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Evaluation of fungicides against *R. solani* causal agent of sheath blight ofpaddy

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Abstract
The present study was undertaken to assess the per cent growth inhibition, per cent disease index, per cent disease control and yield parameter against sheath blight of paddy through various fungicidal treatments in *in vitro* as well as in field conditions. In this experiment results were found as propiconazole 25 % EC, tebuconazole 25.9 % EC and carbendazim 12 %+ mancozeb 63 % (75 WP) gave best results in reduction of per cent inhibition under *in vitro*. Where as, lowest per cent disease index and per cent disease control were recorded by propiconazole 25 % EC, hexaconazole 5 % EC and tebuconazole 25.9 % EC.

Keywords: Paddy, *Rhizoctonia solani*, Sheath blight, Fungicides, Yield

1. Introduction
Paddy (*Oryza sativa* L.) is the world's second most important cereal crop and known with different names in India. It is known as Chawal (U.P., M.P., Bihar), Dangar (Gujarat), Vadlu (A.P.), Bhatt (Maharastra), Dhan (West Bengal, Assam, Chhattisgarh), Chaul (Punjab), Shali (Jammu and Kashmir), Nellu (Tamil Nadu, Kerala). It belong to the grass family: Poaceae, sub-family: Oryzoideae (Manglarai and Mauria, 1999) [9]. Paddy is second most important food crops of the world after wheat. It is the staple food crop for people of south, south-east and eastern Asia where 90 per cent of the world's rice is produced and consumed. It is grown in 114 countries across the world on an area of about 160 million hectares with annual production of 494.3 million tones and total supply of 711.5 million tones (Anonymous 2016) [4]. In India, it is grown in 44.40 million hectares in diverse ecological conditions with an annual production of 104.80 million tons and productivity of 2462 kg ha^{-1} (Anonymous, 2015) [3]. Gujarat state ranks 15th and 9th in terms of rice production and productivity respectively.
In Gujarat, rice occupies about 7 to 8 per cent of the gross cropped area of the state and accounts for around 14 per cent of the total food grain production and it is cultivated on an area of 8.08 lakh hectares with total production of 16.36 lakh tons and productivity of about 2076 kg ha^{-1}. The rice growing area of the state comes under the districts of Valsad, Navsari, Dangs, Surat, Bharuch, Narmada, Vadodara, Kheda, Anand, Dahod and Panchmahals (Anonymous, 2014) [2]. It plays a unique role for supplying calories to the majority of population of Asian and Latin American countries. It contains protein 7.3 g, carbohydrates 78 g, fat 3.6 g, crude fibre 0.4 g, mineral matter 0.6 g, thiamine 0.42 mg, riboflavin 0.02 mg, iron 0.4 mg, magnesium 32 mg, zinc 1.8 mg, calcium 51 mg and phosphorus 150 mg per 100g (Anonymous, 2002) [1].
The low yield of rice in the country may be attributed by a number of biotic factors. Among the biotic stresses, the loss inflicted by pathogens, insect pests and nematodes are considerably significant. Different diseases like blast, bacterial blight, sheath blight, sheath rot and grain discoloration causes significant damage to rice crop.
Sheath blight is the most important disease of rice incited by *Rhizoctonia solani* (Kuhn), first reported by Paracer and Chahal, 1963 [10] from Gurdaspur in Punjab. Initial symptoms occur on leaf sheaths near the water line as water-soaked lesions. Secondary infections are caused by hyphae growing upward towards uninfected plant parts, producing additional lesions and sclerotia on leaf sheaths to complete the disease cycle (Brooks, 2007) [5]. Lesion formation on infected sheaths of lower rice leaves may lead to softness of the stem and subsequently stem lodging (Wu *et al*., 2012) [16]. In addition, the fungus survives between crops as sclerotia that can lie dormant in the soil for at least two to three years (UACES, 2015) [14].

Yield stabilization by incorporating genes for resistance and making rice grain nutritionally rich is the priority of present day. For this, innovative agronomic techniques for cost effective crop management such as conjunctive use of organic and inorganic fertilizers, real time N management (leaf color chart based N top dressing), new organic sources of nutrients, foliar application of fertilizers different methods of crop establishment (direct seeding, SRI method), optimum use of herbicides and labor saving farm implements have been developed and tested successfully. These blend of varietal, crop and integrated disease and pest management strategies can assure the goal of achieving and sustaining food and nutritional security for all in coming years with the productivity up to 3200 kg ha^{-1} (Subbaiah, 2006) [13]. In the absence of suitable resistant donors, fungicides are the main answer to check these diseases. The present study was undertaken to evaluate the different fungicides at different formulation for efficient control of sheath blight of rice.

2. Materials and Methods

2.1 *In vitro* evaluation of fungicides against the *Rhizoctonia solani*

To find out the most suitable fungicides for the disease, a laboratory trial was conducted during 2015-2016 at N.M.C.A., N.A.U., Navsari. The detail of the experiment is given in table 1. Efficacy of ten fungicides listed in table-1 were evaluated against *R. solani* at different concentrations by using poisoned food technique. A series of concentration as 250,500,1000,1500 and 2000 ppm of given fungicides were made on the basis of active ingredient. Required amount of each fungicide was incorporated aseptically in autoclaved PDA. Twenty ml. of molten medium amended with different concentrations of the test fungicides were poured in 90 mm sterilized petriplates and allowed to solidify. Three petriplates were used for each concentration to test the sensitivity of *Rhizoctonia solani*. Suitable controls without fungicides were also maintained simultaneously, The colony diameter of the fungus was recorded from three repetitions periodically. The per cent growth inhibition over control was calculated by using formula given by Vincent, 1947.

$$\mathrm{PGI} = \frac{\mathrm{DC} - \mathrm{DT}}{\mathrm{DC}} \times 100$$

Where,

PGI = Per cent growth inhibition

DC = Average diameter of mycelial colony of control set

DT = Average diameter of mycelial colony of treated set

2.2 *In vivo* evaluation of fungicides against the *Rhizoctonia solani*

The field trials were conducted in a randomized block design (RBD) with three replications and plot size of 5.1 m X 3.2 m (spacing 20 cm X 15 cm) on rice variety GR-11 at Main Rice Research Centre Farm of N.A.U., Navsari Gujarat to study the efficacy of different fungicides against sheath blight of rice. These fungicides presented in table-2 were given two spray, first spray was given at the initiation of the disease and the second spray given at milking stage. For recording the intensity of sheath blight, 30 hills per plot were randomly selected and all plants were labeled per hill. These labeled plants were observed for disease intensity using methods described in SES for Rice (IRRI 2002) [7]. The disease rating was recorded by adopting the methodology using 0-9 SES scale. The observations on sheath blight intensity were recorded one day before spraying and 7 days after each spray and at harvest. Grain and straw yield was recorded from net plot area at after harvest. Per cent disease index (PDI) was calculated by using following formula proposed by Wheeler (1969).

Per cent disease index

$$(\mathrm{PDI}) = \frac{\text{Sum of the individual disease ratings}}{\text{Total number of leaves observed X Maximum grade}} \text{ X } 100$$

3. Results and discussion

3.1 *In vitro* evaluation of fungicides against the *Rhizoctonia solani*

All ten fungicides presented in (Table-3) exhibited varying level of efficacy against *Rhizoctonia solani* for mycelia growth inhibition. These fungicides were prepared at different concentration *viz*., 200, 500, 1000, 1500 and 2000 ppm then tested by poisoned food technique. Among all the concentrations, higher concentration produced the maximum inhibition zone, even though the concentration were different for different fungicides. Among the systemic, non systemic and combination product (systemic + non systemic) group of fungicides, propiconazole 25 % EC and tebuconazole 25.9 % EC and carbendazim 12 %+ mancozeb 63 %, were found significantly superior at all 3 concentrations *viz*., 250 ppm, 500 ppm and 1000 ppm respectively with highest growth inhibition (94.44 %) against *R. solani* followed by hexaconazole 5 % EC at 1000 ppm, azoxystrobin 18.2 % + difenconazole 11.4 % at 500 ppm and 1000 ppm and mancozeb 75 % WP at 1500ppm and 2000 ppm concentration.

The next best in order of efficacy were trifloxystrobin 25 % + tebuconazole 50 % at 250 ppm (88.52 %), 500 ppm (91.11 %) and 1000 ppm (92.22 %) followed by azoxystrobin 18.2 % + difenconazole 11.4% at 250 ppm (83.70 %), carbendazim 50 % WP at 250 ppm (85.18 %), 500 ppm (89.63 %), 1000 ppm (89.77 %), hexaconazole 5 % EC at 250 ppm (89.25 %), 500 ppm (90.36 %), mancozeb 75 % WP at 1000 ppm (88.14 %), kresoxim methyl 40 % EC at 250 ppm (77.77 %), 500 ppm (84.44 %) and 1000 ppm (87.00 %) were found effective against *R.solani*. Whereas, copper oxychloride 50% WP was found least effective against *R. solani* with growth inhibition of (20.74 %), (21.47 %) and (24.44 %) at concentrations of 250 ppm, 500 ppm and 1000 ppm respectively.

Results obtained in present study were in line with the findings of, Raji *et al.* (2016) [11] who reported that tebuconazole + trifloxystrobin, hexaconazole and tebuconazole exhibited cent per cent inhibition of *R. solani* at 1000 ppm concentration. Raji *et al*. (2016) [11] found that propiconazole and hexaconazole at 400 ppm exhibited cent percent inhibition against *R. solani*. Srinivas *et al*. (2014) [12] found that mancozeb and carbendazim+ mancozeb gave cent percent inhibition against *R. solani* at (0.1 %) concentration. Dutta and kulha (2011) [6] observed cent per cent inhibition of *R. solani* by carbendazim + mancozeb followed by carbendazim.

3.2 *In vivo* evaluation of different fungicides

Field trial conducted during *kharif* 2015-2016 at Main Rice Research Centre farm of N.A.U., Navsari, Gujarat to study the efficacy of different fungicides against sheath blight of rice, all the test fungicides reduced disease severity and increased grain yield of cultivar GR-11 significantly (Table-4 and Table-5). The results in terms of per cent disease control revealed that propiconazole 25 % EC (0.025 %) recorded with highest per cent disease control (51.95 %) of sheath blight

followed by hexaconazole 5 % EC at (0.005 %) (47.62 %), tebuconazole 25.9 % EC (0.04 %) (45.33 %), carbedazim 12 % + mancozeb 63 % (0.15 %) (44.01 %) and trifloxystrobin 25 % + tebuconazole 50% (0.03 %) (42.90 %), azoxystrobin 18.2 % + difenconazole 11.4% (0.03 %) (40.10 %) and mancozeb 75 % WP (0.25 %) (38.37 %) disease control respectively. The results of grain yield presented in Table-4 revealed that significantly highest grain yield (9.50 kg plot^{-1}) was harvested in propiconazole 25 % EC (0.025 %) which was at par with hexaconazole 5 % EC (0.005 %) (9.00 kg plot^{-1}) and tebuconazole 25.9 % EC (0.04 %) (8.73 kg plot^{-1}) followed by, carbendazim 12% + mancozeb 63% (0.15 %) (7.74 kg plot^{-1}), trifloxystrobin 25% + tebuconazole 50% (0.03 %) (7.35 kg plot^{-1}) and azoxystrobin 18.2% + difenconazole 11.4% (0.03 %) (7.18 kg plot^{-1}). Whereas, mancozeb 75 % WP (0.25 %) yielded with (6.44 kg plot^{-1}) grain yield. Regarding straw yield (Table-5 and Fig.-3), the highest straw yield (11.20 kg plot^{-1}) was recorded in plot treated with propiconazole 25 % EC which was at par with hexaconazole 5 % EC (10.55 kg plot^{-1}) and tebuconazole 25.9 % EC (10.25 kg plot^{-1}) followed by carbendazim 12% + mancozeb 63% (9.10 kg plot^{-1}), trifloxystrobin 25% + tebuconazole 50% (8.80 kg plot^{-1}), azoxystrobin 18.2% + difenconazole 11.4% (8.65 kg plot^{-1}) and mancozeb 75 % WP (8.03 kg plot^{-1}).

Results obtained in present study were harmony with the findings of several workers, Raji *et al*. (2016) [11] reported tebuconazole + trifloxystrobin found most effective fungicide with least disease severity (29.00 %) followed by hexaconazole (29.93 %). Bag (2009) reported trifloxystrobin + tebuconazole and hexaconazole as most effective fungicide in decreasing disease and increasing yield significantly against sheath blight. Lore *et al*. (2007) [8] found that propiconazole (0.1 %) concentration was most effective fungicides followed by carbendazim (0.1 %) against sheath blight under field condition.

Table 1: List of different fungicides tested for their efficacy against *R. solani in vitro*

Treatment No.	Technical name	Concentrations to be tested (ppm)		
Systemic fungicides				
T_1	Kresoxim methyl 40 % EC	250	500	1000
T_2	Propiconazole 25% EC	250	500	1000
T_3	Carbendazim 50% WP	250	500	1000
T_4	Tebuconazole 25.9 % EC	250	500	1000
T_5	Hexaconazole 5% EC	250	500	1000
Non-Systemic fungicides				
T_6	Mancozeb 75% WP	1000	1500	2000
T_7	Copper oxy chloride 50% WP	1000	1500	2000
Systemic fungicides±Non systemic (Combination products)				
T_8	Trifloxystrobin 25% + Tebuconazole 50% (75 WG)	250	500	1000
T_9	Azoxystrobin 18.2% w/w + Difenoconazole 11.4% w/w (29.6SC)	250	500	1000
T_{10}	Carbendazim 12% + Mancozeb 63% (75 WP)	250	500	1000
T_{11}	Control (Untreated)	-	-	-

Table 2: List of fungicides tested against *R. solani in vivo*

Treatment No.	Technical Name	Trade Name	Conc. (%)	Dose (ml/g l^{-1})
T_1	Propiconazole 25 % EC	Tilt	0.025	1.0 ml
T_2	Tebuconazole 25.9 % EC	Folicur	0.04	1.5 ml
T_3	Hexaconazole 5 % EC	Contaf	0.005	1.0 ml
T_4	Trifloxystrobin 25 % + Tebuconzole 50 % (75 WG)	Nativo	0.03	0.4 g
T_5	Carbendazim 12 % + Mancozeb 63 % (75 WP)	Sixer	0.15	2.0 g
T_6	Azoxystrobin 18.2 % + Difenoconazole 11.4 % (29.6 SC)	Amistar Top	0.03	1.0 ml
T_7	Mancozeb 75 % WP	Dithane M-45 75% WP	0.25	3.3 g
T_8	Control (Water spray)	-		-

Table 3: *In vitro* evaluation of fungicides against paddy sheath blight

Treatment No.	Name of fungicides	Conc. (ppm)	Av. colony diameter of pathogen (mm)	Growth inhibition (%)
T_1	Kresoxim methyl 40 % EC	250	4.47* (20.00)**	77.77
		500	3.74 (14.00)	84.44
		1000	3.41 (11.70)	87.00
T_2	Propiconazole 25% EC	250	2.23 (5.00)	94.44
		500	2.23 (5.00)	94.44
		1000	2.23 (5.00)	94.44
T_3	Carbendazim 50% WP	250	3.64 (13.33)	85.18
		500	3.05 (9.33)	89.63
		1000	2.99 (9.20)	89.77
T_4	Tebuconazole 25.9 % EC	250	2.23 (5.00)	94.44
		500	2.23 (5.00)	94.44
		1000	2.23 (5.00)	94.44
T_5	Hexaconazole 5% EC	250	3.10 (9.67)	89.25
		500	2.94 (8.67)	90.36
		1000	2.23 (5.00)	94.44
T_6	Mancozeb 75 % WP	1000	3.34 (10.67)	88.14
		1500	2.23 (5.00)	94.44
		2000	2.23 (5.00)	94.44

T_7	Copper oxychloride 50% WP	1000	8.44 (71.33)	20.74
		1500	8.40 (70.67)	21.47
		2000	8.24 (68.00)	24.44
T_8	Trifloxystrobin 25% + Tebuconazole 50% (75 WG)	250	3.21 (10.33)	88.52
		500	2.81 (8.00)	91.11
		1000	2.64 (7.00)	92.22
T_9	Azoxystrobin 18.2% w/w + Difenoconazole 11.4% w/w (29.6) SC	250	3.81 (14.67)	83.70
		500	2.23 (5.00)	94.44
		1000	2.23 (5.00)	94.44
T_{10}	Carbendazim 12% + Mancozeb 63% (75 WP)	250	2.23 (5.00)	94.44
		500	2.23 (5.00)	94.44
		1000	2.23 (5.00)	94.44
T_{11}	Control (Untreated)	-	9.48 (90.00)	-
	S.Em±	0.07		
	C.D. at 5 %	0.20		
	C.V. (%)	3.32		

*Figure outside parenthesis are $\sqrt{x} + 0.5$ transformed values
**Figure in parenthesis are original value

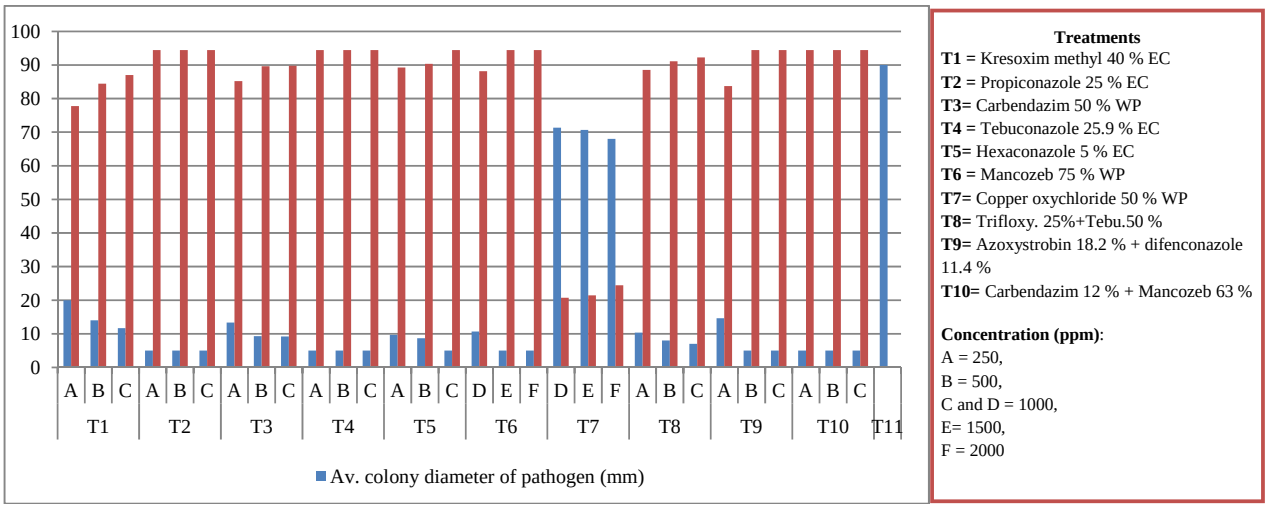

Fig 1: *In vitro* evaluation of fungicides against *R. solani*

Table 4: Evaluation of different fungicides against paddy sheath blight under field condition

Treatment No.	Treatment	Conc. (%)	Dose (gm or ml/l)	PDI				Disease Control (%)
				Before Spray	7 days after first spray	7 days after second spray	At harvest	
T_1	Propiconazole 25 % EC	0.025	1.0 ml	15.66** (7.33)*	22.84** (15.17)*	26.49** (20.00)*	28.58** (23.00)*	51.95
T_2	Tebuconazole 25.9 % EC	0.04	1.5 ml	17.03 (8.67)	25.01 (17.90)	27.92 (22.00)	30.74 (26.17)	45.33
T_3	Hexaconazole 5 % EC	0.005	1.0 ml	16.41 (8.00)	23.83 (16.50)	27.69 (21.67)	30.04 (25.07)	47.62
T_4	Trifloxystrobin 25 % + Tebuconazole 50 % (75WG)	0.03	0.4 g	17.44 (9.00)	25.57 (18.67)	29.07 (23.67)	31.45 (27.33)	42.90
T_5	Carbendazim 12 % + Mancozeb 63 % (75 WP)	0.15	2.0 g	17.02 (8.83)	25.10 (18.00)	28.71 (23.17)	31.17 (26.80)	44.01
T_6	Azoxystrobin 18.2 % + Difenconazole 11.4 % w/w (29.6 SC)	0.03	1.0 ml	17.78 (9.33)	26.18 (19.50)	29.32 (24.00)	32.34 (28.67)	40.10
T_7	Mancozeb 75 % WP	0.25	3.3 g	17.95 (9.50)	26.79 (20.33)	29.99 (25.00)	32.89 (29.50)	38.37
T_8	Control (Water spray)			19.97 (11.00)	33.20 (30.00)	45.00 (42.13)	55.00 (47.87)	-
	S. Em±			1.77	1.24	1.30	1.35	-
	C.D. at 5 %			N.S.	3.77	3.91	4.11	-
	C.V. (%)			9.54	8.26	7.58	7.08	-

* Figure in parenthesis are original value
** Figure outside parenthesis are arc sine transformed value

Table 5: Effect of fungicidal spray on yield parameters of paddy (cv. GR-11)

Treatment No.	Treatment	Conc. (%)	Dose (g or ml/l)	Parameters	
				Grain Yield kg/plot	Straw Yield kg/plot
T_1	Propiconazole 25 % EC	0.025	1.0 ml	9.50	11.20
T_2	Tebuconazole 25.9 % EC	0.04	1.5 ml	8.73	10.25
T_3	Hexaconazole 5 % EC	0.005	1.0 ml	9.00	10.55
T_4	Trifloxystrobin 25 % + Tebuconazole 50 % (75WG)	0.03	0.4 g	7.35	8.80
T_5	Carbendazim 12 % + Mancozeb 63 % (75 WP)	0.15	2.0 g	7.74	9.10
T_6	Azoxystrobin 18.2 % + Difenconazole 11.4 % w/w (29.6 SC)	0.03	1.0 ml	7.18	8.65
T_7	Mancozeb 75 % WP	0.25	3.3 g	6.44	8.03
T_8	Control (Water spray)	-	-	5.40	6.90
S. Em ±				0.41	0.55
C.D. at 5 %				1.26	1.67
C.V. (%)				9.35	10.37

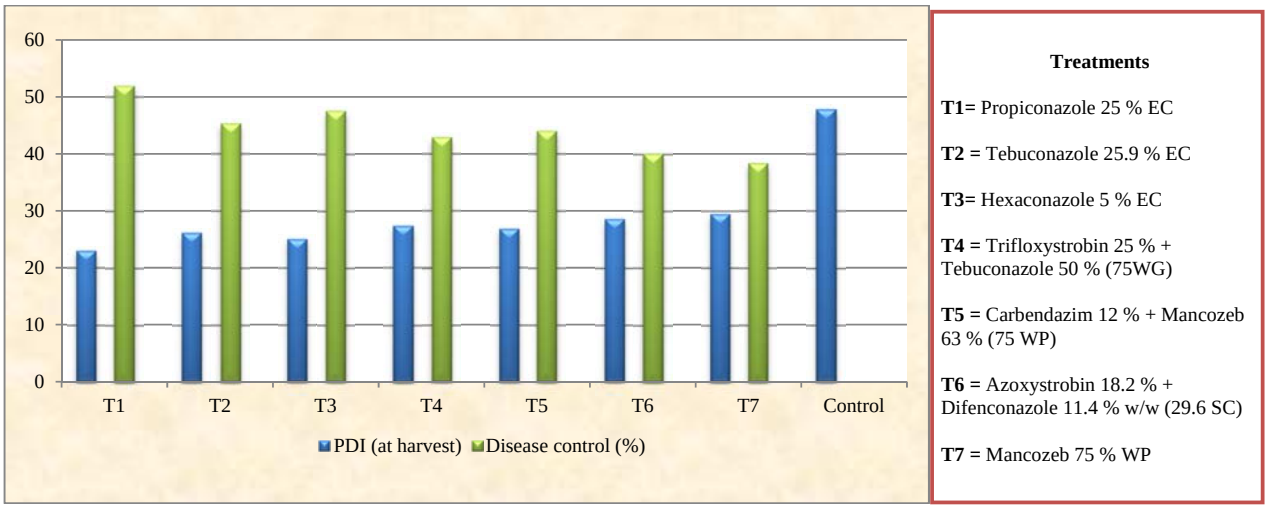

Fig 2: Evaluation of different fungicides against sheath blight under field condition

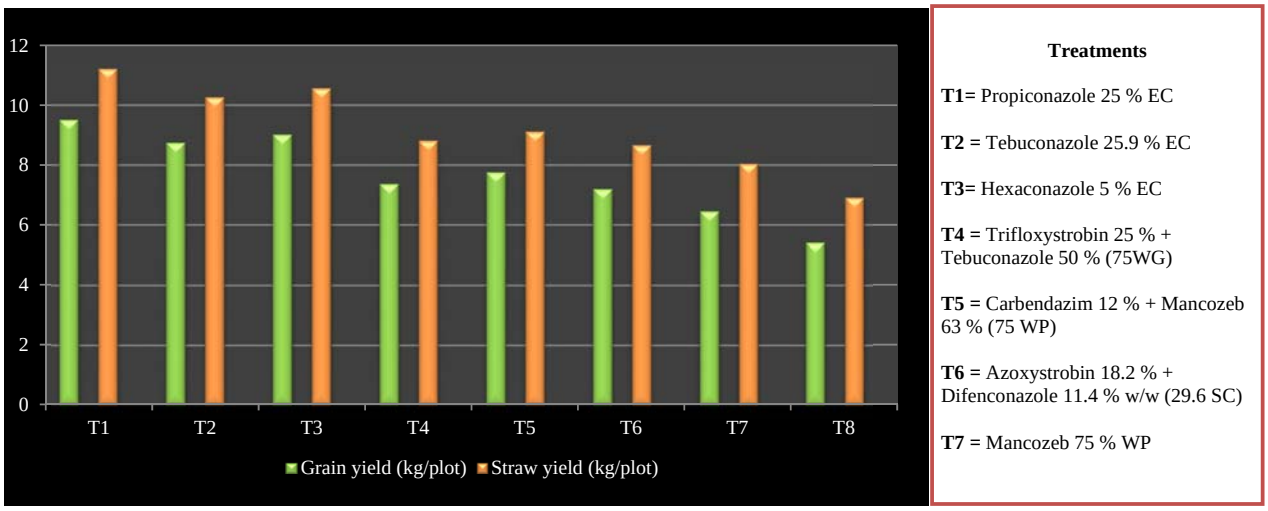

Fig 3: Effect of fungicidal treatments on grain and straw yield

4. Conclusion

From the result of this experiment we can concluded that the management studies against sheath blight of paddy showed Among the systemic, non systemic and combi-product (systemic + non systemic) of fungicides, propiconazole 25 % EC, tebuconazole 25.9 % EC and carbendazim 12 %+ mancozeb 63 %, were found significantly superior at all 3 concentrations *viz*., 250 ppm, 500 ppm and 1000 ppm respectively with highest growth inhibition against *R. solani* followed by hexaconazole 5 % EC at 1000 ppm, azoxystrobin 18.2 % + difenconazole 11.4 % at 500 ppm and 1000 ppm and mancozeb 75 % WP at 1500 ppm and 2000 ppm. Whereas, copper oxychloride was found least effective in all three concentrations *viz*., 1000, 1500 and 2000 ppm against *R. solani*.

Propiconazole (0.025 %) recorded minimum per cent disease intensity and highest per cent disease control followed by hexaconazole (0.005 %), tebuconazole (0.04 %), carbendazim 12 % + mancozeb 63 % (0.15 %) and trifloxystrobin 25 % + tebuconazole 50 % (0.03 %). Similarly, significantly higher grain yield (9.50 kg plot^{-1}) and straw yield (11.20 kg plot^{-1}) were recorded in propiconazole (0.025 %).

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