The Bioscan 13(1): 33-39, 2018
AN INTERNATIONAL QUARTERLY JOURNAL OF LIFE SCIENCES
www.thebioscan.com

BIO-EFFICACY OF TEBUCONAZOLE 060 FS (RAXIL 060 FS) AS SEED TREATMENT AGAINST KARNAL BUNT, LOOSE SMUT AND FLAG SMUT OF WHEAT

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KEYWORDS
Wheat
Karnal bunt
loose smut
Flag smut
Tebuconazole
Carboxin
Carbendazim

Received on :
29.12.2017

Accepted on :
28.02.2018

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ABSTRACT
A new molecule tebuconazole 060 FS (Raxil 060 FS) was evaluated against Karnal bunt, loose smut and flag smut diseases of wheat. The results revealed that seed treatment with tebuconazole 060 FS @ 0.333/ kg seed was found to be the best, recorded lowest incidence of loose smut (0.03% smutted tillers and 0.09% infected plants) and highest disease control (96.94 per cent on tiller basis and 94.67 per cent on plant basis). It also provided highest (13.42 per cent) increase in grain yield in case of variety UP 2338 and 8.88 per cent in case of variety HD 2329. The test fungicide tebuconazole 060FS @ 0.333ml/kg seed also improved field emergence (89.73 as compared to 88.15 per cent in control). Moreover, no phytotoxicity symptoms were observed due to any fungicides treatments. None of the fungicidal seed treatment was effective in managing the Karnal bunt. However, no inference can be drawn for flag smut as the disease did not occur during both the seasons. Hence, seed treatment with tebuconazole 060 FS @ 0.333 ml/kg seed can be recommended as an alternate molecule to existing fungicides for effective management of loose smut diseases of wheat.

INTRODUCTION

Wheat (*Triticum aestivum* L.) belonging to family Poaceae is one of the most widely cultivated staple food crops among the cereals in India and world. It is contributing about 30% to the food basket of the country. To feed the ever growing population, the country's wheat requirement by 2030 has been estimated to be 100 million metric tons. To achieve this goal, the wheat production has to be increased at the rate of < 1mmt per annum (Swati *et al*., 2014). However, wheat production is constrained by a number of diseases. Among these, Karnal bunt [*Tilletia indica* (Mitra) = (*Neovossia indica*) (Mitra) Mundkar], loose smut (*Ustilago segetum* (Pers.) Rostr. var. *tritici*), and flag smut (*Urocystis agropyri* (Preuss.) Shroeter) are important seed-borne diseases of wheat in cooler parts of India. Seed-borne pathogens of wheat are responsible for reduction in yield up to 15-19 per cent if untreated seeds are grown in the field (Wiese, 1984 and Bhoyar *et al*., 2014). These diseases are known to cause significant losses in grain yield especially where farmers use their own saved seeds of old susceptible cultivars without applying any seed treatment before sowing.

Since, most of the present day cultivars lack resistance to these diseases, the application of chemicals to seed is safest, cheapest and could be effective means of controlling most seed-borne pathogens. The use of fungicides as seed treatment is the most widely followed disease control practice used in all crops (Nene and Thapliyal, 1979 and Sharvelle, 1979). Carboxins were among the first systemic fungicides (von Schmeling and Kulka, 1966), marketed as 'Vitavax' and 'Plantvax' (Edgington *et al*., 1966) for wheat seed treatment. The success of carboxins led to the introduction of several carboxamide seed dressings including fenfuram (Martin and Edgington, 1980). Since the late 1970s, a number of broad-spectrum systemic fungicides, including the triazoles, triadimenol, flutriafol and tebuconazole have been introduced as seed treatments for cereal diseases. These chemicals are in use for the last 3 decades. Unfortunately, the continuous use of carboxins and fenfuram led to the development of resistance in loose smut on barley (Leroux and Berthier, 1988). Continuous use of systemic fungicides for long period of time may pose threat of development of resistance in pathogens. Thus products may become less effective - or even useless for controlling resistant pathogens and pests. Identification of new molecules that are effective against target pathogen and rotating them with other available fungicides can be one of the methods to manage the pesticide resistance. With this objective the present study was undertaken to screen newer formulation and chemical against these diseases.

MATERIALS AND METHODS

Two field experiments were conducted at Norman E. Borlaug Crop Research Centre of G.B. Pant University of Agriculture

and Technology, Pantnagar to test the efficacy of tebuconazole 060 FS (Raxil 060FS) as seed treatment against Karnal bunt, loose smut and flag smut in wheat during *Rabi* 2013-14 and 2014-15 crop seasons. The experiment was laid out in a Randomized Block Design (RBD) with three replications and seven treatments. Seeds were pretreated with required quantity of chemicals as per the treatment schedule (Table 1) using slurry method (Sharma *et al*., 2015). Treated seeds were further dried under shade before sowing in the field. Varieties UP 2338 (for loose and flag smuts) and HD 2329 (for Karnal bunt) were sown on 10th Dec, 2013 and 3rd Dec 2014 having 9 rows of 5 meters length at 23 cms row to row distance. The crop was raised as per the recommended agronomic practices. The treatment comprised as follows.

The observations on field emergence and incidence of loose smut and flag smut were recorded at the complete emergence of ears and that of Karnal bunt after threshing. Incidence of loose smut and flag smut was recorded on plant and tiller basis as follows:

PDI = (No. of infected plants or tillers / total no. of plants or tillers) X 100

In order to record the incidence of Karnal bunt, a working sample of 2000 seeds was obtained from each replication and was visually examined for Karnal bunt infection. Karnal bunt incidence was calculated using the following formula (Sharma *et al*., 2007):

Per cent Karnal bunt incidence = (No. of infected seeds/2000) X 100

Per cent increase in yield and avoidable yield loss (AYL) due to loose smut and Karnal bunt were calculated separately using grain yield data from the management trials using following formula:

AYL = [(Yp-Yu)/Yp] x 100

Where, Yp = Yield under protected condition and Yu = Yield under unprotected condition (Kumar, 2011, 2013 and Nagaraja *et al*., 2012).

Evaluation of phytotoxicity of tebuconazole 060 FS (W/V) (Raxil 060 FS) in wheat

The test fungicide Raxil 060FS was applied as seed treatment at the concentration of 0.333, 0.666 and 1.332ml/kg seed and compared with untreated control. Variety UP 2338 was used for evaluation of phytotoxicity. Ten plants were randomly selected and phytotoxicity symptoms (leaf chlorosis, leaf tip burning, leaf necrosis, leaf epinasty, leaf hyponasty, vein clearing, wilting and resetting) were recorded at 10, 20 and 30 days after germination as per CIB guidelines using a rating scale of 0-10 (Muthukumar and Udhayakumar, 2015).

RESULTS AND DISCUSSION

Effect of tebuconazole 060 FS (Raxil 060 FS) on field emergence of wheat.

The data presented in table 2 revealed that field emergence of wheat ranged from 88.34 to 93.36 per cent during 2013-14 and 87.82 to 92.87 per cent during 2014-15 crop seasons. During both the years, maximum field emergence (93.36 and 92.87 per cent) was recorded with carbendazim 50% WP @

Table 1: Details of the fungicides used as seed treatment against Karnal bunt, loose smut and flag smut of wheat.

S. No.	Chemical	Chemical name	Trade name	Formulation	Dosage/kg seed g.a.i.	Fomul. (g./ml.)	Source of supply
1	Untreated control	-	-	-	-	-	-
2	Tebuconazole	(RS)- 1-(4-Chlorophenyl)- 4,4-dimethyl-3-(1*H*, 1,2,4-triazol-1-ylmethyl) pentan- 3-ol	Raxil 060 FS	60% FS	0.010	0.167	Syngenta India ltd.
3	Tebuconazole	(RS)- 1-(4-Chlorophenyl)- 4,4-dimethyl-3-(1*H*, 1,2,4-triazol-1-ylmethyl) pentan- 3-ol		60% FS	0.015	0.250	
4	Tebuconazole	(RS)- 1-(4-Chlorophenyl)- 4,4-dimethyl-3-(1*H*, 1,2,4-triazol-1-ylmethyl) pentan- 3-ol		60% FS	0.020	0.333	
5	Tebuconazole	(RS)- 1-(4-Chlorophenyl)- 4,4-dimethyl-3-(1*H*, 1,2,4-triazol-1-ylmethyl) pentan- 3-ol	Raxil 2 DS	2% DS	0.020	1.000	Bayer Crop Science Ltd. Mumbai
6	Carboxin	5,6-dihydro-2-methyl-N-phenyl-1,4-oxathiin-3-carbamil	Vitavax	75% WP	1.500	2.000	Uniroyal Chemical Company ltd. Middlebury, Connecticut.
7	Carbendazim	Methyl *1H*-benzimidazol-2-ylcarbamate	Bavistin	50% WP	1.000	2.000	BASF India Ltd., Mumbai

Table 2: Effect of tebuconazole 060 FS w/v (Raxil 060 FS) on field emergence of wheat

	Treatment	Field emergence (%) 2013-14	2014-15	Pooled mean	Increase in emergence (%)
T1	Untreated control	88.47	87.82	88.15	-
T2	Tebuconazole 060 FS (Raxil 060 FS) @ 0.167ml/kg seed	88.34	87.88	88.11	-0.05
T3	Tebuconazole 060 FS (Raxil 060 FS) @ 0.25ml/kg seed	89.65	89.70	89.68	1.74
T4	Tebuconazole 060 FS (Raxil 060 FS) @ 0.333ml/kg seed	89.63	89.83	89.73	1.79
T5	Tebuconazole 2% DS (Raxil 2 DS) @ 1g/ kg seed	88.49	88.16	88.33	0.20
T6	Carboxin 75% WP@ 2g/kg seed	90.43	90.09	90.26	2.39
T7	Carbendazim 50% WP @ 2g/kg seed	93.36	92.87	93.12	5.64
	CD at 5%	3.87	3.27		

Table 3: Effect of tebuconazole 060 FSw/v (Raxil 060 FS) against Karnal bunt of wheat.

	Treatment	Incidence of Karnal bunt (%) 2013-14	2014-15	Pooled mean
T1	Untreated control	0.17	0.23	0.20
T2	Tebuconazole 060 FS (Raxil 060 FS) @ 0.167ml/kg seed	0.18	0.22	0.20
T3	Tebuconazole 060 FS (Raxil 060 FS) @ 0.25ml/kg seed	0.15	0.17	0.16
T4	Tebuconazole 060 FS (Raxil 060 FS) @ 0.333ml/kg seed	0.18	0.15	0.17
T5	Tebuconazole 2% DS (Raxil 2 DS) @ 1g/ kg seed	0.10	0.15	0.13
T6	Carboxin 75% WP@ 2g/kg seed	0.18	0.20	0.19
T7	Carbendazim 50% WP @ 2g/kg seed	0.15	0.23	0.22
	CD at 5%	0.12	0.21	

2 g/kg seed, which was significantly at par with treatments wherein seeds were treated with the test fungicide tebuconazole 060 FS @ 0.25ml/kg seed and 0.333 ml/kg seed. As evident from the results that all the treatments except seed treatment with tebuconazole 060 FS (Raxil 060 FS) @ 0.167ml/ kg seed increased the field emergence, however, maximum increase in field emergence (5.64%) was recorded when seeds were treated with carbendazim 50% WP @ 2g/kg seed, followed by carboxin 75% WP (@2g/kg), tebuconazole 060FS (@ 0.333ml/kg) and tebuconazole 060FS (@ 0.25ml/kg). Present findings are in accordance with the work of Shivankar *et al*. (2000) and Rangwala *et al*. (2013) who reported that seed treatment with carbendazim significantly increased germination of wheat. However, no record is available in the literature on the effect of tebuconazole 060 FS on germination/ field emergence of wheat seeds. Therefore, it should be considered as the first record.

Evaluation of tebuconazole 060 FS (Raxil 060 FS) against Karnal bunt (*Tilletia indica*) of wheat

The results presented in table 3 revealed that the incidence of Karnal bunt ranged from 0.10 to 0.18 per cent in first season (2013-14) and 0.15 to 0.23 per cent in second season (2014-15), however, no significant difference was observed among the treatments. This suggests that none of the fungicidal seed treatment is effective in controlling the Karnal bunt disease under field conditions. This may be because the disease is seed, soil-borne and the infection occurs at the time of flowering (Mitra, 1931 and Mundakar, 1943). Only the allantoid types of secondary sporidia are the real incitant of Karnal bunt in nature (Dhaliwal and Singh, 1988). Warham *et al*. (1989) and Gill *et al*. (1993) have reported chemical seed treatments to be ineffective in killing the teliospores of *T. indica* on seeds of wheat, with the exception of mercurial compounds which are banned in most countries. Even if fungicides are effective, the effect of seed treatment alone with fungicides may not persist until anthesis, the most vulnerable stage for seed infection by *T. indica* (Dhaliwal and Singh, 1988). Bleach, in combination with heat treatment, is effective (Smilanick *et al*., 1989). However, foliar sprays of propiconazole, tebuconazole (Folicur), hexaconzole (contaf), thifluzamide etc. were shown to be effective against natural infection in India (Singh *et al*., 1989, Gill *et al*., 1993, Singh *et al*., 1998). The test fungicide needs to be evaluated through spray trials rather than seed treatment alone.

Evaluation of tebuconazole 060 FS (Raxil 060 FS) against loose smut (*Ustilago segetum* var. *tritici*) of wheat

The data presented in table 4 revealed that during first season (2013-14) the incidence of loose smut ranged from 0.04 to 1.03 per cent on tillers basis and 0.12 to 1.82 per cent on plant basis. All the treatments were significantly effective in managing the loose smut disease as compared to control. During the first season trial, the lowest incidence of smutted tillers (0.04%) and infected plants (0.12%) were recorded by tebuconazole 060 FS (Raxil 060 FS) @ 0.333ml/kg seed (T_4) with 96.94 and 94.67 per cent control of smutted tillers and infected plants, respectively. However, it was significantly at par with the other doses (@ 0.167ml (T_2) and 0.25ml/kg seed (T_3)) of the same fungicide.

In the second season trial also, similar results were obtained with different treatments (Table 4). Seed treatment with tebuconazole 060 FS (Raxil 060 FS) @ 0.333ml/kg seed (T_4) provided maximum loose smut control, recorded 98.92 per cent control on tiller basis and 96.77 per cent control on plant basis which was significanty at par with the other doses (@ 0.167ml (T_2) and 0.25ml/kg seed (T_3)) of tebuconazole 060 FS (Raxil 060 FS).

The results from first and second season trials clearly revealed that seed treatment with tebuconazole 060 FS (Raxil 060 FS)

Table 4: Effect of tebuconazole 060 FS w/v (Raxil 060 FS) against loose smut of wheat.

	Treatment	Smutted Tillers (%)			Disease Control (%)			Infected plants (%)			Disease Control (%)		
		2013-14	2014-15	Pooled mean	2013-14	2014-15	Pooled mean	2013-14	2014-14	Pooled mean	2013-14	2014-15	Pooled mean
T1	Untreated control	1.03	0.93	0.98	-	-	-	1.82	1.55	1.69	-	-	-
T2	Tebuconazole 060 FS (Raxil 060 FS) @ 0.167ml/kg seed	0.08	0.04	0.06	92.23	95.70	93.88	0.30	0.20	0.25	83.52	87.10	85.21
T3	Tebuconazole 060 FS (Raxil 060 FS) @ 0.25ml/kg seed	0.06	0.03	0.05	94.17	96.77	94.90	0.21	0.14	0.18	88.46	90.97	89.35
T4	Tebuconazole 060 FS (Raxil 060 FS) @ 0.333ml/kg seed	0.04	0.01	0.03	96.12	98.92	96.94	0.12	0.05	0.09	93.41	96.77	94.67
T5	Tebuconazole 2% DS (Raxil 2 DS) @ 1g/kg seed	0.37	0.33	0.35	64.08	64.52	64.29	0.85	0.75	0.80	53.30	51.61	52.66
T6	Carboxin 75% WP@ 2g/kg seed	0.61	0.57	0.59	40.78	38.71	39.80	1.15	1.05	1.10	36.81	32.26	34.91
T7	Carbendazim 50% WP @ 2g/kg seed	0.53	0.49	0.51	48.54	47.31	47.96	1.11	1.01	1.06	39.01	34.84	37.28
	CD at 5%	0.14	0.12					0.44	0.42				

@ 0.333ml/kg seed (T_4) recorded the lowest incidence of loose smut which is at par with other doses (@ 0.167ml (T_2) and 0.25ml/kg seed (T_3)) of the same fungicide. This is in agreement with the findings of Singh and Singh (2013) who reported that seed treatment with tebuconazole (Raxil 060 FS) @ 0.333 g/kg seed resulted in complete control of loose smut. Effective control of loose smut through seed treatment with Carboxin has been reported earlier by Chatrath *et al.* (1969, 1976), Nene *et al.* (1971), Goel *et al.* (2001), Deepshikha (2005), Singh and Singh (2013). The efficiency of Raxil 2DS (tebuconazole 2DS) in controlling loose smut of wheat is corroborated by the findings of Sinha and Singh (1993), Singh (1997), Tewari *et al.* (1999), Goel *et al.* (2001), Deepshikha (2005). Similarly, Tewari *et al.* (1999) and Deepshikha (2005) reported that seed treatment with Vitavax 200 WP @ 2.5 g/kg seed provided effective control of loose smut of wheat. Efficacy of Carbendazim 50 WP as seed treatment @ 2.5 g/kg seed was advocated by several workers (Arora *et al.,* 1990; Sirvastava *et al.,* 1991; Bhardwarj and Thakur, 1992; Paul, 1996; Sinha and Singh, 1996; Deepshikha, 2005). The above results lend support to the present findings.

Evaluation of tebuconazole 060 FS (Raxil 060 FS) against Flag smut (*Urocystis agropyri*) of wheat.

The data pertinent to flag smut incidence are presented in table 5. No inference can be drawn as symptoms of the disease were not noticed till harvesting during both the crop seasons (2013-14 and 2014-15). Flag smut infection is influenced to a considerable extent by environmental factors including soil moisture, soil temperature, soil pH as well as cultural practices such as planting date, sowing depth, host variety and its stage of development. Sowing in relatively dry soil favours infection whereas sowing in moist soil is detrimental to disease development (Ram and Singh, 2004). Since, the experimental site Pantnagar is situated in *tarai* region of Uttarakhand which may not provide conditions favourable for disease development. Although its occurrence in the country is not widespread due to absence of favourable environmental conditions, its importance cannot be underestimated since, unlike most smut, it is long persisting and if environmental conditions are favourable and susceptible varieties are grown the disease may assume serious form.

Effect of tebuconazole 060 FS (Raxil 060 FS) on grain yield of wheat.

Since, the effect of fungicides against loose and flag smuts was evaluated using variety UP 2338 and against Karnal bunt using HD 2329, therefore, the effect of tebuconazole 060 FS (Raxil 060FS) on grain yield was observed separately on these two wheat varieties (table 6). Pooled analysis of the data revealed that in case of variety UP 2338, the yield varied from 42.84 to 49.47q/ha and that of HD 2329 ranged from 54.75 to 59.62 being lowest in untreated control and highest in seed treatment with tebuconazole 060 FS (Raxil 060 FS) @ 0.333ml/kg seed. In case of variety UP 2338, seed treatment with tebuconazole 060 FS (Raxil 060 FS) @ 0.333ml/kg seed (T_4) provided highest (49.47q/ha) grain yield, per cent increase in yield (13.42%) and avoidable loss (13.42%) in yield, however, it was significantly at par with seed treatment with Carboxin 75% WP @ 2g/kg seed (T_6). The other treatments did not differ significantly from untreated control. In case of variety HD 2329,

Table 5: Effect of tebuconazole 060 FSw/v (Raxil 060 FS) against Flag smut of wheat.

Treatment	Smutted Tillers (%)	Infected plants (%)					
		2013-14	2014-15	Pooled mean	2013-14	2014-15	Pooled mean
T1	Untreated control	0.00	0.00	0.00	0.00	0.00	0.00
T2	Tebuconazole 060 FS (Raxil 060 FS) @ 0.167ml/kg seed	0.00	0.00	0.00	0.00	0.00	0.00
T3	Tebuconazole 060 FS (Raxil 060 FS) @ 0.25ml/kg seed	0.00	0.00	0.00	0.00	0.00	0.00
T4	Tebuconazole 060 FS (Raxil 060 FS) @ 0.333ml/kg seed	0.00	0.00	0.00	0.00	0.00	0.00
T5	Tebuconazole 2% DS (Raxil 2 DS) @ 1g/ kg seed	0.00	0.00	0.00	0.00	0.00	0.00
T6	Carboxin 75% WP@ 2g/kg seed	0.00	0.00	0.00	0.00	0.00	0.00
T7	Carbendazim 50% WP @ 2g/kg seed	0.00	0.00	0.00	0.00	0.00	0.00
	CD at 5%	NS	NS		NS	NS	

Table 6: Effect of tebuconazole 060 FS w/v (Raxil 060 FS) on grain yield of wheat during 2013-14 and 2014-15 crop seasons

Treatment		UP 2338					Yield(q/ha)		HD 2329		
Yield (q/ha)		2013-14	2014-15	Pooled mean	Increase in yield (%)	AYL (%)	Increase in AYL (%) yield (%)		2013-14	2014-15	Pooled mean
T1	Untreated control	43.16	42.51	42.84	-	-	54.91	54.59	54.75	-	-
T2	Tebuconazole 060 FS (Raxil 060 FS) @ 0.167ml/kg seed	45.09	43.99	44.54	3.84	4.00	55.88	55.56	55.72	1.73	1.77
T3	Tebuconazole 060 FS (Raxil 060 FS) @ 0.25ml/kg seed	47.99	46.38	47.19	9.23	10.16	57.65	56.68	57.17	4.22	4.41
T4	Tebuconazole 060 FS (Raxil 060 FS) @ 0.333ml/kg seed	49.60	49.34	49.47	13.42	15.50	59.90	59.32	59.62	8.16	8.88
T5	Tebuconazole 2% DS (Raxil 2 DS) @ 1g/ kg seed	47.02	46.15	46.59	8.06	8.77	58.70	57.97	58.34	6.14	6.54
T6	Carboxin 75% WP@ 2g/kg seed	49.28	48.70	48.99	12.57	14.37	59.32	58.70	59.01	7.22	7.78
T7	Carbendazim 50% WP @ 2g/kg seed	46.38	46.54	46.46	7.81	8.47	57.97	57.49	57.73	5.16	5.44
	CD at 5%	4.85	1.03	5.78			3.02	3.94	2.04		

Table 7: Evaluation of phytotoxicity of tebuconazole 060 FS w/v (Raxil 060 FS) on wheat during 2013-14 and 2014-15 crop seasons.

Days of observation after germination		Treatment	Phytotoxicity symptoms*						
		Chlorosis	Tip burning	Necrosis	Epinasty	Hyponasty	Vein clearing	Wilting	Rosetting
10th day	Tebuconazole 060 FS (Raxil 060 FS) @ 0.333ml/ kg seed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Tebuconazole 060 FS (Raxil 060 FS) @ 0.666ml/ kg seed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Tebuconazole 060 FS (Raxil 060 FS) @ 1.332ml/ kg seed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Untreated control	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20th day	Tebuconazole 060 FS (Raxil 060 FS) @ 0.333ml/ kg seed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Tebuconazole 060 FS (Raxil 060 FS) @ 0.666ml/ kg seed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Tebuconazole 060 FS (Raxil 060 FS) @ 1.332ml/ kg seed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Untreated control	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30th day	Tebuconazole 060 FS (Raxil 060 FS) @ 0.333ml/ kg seed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Tebuconazole 060 FS (Raxil 060 FS) @ 0.666ml/ kg seed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Tebuconazole 060 FS (Raxil 060 FS) @ 1.332ml/ kg seed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Untreated control	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS

* Mean of two seasons

all the treatments except tebuconazole 060 FS (Raxil 060 FS) @ 1.67ml/10 kg seed (T_2) increase the yield. However, the highest grain yield (59.62q/ha) and per cent increase in yield (8.16%) and per cent avoidable loss (8.88%) were recorded when seeds were treated with tebuconazole 060 FS (Raxil 060 FS) @ 0.333ml/kg seed (T_4), however, it was significantly at par with seed treatment with tebuconazole 2% DS (Raxil 2 DS) @ 1g/kg seed (T_5), Carboxin 75% WP @ 2g/kg seed (T_6) and Carbendazim 50% WP @ 2g/kg seed (T_7). Present findings are in accordance with the work of Singh and Singh (2013), Deepshikha (2005) and Sahi *et al*. (1985) who reported significant increase in grain yield due to seed treatment with tebuconazole 060 FS, Vitavax 75 WP (carboxin) Raxil 2DS (tebuconazole), Vitavax 200 WP (carboxin + thiram).

Evaluation of Phytotoxicity of tebuconazole 060 FS (Raxil 060 FS) in wheat.

Tebuconazole 060 FS was evaluated at 3 doses i.e. 0.333, 0.666 and 1.332 ml/kg seed at 10, 20 and 30 days after germination for phytotoxicity symptoms (Table 7). Plants were observed for symptoms of phytotoxicity viz., leaf chlorosis, leaf tip burning, leaf necrosis, leaf epinasty, leaf hyponasty, vein clearing, wilting and rosetting. No phytotoxic symptoms were noticed even at the highest tested dose of 1.332ml/kg seed of tebuconazole 060 FS (Raxil 060 FS) during both the crop seasons (2013-14 and 2014-15). There is no phytotoxicity of tebuconazole formulations namely; Orius 060 FS (Tomlin, 2000) and Raxil 060 FS (Singh and Singh, 2013) on wheat plants after seed treatment with this fungicide. However, foliar application of tebuconazole is toxic to plants (phytotoxic) at rates normally required to provide adequate control against fungal diseases (Pederson, 2007). Tebuconazole phytotoxicity has been recorded at higher use rates in many crop species including soybeans, cocoa, winter grass and rock melons (Holderness, 1990 and Vawdrey, 1994). In most of these published cases, symptoms have included obvious death of

leaf tissue. However, Pederson (2007) notes that symptoms of tebuconazole phytotoxicity may affect all or only parts of the plant (including roots), and can include only a subtle growth reduction. The phytotoxic effects of tebuconazole appear to be exacerbated when applied to plants under drought stress (Pederson 2007).

Based on the results of two crop seasons it can be concluded that the test fungicide tebuconazole 060 FS (Raxil 060 FS) (@ 0.333 ml/kg seed) is found effective in improving the field emergence, managing loose smut and improving the grain yield. There were no phytotoxic symptoms observed on the plants due to any tebuconazole 060 FS (Raxil 060 FS) treatments. None of the fungicidal seed treatment was effective in managing the Karnal bunt. However, no inference can be drawn for flag smut as the disease did not occur during both the seasons. Hence, seed treatment with tebuconazole 060 FS @ 0.333 ml/kg seed can be recommended as an alternate molecule to existing fungicides for effective management of loose smut diseases of wheat.

ACKNOWLEDGEMENTS

The author is grateful to the Bayer Crop Science limited for the financial assistance and the University for providing necessary field facilities during the course of the investigation.

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Cont. ..... P. 046