem rot caused by *M. phaseolina* from 7.4 to 1.6 % at 30 DAS and 49.1 to 19.8 % 90 DAS. It was followed by hexaconazole, carbendazim and copper oxychloride with 24.6, 26.4 and 31.6% incidence of stem rot, respectively. Thiophanate methyl and tricyclazole were least effective in checking stem rot of jute showing 36.8 and 34.1 % stem rot, respectively.

In tebuconazole, the stem rot was reduced by 60.3 % and it was followed by hexaconazole, carbendazim, copper oxychloride, respectively, with 49.7, 46.1 and 35.5 % reduction. In case of mancozeb, tricyclazole and thiophanate methyl 31.2, 30.5 and 25.1 % reduction in stem rot incidence was observed, respectively. Tebuconazole showed lowest stem rot (1.6 %) at 30 DAS followed by hexaconazole and mancozeb with 2.3 and 2.9 % incidence. At 45 DAS, stem rot was also lowest in tebuconazole with 3.9 % followed by copper oxy chloride and mancozeb with 7.2 and 10.8 % incidence. At 60 to 75 DAS, tebuconazole again showed best result against stem rot (7.8 and 13.8 %) followed by copper oxychloride at 60 DAS and hexaconazole at 75 DAS (Table 4).

2) Dynamics of Stem rot of jute with fungicides

In untreated check plot the stem rot increased very rapidly from initial level at 30 days finally to peak during the maturity of the crop. But in all the fungicide treated plots the growth of stem rot disease was restricted showing high efficacy of these fungicides. The progress of stem rot was slowest in tebuconazole followed by hexaconazole, carbendazim as compared to untreated check. In tebuconazole, stem rot appeared with a low level of 1.6 % which later rose gradually to 3.9, 7.8, 13.8 %, respectively, at 45, 60, 75 DAS and finally to a peak of 19.8 % at maturity of the crop at 90 DAS. In comparison, in untreated check, stem rot appeared with 7.4 % which later increased quickly to 18.8, 28.6, 31.6 %, respectively, at 45, 60, 75 DAS and finally to a highest peak of 49.1 % at maturity of the crop at 90 DAS. Stem rot was observed with a low level of 2.3 % which later rose slowly to 11, 16.2, 16.4 %, respectively, at 45, 60, 75 DAS and finally to a peak of 24.6 % at maturity of the crop at 90 DAS, in hexaconazole treated plots. In carbendazim, stem rot appeared with a low level of 4.4 % which later rose gradually to 13.9, 19.4, 24 %, respectively, at 45, 60, 75 DAS and finally to a peak of 26.4 % at maturity of the crop at 90 DAS.

So, tebuconazole 25.9 EC and carbendazim 50 WP not only managed the stem rot of jute effectively but also decreased the build-up of disease over the crop growth period drastically. At the harvest of the crop, the variation in incidence of stem rot was great ranging from a minimum of 19.8 % in tebuconazole to a maximum of 49.1 % in untreated check (Table 4).

Effect of fungicides against Stem rot of jute during 2012

Among the fungicides, carbendazim 50 WP and tebuconazole 25.9 EC were most effective against stem rot of jute showing only 30 % disease compared to 41.2 % in check. Tricyclazole 75 WP and hexaconazole 5 EC were also effective against stem rot with only 32 % stem rot, whereas, thiophanate methyl 70 WP was least effective showing 40 % stem rot incidence at 105 DAS. Highest stem rot (41.2%) was recorded in check.

Pre-sowing seed treatment and one foliar spraying @ 0.1 % active ingredient at one month after sowing with carbendazim or tebuconazole reduced jute stem rot significantly over check with 41.2 % disease. Highest per cent stem rot reduction over check was achieved in case of treatment with tebuconazole (26.5), it was followed by carbendazim (25.6), hexaconazole (20.8) and tricyclazole (20.7). Lowest stem rot reduction was recorded in mancozeb (7.6%) (Table 5).

3) Dynamics of Stem rot of jute with fungicides

In untreated check plot, stem rot increased very rapidly from initial low level at 30 days to finally peak during the maturity of the crop. But in all the fungicide treated plots the growth of stem rot was retarded showing high efficacy of these fungicides. So, carbendazim 50 WP and tebuconazole 25.9 EC not only managed the stem rot of jute effectively but also decreased the build-up of disease inoculum over the crop growth period drastically. At the harvest of the crop, the variation in incidence of stem rot was great ranging from a lowest of 30.3% (in tebuconazole) to a highest of 41.2 % in untreated check. This difference over check was due to the rate of spread of stem rot over time in presence of various fungicides (Table 5).

Pooled mean of all three years (2010, 2011 and 2012)

Pre-sowing seed treatment @ 0.1 % active ingredient followed by one foliar spraying of tebuconazole at one month after sowing resulted in lowest stem rot incidence of 25 % but it was statistically at par with carbendazim (28.5%) and hexaconazole (28.6%). These were best fungicides against jute stem rot pathogen as also observed in *in vitro* tests. These were followed by tricyclazole, copper oxychloride and mancozeb, respectively, with 33.4, 33.5 and 35.9 % stem rot incidence. Maximum stem rot of 45.2% was noted in check where no chemical was applied. Among the fungicides tested, thiophanate methyl was least effective against stem rot of jute with 38.7% disease. Tebuconazole reduced the stem rot of jute over check to a maximum extent (44.5%), it was followed by carbendazim (36.7%) and hexacoazole (36.5%) (Table 6).

When the progress of stem rot was compared with time, it was observed that tebuconazole kept the disease at the lowest levels in all the dates of observations. In tebuconazole, stem rot incidence varied from lowest level of 1.1% at 30 DAS to 11.9% at 75 DAS to further 25% at 90 DAS. The stem rot progressed very fast in check and it rapidly increased from 4.5% at 30 DAS to highest level of 45.2% at 90 DAS. But in all other treatments, the progress of stem rot was somehow checked due to presence of fungicides. Copper oxychloride and hexaconazole performed better that carbandazim up to 60 DAS, as the stem rot was lower in former than latter. In case of carbendazim treated plots, the disease progress was also slow from 2.5% at 30 DAS to 28.5% at 90 DAS. Copper oxychloride also managed to keep the stem rot at low level of 1.6% at 30 DAS to 33.5% at 90 DAS. A low stem rot of 1.2 % was recorded at 30 DAS in hexaconazole and it further slowly increased to 28.6 % at 90 DAS (Table 6). Liquid formulation of fungicide, especially, tebuconazole and hexaconazole exhibited detrimental effect on germination and emergence on jute seeds. However, this negative effect of good fungicide may be overcome by increasing seed rate to some extent or using them as foliar spray.

Ready reckoner of fungicides for management of Stem rot of jute

For the management of Stem rot of jute caused by *M. phaseolina*, the best available option was carbendazim 50 WP which caused 100 % inhibition with as low as 25 μg/ml concentration. Copper oxychloride 50 WP and tebuconazole 25.9 EC were also very good with complete inhibition at only 50 μg/ml. Hexaconazole 5 EC was also effective against pathogen of stem rot of jute at 100 μg/ml with 100 % inhibition. Thiram may also be used when all other fungicides mentioned above are not available and application of mancozeb 75 WP may be discouraged in jute for management of stem rot (De, 2010). Propiconazole 25 EC and turmeric oil were also excellent fungicide and caused complete inhibition of *M. phaseolina* at as low as 10 μg/ml. Curcumin mixture caused complete inhibition of *M. phaseolina* at 100 μg/ml but tricyclazole 75 WP was least preferable fungicide against *M. phaseolina* as it caused complete inhibition at much higher dosage of 10000 μg/ml. The radial growth of *M. phaseolina* was completely checked in food poisoning technique *in vitro* at 5000 μg/ml of bleaching power both at 24 and 48 hours after incubation (Table 7).

Treatment with organo-mercuric compounds for elimination of the pathogen from seed was reported (Mukherjee and Basak, 1973), but these compounds were hazardous for health consideration. Bavistin 50 WP (carbendazim) @ 2.0 g kg^{-1} or Dithane M 45 (mancozeb) @ 5.0 g kg^{-1} and Captan are very effective compounds for this purpose (Som, 1977). Two promising herbicides, namely, trifluraline and quizalofop ethyl completely inhibited the growth of *M. phaseolina in vitro* at 1000 mg ml^{-1} and 25 mg ml^{-1}, respectively, apart from their usual weed management ability in jute (De *et al.*, 2005, 2007). De (2013) also reported that early sown jute crop suffered from more stem rot caused by *M. phaseolina* than late sown crops with 8 dates of sowing of JRO 8432. March sown jute crop was more prone to stem rot (De, 2012a). Overcast cloudy condition, heavy rainfall resulting in near field capacity soil moisture, high atmospheric humidity, air temperature below 32°C and soil temperature below 30°C favoured infection (Rao, 1980). De and Mandal (2012a,b) reported four resistant lines of olitorius against stem rot in evaluation at hot spot of Sorbhog (Assam). Seed infection of jute (De and Mandal, 2012c), fungicidal management (De, 2012b; De *et al.*, 2010; Hembram and De, 2010) and inoculation technique (De and Mandal, 2008) were also reported. Out of eight isolates of *M. phaseolina* tested on 20 jute varieties (of both the species), six isolates showed different degrees of disease reactions while against the remaining two, all the varieties gave similar resistant reaction. From the cultural characteristics, however, all the eight isolates differed from each other and were fitted in a dichotomous key as eight cultural races (Ahmed and Ahmed, 2005).

ACKNOWLEDGEMENTS

The author is grateful to the Director, Central Research Institute for Jute and Allied Fibres (Indian Council of Agricultural Research), Barrackpore, Kolkata 700120 for providing the necessary facilities and Dr. H. Chowdhury for supplying turmeric oil and curcumin mixture necessary for the experiments.

REFERENCES

Ahmed, N., and Ahmed Q. A. 2005. Physiologic specialisation in *Macrophomina phaseoli* (Maubl.) Ashby., causing stem rot of jute, *corchorus species*, Jute Research Institute, Dacca, East Pakistan, *Mycopathologia*. **39**: 129-138.

Anonymous, 2012. Directorate of Jute Development, Ministry of

Agriculture, Government of India, Kolkata, India.

De, R K. 2010. Ready reckoner of fungicides for the management of diseases of jute and mesta. *JAF News (ICAR)* **8**: 19 – 20.

De, R K. 2012a. Influence of date of sowing date on stem rot of jute (*Corchorus olitorius* L.) caused by *Macrophomina phaseolina* (Tassi) Goid. Paper presented in the National symposium on blending conventional and modern plant pathology for sustainable agriculture held on 04 – 06 December at Indian Institute of Horticultural Research, Bangalore, India. pp. 99 -100.

De, R K. 2012b. Search for new fungicides against stem rot of jute. Paper presented in the National symposium on plant microbe interaction and crop health management held on 06 – 07 October at Visva Bharati, Sriniketan, India. pp. 65 - 67.

De, R. K. 2013. Effect of date of sowing on the incidence of stem rot of jute (*Corchorus olitorius* L.) caused by *Macrophomina phaseolina* (Tassi) Goid. *Journal of Mycopathological Research* **51:** 251—257.

De, R. K.; Hembram, S. and R.K. Mandal. 2010. Evaluation of new fungicides on *Macrophomina phaseolina* causing stem rot of jute. *Pestology* **XXXIV :** 39 - 44.

De R K and Mandal R K. 2008. Simple method of inoculation of stem rot pathogen *Macrophomina phaseolina* on jute (*Corchorus* spp.). *Journal of Mycopathological Research* **46 :** 138 1.13.

De, R K. and Mandal R K. 2012a. Four *Corchorus olitorius* L. lines resistant to stem rot pathogen *Macrophomina phaseolina* (Tassi) Goid. *Journal of Mycopathological Research* **50:** 126.

De, R K. and Mandal R K. 2012b. Identification of resistant sources of jute (*Corchorus olitorius* L.) against stem rot caused by *Macrophomina phaseolina* (Tassi) Goid. *Journal of Mycopathological Research* **50:** 217 - 222.

De, R K. and Mandal R K. 2012c. Seed infection of jute (*Corchorus olitorius* and *C. capsularis*) and its management. Paper presented in the National symposium on biotic and abiotic stresses in plants under changing climate scenario held on 29 -30 November at Uttar Banga Krishi Viswavidyalaya, Coochbehar, India. pp. 6-7.

De, R. K.; Mandal, R.K.; Sarkar , S and Ghorai, A.K. 2005. Inhibitory effect of herbicides on *Macrophomina phaseolina* causing stem rot of jute. *JAF News*. **3:** 16.

De, R. K.; Mandal, R.K.; Sarkar , S and Ghorai, A.K. 2007. Non-target effect of herbicides on *Macrophomina phaseolina* causing stem rot of jute. *Environment and Ecology* **25**, *475 – 478.*

De, R K. and Mukhopadhyay, A.N. 1994. Biological Control of Tomato Damping-off by *Gliocladium virens*. *Journal of Biological Control* **8:** 34 – 40.

Hembram, S. and R. K. De. 2010. Effect of thiram, carbendazim, copper oxychloride and mancozeb on *Macrophomina phaseolina* causing stem rot of jute *in vitro*. In Jute And Allied Fibres Production, Utilization And Marketing, Editors, Palit, P.; Sinha, M. K.; Meshram, J.H.; Mitra, S.; Laha, S. K.; Saha, A. R. and Mahapatra, B. S., Indian Fibre Society, Eastern region, Central Research Institute for Jute and Allied Fibres (CRIJAF), Barrackpore, Kolkata 700120. pp 286 -290.

Mukherjee, N., and Basak, M. 1973. Chemotherapeutic control of foot and stem rot of roselle *(Hibiscus sabdariffa* var. *altissima)* caused by *Phytophthora parasitica* var. *sabdariffae. Indian Phytopathol.* **26:** 576-577.

Rao, P. V. 1980. Effect of rainfall and temperature on yield of tossa jute. *Indian J. Agric. Sci.* **50:** 608-611.

Roy, A., De, R.K. and Ghosh, S.K. 2008. Diseases of bast fibre crops and their management. In book, Jute and allied fibres updates, production and technology. Central Research Institute for Jute and Allied Fibres, (Indian council of Agricultural Research), Barrackpore, Kolkata 700120, India. pp. 217 – 241.

Som, D. 1977. Recent concept on jute disease and control measures. *Jute Bull.* April-March issue 1-4.