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Full Length Research Paper

Management of ufra disease of rice caused by *Ditylenchus angustus* with nematicides and resistance

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The effects of nematicide application timing and type on the management of ufra disease of rice caused by *Ditylenchus angustus* were investigated in the rain-fed and irrigated rice ecosystems. A broad range of rice (*Oryza sativa* L.) genotypes were also screened for resistance to *D. angustus*. Ufra infestation was significantly reduced when 1 kg ai/ha furadan 5G was applied up to 20 d before transplanting of infested seedlings in the field. Three granular nematicides, sunfuran 5G, edfuran 5G and forwafuran 5G, all applied at 1 kg ai/ha were evaluated against ufra in comparison with 1 kg ai/ha furadan 5G and a non-treated control. In both the ecosystems, all the 3 nematicides significantly reduced the number of damaged-tillers and total ufra infestation compared to the non-treated control. Similarly, sunfuran 5G, edfuran 5G, and forwafuran 5G treated plots had 45.3 to 52.7% healthy panicles with 3.89 to 4.02 t/ha yield in rain-fed rice and 47.6 to 53.0% healthy panicles with 3.85 to 3.97 t/ha yield in rain-fed and irrigated rice, respectively. These yields were similar to furadan-treated rice in 2 ecosystems. Yield losses due to ufra disease were 49.1 and 42.4% in the rain-fed and irrigated rice, respectively. Soil application of the nematicides, forwafuran, edfuran and sunfuran was cost-effective especially in fields of endemic areas. A total of 53 rice entries were tested, only 4 entries, fukuhonami, hyakikari, akiyu taka and matsuhonami showed highly resistance reactions to *D. angustus*.

Key words: Cost-effective, *Ditylenchus angustus,* management, nematicides, rice ufra disease, resistance reaction.

INTRODUCTION

Ufra, caused by the rice stem nematode, *Ditylenchus angustus* (Butler, 1913) is a serious disease of deep-water rice (*Oryza sativa*) in Bangladesh (Rahman, 1987). The disease also occurs in irrigated (Prasad et al., 2000; Patil, 1998; Latif et al., 2006) and rain-fed low land rice (Miah and Rahman, 1985; Latif et al., 2004a). *D. angustus* reproduces amphimitically, and at least 3 generations occur in a growing season. The nematode is able to survive from one crop to the next by remaining coiled in rice stubble and debris and in soil. Infested ratoons are also sources of inoculum. *D. angustus* can survive desiccation for at least 6 months, but the number of survivors declines over time, with an average half-life of about 2 (Ou, 1985). Live *D. angustus* were recovered from dried seeds, mainly located in the germ portion, 3 months after harvest (Prasad and Varaparsad, 2002). The nematode becomes active when the fields are flooded. Initially, the nematode parasitizes the terminal buds of newly sprouted seeds and then migrates upwards as the rice plant grows, feeding on new tissues. During flowering and heading stages, *D. angustus* is found mainly on the stem just above the nodes, on the peduncles and inside the glumes. The nematode becomes inactive when the plants are matured. With the exception of *Leersia hexandra*, the known host range of

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Table 1. Information of nematicides used in this study.

Nematicides	Source of Nematicides	Registration status	Manufacturing country
Sunfuran 5G	Shetu group Ltd., Bangladesh	Registered	China
Edfuran 5G	Nokon Ltd., Bangladesh	Registered	Taiwan
Forwafuran 5G	Shetu group Ltd., Bangladesh	Registered	India
Furadan 5G	Padma Oil Co. Ltd., Bangladesh	Registered	USA

D. angustus is confined to *Oryza* spp., *Oryza alta, Oryza glaberrima*, *Oryza eichingeri*, *Oryza latifolia*, *Oryza meyerriana*, *Oryza minuta* and *Oryza officinalis* (McGeachie and Rahman, 1983; Cox and Rahman, 1979b; Ou, 1985). According to Miah and Bakr (1977b), it is known that *Oryza sabulata* (wild rice) and the cultivar R16-06 showed some resistance to this nematode (Miah and Bakr, 1977b).

Yield loss caused by ufra has been reported up from 10 to 15% in India (Rao et al., 1986), 20 to 90% in Thailand (Hashioka, 1963), 50 to 100% in Vietnam (Cuc and Kinh, 1981), and 40 to 60% or occasionally 100% in Bangladesh (Miah and Bakr, 1977a). *D. angustus* can be controlled by cultural practices, organic amendments, crop rotation, and/or chemicals (Latif et al., 2006; Khan, 2008). Chemicals such as benomyl, fensulfothion, hexadrin, monocrotophos and phenazine have been tested to control *D. angustus* (Miah and Bakr, 1977a; Cox and Rahman, 1979a; Miah and Rahman, 1985). Application of carbofuran in *D. angustus* infested field has also been reported to control the ufra (Cox and Rahman, 1979a; Latif et al., 2004b). Information on effect of timing of application of nematicides 2 to 3 w before transplanting (that is during land preparation) the profitability of 3 the nematicides under carbofuran group, and confirmation of highly resistant genotypes are scant. Considering the above facts the present research activities were undertaken to: (1) determine the length of effectiveness of furadan 5G in soils against D. *angustus*; (2) evaluate the efficacy of new nematicides for the control of ufra disease; and (3) discover rice genotype(s) resistant to *D. angustus*.

MATERIALS AND METHODS

Experimental site, inoculum preparation and propagation

Four experiments were conducted at the Plant Pathology Division of Bangladesh Rice Research Institute (BRRI), Gazipur both in rain-fed and irrigated rice ecosystems during 2005 to 2006. The isolate of *D. angustus* used in all experiments was collected from an infested field of rice cv. BR3 in Gazipur District, Bangladesh. Infected stems were cut into small species, placed in a Petri-dish, and immersed into distilled water for approximate 4 h to release nematodes from the plant tissue. Nematodes were then collected onto a sieve (0.02 mm-pores) and quantified using a compound microscope (Nikon AFX-IIA, Japan). This population was maintained and increased by inoculating nematodes onto rice cv. BR3 and placing plants in a glass house (25 to 28°C; RH 80%) at BRRI.

For the field experiments, two popular rice varieties cv. BR11 and BRRI dhan28 (susceptible to ufra) were used in the rain-fed and irrigated ecosystems, respectively. Seedlings of each variety were propagated on a small piece of medium low-land. Clean, healthy and mature seeds (germination rate >85%) were pre-germinated for 24 h in a moist-plastic tray in the dark at 28°C before sowing in the seedbed. Twenty days after sowing (DAS), the seedlings were inoculated by spreading *D. angustus* infested plant material (small pieces of stems) from cultures into the seedbed of each pot. Following the inoculation method, each seedling was received approximate 100 nematodes (Rahman and Evans, 1988).

Field trials of the nematicides

For the effect of timing of application of furadan 5G in soils, 2 experiments were conducted in the rain-fed and irrigated eco-systems. Furadan applied at 1 kg/ha was incorporated into the soil (by hand spreading) at 40, 30, 20, 10, 0 days before transplanting (DBT) *D. angustus* infected seedlings. There were 6 treatments: T_1: furadan 5G 40DBT, T_2: furadan 5G 30DBT, T_3: furadan 5G 20DBT, T_4: furadan 5G 10DBT, T_5: furadan 5G 0DBT and T_6: healthy (control).

For the management of *D. angustus,* 2 field trials were conducted to evaluate the 3 granular nematicides, sunfuran 5G, edfuran 5G and forwafuran 5G in both the environments. The information about source, registrations status and chemical names of the tested nematicides are shown in the Table 1. The treatments were: T_1: sunfuran 5G, T_2: edfuran 5G, T_3: forwafuran 5G, T_4 : furadan 5G, T_5: control (diseased), T_6: control (healthy). The rate of application of all the nematicides was 1 kg ai/ha and all nematicides were incorporated into the soil at the time of transplanting. Furadan 5G was used as a standard check.

For all the field trials, intercultural operations including fertiliza-tion, weeding and irrigation were done in the field (BRRI, 2003). Thirty five-day-old seedlings with visible chlorotic symptom on the leaf sheath were transplanted in the plots following 2 to 3 seedlings/ hill. The distance between hill to hill and row to row was 20 cm. The plot size was 2 x 3 m and each plot was surrounded by a 20 to 25 cm high mud plastered levee to prevent the spread of *D. angustus*. Experiments were laid out in a randomized block design (RBD) with 4 replications. The whole plot was cut and diseased panicles were categorized into damaged tillers (no panicle initiation), ufraI (panicle completely enclosed in leaf sheath), ufraII (partially emerged panicle but unfilled grain) and ufraIII (completely emerged panicle with unfilled grain) (Cox and Rahman, 1980). Data on damaged-tiller (%), ufraI (%), ufraII (%), ufraIII (%), total ufra (%), healthy panicle and yield (t/ha) were recorded after harvesting the crop.

Screening of different genotypes of rice against ufra disease, 2005-2006

A total of 53 rice entries including a resistant and susceptible check were collected from the gene bank of BRRI (Table 2). Two trials

Table 2. Screening of different rice genotypes against ufra disease.

Variety name	Accession No.	2005-2006[a]		
		Tiller infection (%)	DI	Reactions
IR5	2276	40	3	MR
IR28	2282	44.5	5	MS
IR36	2284	39.5	3	MR
IR30	2287	30.5	3	MR
IR42	2290	59	5	MS
IR50	2295	50.5	5	MS
IR56	2298	72.5	7	S
Manohor salio (A)	3334	86	9	HS
Fukuhonami	3342	0	0	HR
Gohyakumangoku	3345	70	7	S
Tomoyo taka	3346	34	3	MR
Hunenwase	3348	13	1	R
Yone shiro	3349	33.5	3	MR
Matsuhonami	3352	0	0	HR
Akiyu taka	3355	0	0	HR
Niigatawase	3357	27.5	3	MR
Shinanokogane	3359	9.5	1	R
Hayakikari	3361	0	0	HR
Kinonishiki	3362	15	1	R
Koshihikari	3363	38.5	3	MR
Akinishiki	3367	16.5	1	R
Reihou	3370	96	9	HS
Asominori	3371	25	3	MR
Akitsuho	3376	56	5	MS
Minamini shiki	3379	47.5	5	MS
Kogane masar	3380	45.5	5	MS
Yamahikari	3382	57	5	MS
Yamabiko	3383	27.5	3	MR
Akebono	3385	33.5	3	MR
Musashikogane	3387	49	5	MS
Sachikaze	3389	47.5	5	MS
Kinmazi	3390	41.5	5	MS
Aokazi	3395	12.5	1	R
Kinkino-33	3396	57.5	5	MS
Koshinishini	3397	12.5	1	R
Fujiminori	3398	59	5	MS
Ozora	3400	31.5	3	MR
Chinese var#8	3709	81	9	HS
Chinese var#10	3411	41.5	5	MS
Chinese var#11	3412	42.5	5	MS
Bazail	165	33	3	MR
Bazail	171	33.5	3	MR
Bazail	249	77.5	7	S
Bazail	251	79	7	S
Bazail	252	30	3	MR
Bazail	1414	68	7	S
Rayeda	4849	15	1	R
Chapla	1961	58.5	5	MS
Uttara	2153	79	7	S
Ndr-97	5023	59	5	MS

Table 2. Contd.

Lolat	5024	51	5	MS
Rayeda (resistant check)	4851	15.5	1	R
BR3 (susceptible check)	-	89	9	HS

[a-]Data are average of rain-fed and irrigated rice ecosystems. HR= highly resistant; R= resistant; MR= moderate resistant; MS= moderate susceptible; S= susceptible; HS= highly susceptible; DI= disease index.

Table 3. Length of effectiveness of furadan 5G at 1 kg ai/ha applied at different application intervals for the control of ufra disease of rice in irrigated rice ecosystem.

Time of application	Ufra infestation (%)					Healthy panicle (%)	Yield (t/ha)
	Damaged tiller	UfraI[a]	UfraII[b]	UfraIII[c]	Total ufra		
40 DBT	6.2[a]	8.0[a]	17.8[a]	63.2[a]	95.2[a]	4.8[c]	2.60[d]
30 DBT	3.4[b]	5.5[a]	9.2[ab]	50.0[ab]	68.0[ab]	32.0[b]	3.02[d]
20 DBT	1.6[bc]	4.3[a]	8.1[ab]	43.5[ab]	58.4[b]	41.6[b]	3.48[c]
10 DBT	1.4[bc]	3.7[a]	6.5[ab]	46.3[ab]	57.9[b]	42.1[b]	3.76[bc]
0 DBT	1.3[bc]	4.3[a]	10.9[ab]	28.4[b]	44.9[b]	55.1[b]	4.05[b]
Control(healthy)	0.7[c]	0.2[b]	0.50[b]	1.88[c]	3.3[c]	96.7[a]	4.55[a]

Column means bearing common small letter(s) do not significantly differ at the *p*=0.05 by DMRT. DBT= days before transplanting; 0DBT= at transplanting. [a]-UfraI= panicle completely enclosed in leaf sheath, [b]-UfraII= partially emerged panicle but unfilled grain, [c]-UfraIII= completely emerged panicle with unfilled grain.

were conducted using the same genotypes in 2 conditions. Pre-germinated seeds were sown approximate 0.5 cm deep in each earthen pot (40 cm diameter and 40 cm in height) by using sterilized forceps. The trial was laid out in a completely randomized design (CRD) and each genotype was replicated 3 times in both the ecosystems. A total of 100 seedlings were maintained in each replication for each genotype. Based on the percentage of infection, the test entries were classified into 6 broad groups including highly resistant (0% incidence), resistant (1 to 20% incidence), moderate resistant (21 to 40% incidence), moderate susceptible (41 to 60% incidence), susceptible (61 to 80% incidence) and highly susceptible 81 to 100% incidence (Rahman, 1993; IRRI, 1996). Data on total number of tillers, total number of infested tillers and percentage of infested tillers were recorded at 42 DAS.

Economic analysis and statistics

Benefit cost ratio (BCR) is an important, but underutilized economic analysis tool is the benefit/cost ratio or profitability index. The benefit/cost ratio, B/C or BCR, is the present value of an investment's benefits divided by the present value of the initial cost. Average profitability analysis of 3 nematicides was done in the on-farm trials of 2 seasons. Statistical analyses were performed by analysis of variance (ANOVA) followed by protected Fisher's least significance difference (LSD) test at the p 0.05 using CropStats (Gomez and Gomez, 1984).

RESULTS

Effect of application time of furadan 5G on ufra disease in irrigated rice

The highest percentage of damaged-tillers was observed at 40DBT (6.2%) followed by 30DBT (3.4%), 20DBT (1.6%), 10DBT (1.4%), 0DBT (1.3%) and in the control (healthy) (0.7%). The effects of 5 intervals of furadan 5G application were significantly different. The application of nematicide at 40 and 30DBT failed to reduce *D. angustus* infestation and resulted in a higher percentage of damaged tillers. With respect to ufraI, ufraII, ufraIII and total ufra, the highest percentage of ufra infestation was observed at 40DBT followed by 30 and 20DBT. Total ufra infestation was statistically similar between 40 and 30DBT but insignificant among the treatments, 20, 10 and 0DBT (Table 3). The highest percentage of healthy panicle was observed in the control (healthy) (96.7%) followed by 0DBT (55.1%), 10DBT (42.1%) and 20DBT (41.6%), respectively. The highest yield was obtained in the control (healthy) (4.55 t/ha) followed by 0DBT (4.05 t/ha), 10DBT (3.76 t/ha) and 20DBT (3.48 t/ha). The yield was significantly reduced at 40 and 30DBT compared to other treatments (Table 3).

Effect of application time of furadan 5G on ufra disease in rain-fed rice, 2006

In the rain-fed rice ecosystem, the lowest percentages of damaged tillers, ufraI, ufraII, ufraIII and total ufra were recorded at 0DBT followed by 10 and 20DBT, which were statistically differed from 30 and 40DBT. Conversely, the highest percentage of healthy panicle was observed at 0DBT followed by 10 and 20DBT. A lower percentage of healthy-panicles were observed at 40 and 30DBT. The

Table 4. Length of effectiveness of furadan 5G at 1 kg ai/ha applied at different application intervals for the control of ufra disease of rice in rain-fed rice ecosystem.

Time of application	Ufra infestation (%)					Healthy panicle (%)	Yield (t/ha)
	Damaged tiller	UfraI[a]	UfraII[b]	UfraIII[c]	Total ufra		
40 DBT	12.5^a	10.2^a	20.2^a	53.7^a	96.6^a	3.4^e	1.3^c
30 DBT	11.3^a	9.3^a	18.7^a	42.9^b	82.2^a	17.8^d	1.9^c
20 DBT	3.3^b	5.1^b	10.2^b	32.5^c	51.1^b	48.9^c	3.2^b
10 DBT	2.4^b	4.2^b	9.3^b	30.3^c	46.2^b	53.8^c	3.5^b
0 DBT	$1.1b^c$	3.6^b	5.5^c	10.4^d	20.6^c	79.4^b	4.2^a
Control (healthy)	0.2^c	0.5^c	0.8^d	1.5^e	3.0^d	97.0^a	4.6^a

Column means bearing common small letter(s) do not differ significantly at the p = 0.05 by DMRT. DBT= days before transplanting; 0DBT= at transplanting. [a]-UfraI = panicle completely enclosed in leaf sheath, [b]-UfraII= partially emerged panicle but unfilled grain, [c]-UfraIII = completely emerged panicle with unfilled grain.

Table 5. Efficacy of 3 granular nematicides applied at 1 kg ai/ha for the control of ufra disease of rice in the rain-fed rice ecosystem.

Treatments	Ufra infestation (%)					Healthy panicle (%)	Yield (t/ha)
	Damaged tiller	UfraI[a]	UfraII[b]	UfraIII[c]	Total ufra		
Sunfuran 5G	14.4^b	4.0^a	12.9^b	13.4^b	44.7^{ab}	55.3^b	3.89^a
Edfuran 5G	7.8^{bc}	5.0^a	10.8^b	13.6^b	37.3^b	62.7^b	4.02^a
Forwafuran 5G	10.4^b	7.8^a	17.5^b	18.8^b	44.5^{ab}	57.5^b	3.94^a
Furadan 5G	7.1^b	2.5^a	8.2^b	18.3^b	36.0^{bc}	64.0^b	4.00^a
Control (diseased)	26.2^a	8.2^a	31.4^a	32.1^a	97.8^a	2.2^c	2.05^b
Control (healthy)	2.4^c	0.3^a	0.9^b	1.9^b	5.4^c	94.6^a	4.03^a

Column means bearing common small letter(s) do not differ significantly at the p < 0.05 by DMRT, [a]-UfraI = panicle completely enclosed in leaf sheath. [b]-UfraII= partially emerged panicle but unfilled grain. [c]-UfraIII = completely emerged panicle with unfilled grain.

higher yields were found at 0, 10 and 20DBT due to lower percentage of total ufra infestation and higher percentage of healthy panicle. Results from both rice ecosystems showed that the considerable yield was obtained up to 20DBT (Tables 3 and 4).

Efficacy of nematicides for the control of ufra of rice in rain-fed rice, 2005

Three tested nematicides, sunfuran 5G, edfuran 5G and forwafuran 5G reduced the percentages of damaged tiller, ufraI, ufraII and ufraIII significantly compared to the control (diseased) (Table 5). The higher percentage of total ufra was observed in the control (diseased) (97.8%) followed by sunfuran 5G (44.7%), forwafuran 5G (44.5%), edfuran 5G (37.3%), furadan 5G (36%) and control (healthy) (5.4%). The highest number of healthy- panicles was observed in the control (healthy) (94.6%) followed by furadan 5G (64%), edfuran 5G (62.7%), forwafuran 5G (57.5%), sunfuran 5G (55.3%) and control (diseased) (2.2%). The higher yield was obtained in the control (healthy) (4.03t/ha) followed by edfuran 5G (4.02 t/ha), furadan 5G (4.0 t/ha), forwafuran 5G (3.94 t/ha), sunfuran 5G (3.89 t/ha) and control (diseased) (2.05 t/ha). Yield did not significantly differ among the 3 tested nema-ticides. The higher percentage of healthy panicles and lower percentage of total ufra resulted in higher yield compared to the control (diseased) (Table 5).

Efficacy of nematicides for the control of ufra disease in irrigated rice, 2005-2006

The higher percentage of damaged tiller was observed in the control (diseased) (6.2%) followed by edfuran 5G (2.1%), forwafuran 5G (1.6%), sunfuran 5G (1.3%), furadan 5G (1.1%) and control (healthy) (0.6%), but there was no significant difference among 3 tested nema-ticides. Application of nematicides, sunfuran 5G, edfuran 5G and forwafuran 5G in soil significantly reduced the incidence of ufraI, ufraII ufraIII and total ufra compared to the control (diseased) (Table 6). Higher percentage of healthy-panicles was observed in the control (healthy) (96.6%) followed by furadan 5G (56.9%), edfuran 5G (53.0%), forwafuran 5G (48.3%), sunfuran 5G (47.6%)

Table 6. Efficacy of 3 granular nematicides applied at 1 kg ai/ha for the control of ufra disease of rice in the irrigated rice ecosystem.

Treatment	Ufra infestation (%)					Healthy panicle (%)	Yield (t/ha)
	Damaged tiller	UfraI^{a}	UfraII^{b}	UfraIII^{c}	Total ufra		
Sunfuran 5G	1.3^{bc}	3.7^{b}	7.2^{ab}	40.2^{bc}	52.4^{b}	47.6^{b}	3.85^{b}
Edfuran 5G	2.1^{b}	2.2^{bc}	6.8^{ab}	35.9^{bc}	47.0^{b}	53.0^{b}	3.88^{b}
Forwafuran 5G	1.6^{bc}	4.4^{b}	5.5^{ab}	40.2^{bc}	51.8^{b}	48.3^{b}	3.97^{b}
Furadan 5G	1.1^{b}	2.2^{b}	17.2^{a}	22.6^{c}	43.2^{b}	56.9^{b}	4.01^{ab}
Control (diseased)	6.2^{a}	9.2^{a}	17.3^{a}	63.0^{a}	95.6^{a}	4.4^{c}	2.58^{c}
Control (healthy)	0.6^{c}	0.2^{c}	0.4^{b}	2.3^{d}	3.4^{d}	96.6^{a}	4.48^{a}

Column means bearing common small letter(s) do not differ significantly at the p=0.05 by DMRT, ^{a}-UfraI = panicle completely enclosed in leaf sheath, ^{b}-UfraII= partially emerged panicle but unfilled grain, ^{c}-UfraIII = completely emerged panicle with unfilled grain.

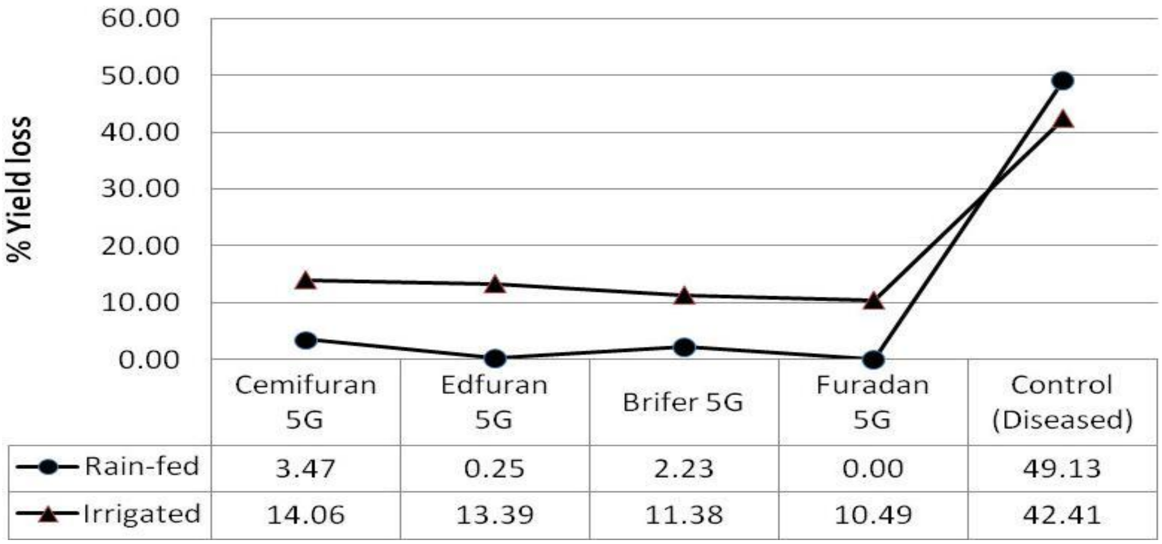

Figure 1. Yield loss due to ufra disease of rice under different nematicidal treatments in the rain-fed and irrigated rice ecosystems.

and control (diseased) (4.4%), but there was no significant difference among the 3 tested nematicides. The highest yield was observed in the control (healthy) (4.48 t/ha) followed by furadan 5G (4.01 t/ha), forwafuran 5G (3.97 t/ha) edfuran 5G (3.88 t/ha), sunfuran 5G (3.85 t/ha) and (2.58 t/ha). Among the nematicides tested, all gave better yields which were statistically similar with furadan 5G (Table 6). Yields of 3 tested nematicides were close to the control (healthy) both in both the ecosystems (Table 5 and 6).

Yield losses due to ufra disease of rice

Yield loss due to ufra disease was 49.1% in the control (diseased), while it was 0.3 to 3.5% in the nematicidal treated plants in the rain- fed rice ecosystem. In the irrigated rice ecosystem, the yield reduction was 42.4% in the control (diseased), while it was 10.5 to 14.1% in the treated plants (Figure 1).

Analysis of benefit cost ratio

A simple economic analysis on the use of sunfuran 5G, edfuran 5G, forwafuran 5G and furadan 5G showed 6.8, 7.1, 6.9 and 7.1 times profitable, respectively over the control (diseased) (Table 7).

Screening of different genotypes of rice against ufra disease, 2005-2006

Of 53 entries including checks were examined, 4 entries, fukuhonami, hayakikari, akiyu taka and matsuhonami with disease scale 0 (zero) showed highly resistance reaction to the ufra disease, 8 entries, aokazi, koshinishini, kinonishiki, akinishiki, shinanokogane, hunenwase, rayeda4849 and rayeda4851 with disease scale 1 showed resistance reaction to ufra, 31 entries with disease scale 3 to 5 showed moderate resistant or moderate susceptible to ufra and 10 entries with disease

Table 7. Yield difference and economic benefit of different nematicidal treatments applied at 20 kg/ha in rain-fed and irrigated rice ecosystems.

Treatment [b]	Price of nematicides (US$/ kg)	Average Yield (t/ha) [a]	Yield difference (t/ha)	Price of rice at 150 US$/t	Cost of Nematicide/ha (US$)	Benefit ratio over nematicide cost
Sunfuran 5G	1.72	3.87	1.55	232.5	34.4	6.8
Edfuran 5G	1.71	3.95	1.63	244.5	34.3	7.1
Forwafuran 5G	1.79	3.96	1.64	246.0	35.7	6.9
Furadan 5G	1.79	4.01	1.69	253.5	35.9	7.1
Control (diseased)	-	2.32	-	-	-	-

[a]- Data are average of rain-fed and irrigated rice ecosystems, [b]- Cost of other agronomic practices is the same for all treatments.

scale 7 to 9 showed susceptible to highly susceptible reaction to the disease (Table 2).

DISCUSSION

Results of the present study showed that the length of effectiveness of furadan 5G in soils was approximate 20 days. This result partially agrees with the previous research (Rahman, 1993a; Latif et al., 2004a, b). It is reported that the application of carbofuran at 0.75 or 1 kg ai/ha at transplanting reduced the ufra incidence and increased the yield (Rahman et al., 1981) . We applied nematicide at intervals up to 40 d before transplanting and at transplanting. Our results clearly demonstrate that furadan 5G was effective in reducing *D. angustus* population densities and the occurrence of ufra disease when applied at transplanting and could be used at land preparation (2 to 3 w before transplanting) . To our knowledge, this study is the first to examine the effects of nematicide 2 to 3 w before transplanting or during land preparation for reducing the incidence of ufra disease and population densities of *D. angustus*.

A high proportion of healthy panicles and a low proportion of total ufra infestation compared to the control (diseased) in the nematicide trial might have contributed to such a high rice yield in both the ecosystems and their combined analysis. However, sunfuran 5G, edfuran 5G and forwafuran 5G were also effective in reducing the ufra disease incidence and in increasing the yield. These results corroborated the previous work of several authors' (Mondal and Miah, 1989; Mondal et al., 1989b; Rahman and Miah 1991). Soil incorporation with carbofuran at the rate of 0.67 or 1 kg ai/ha (Miah and Bakr, 1977a; Latif et al., 2004a) and 30 kg/ha (Sein and Sein, 1977) were also been reported to reduce ufra incidence both in the rain-fed and deep-water rice.

The higher percentages of damaged tillers and ufra infestations resulted in lower yield in the control (diseased). In the present study, 42.4 and 49.1% yield losses occurred due to the ufra disease in the artificially inoculated fields of rain-fed and irrigated ecosystems, respectively. Several authors reported that ufra is one of the most devastating rice diseases in Southeast Asian countries (Miah and Bakr, 1977a; Ou, 1985; Bridge et al., 1990) , it caused 100% yield loss of rice in Bangladesh (Miah and Bakr, 1977a).

The profitability analysis in the present study suggests that the management of ufra disease by the application of sunfuran 5G, edfuran 5G and forwafuran 5G in comparisons with furadan 5G is possible and profitable esp. in the fields where the disease is endemic. The profitability analyses of the use of other nematicides or other management strategies of rice production were also previously studied by several authors (Rahman and Miah, 1994; Latif et al., 2004c, 2009).

Based on the results of 2 ecosystems, 4 rice entries, fukuhonami, hayakikari, akiyu taka, and matsuhonami were found highly resistant to *D. angustus*. Our interest was to find sources of resistance against the ufra disease. A large number of wild rice, modern rice varieties and breeding lines have been screened for resistance to *D. angustus* (Miah and Bakr, 1977a; Bora and Medhi, 1992; Rahman, 1987; Bhagawati and Bora, 1994; Waliullah, 2007). B-69- 1 in Myanmar (Sein, 1977), BKN 6986-8 in Vietnam (Kinh and Nghiem, l982), R16-06 and *O. subulata* (Miah and Bakr, 1977a) and 9 Rayeda lines (Rahman, 1987), were found to be resistant or moderately resistant sources. After a long gap, this is a recent search for highly resistant sources against the ufra. However, by screening a large number of genotypes from the germplasm, we found plant materials that are highly resistant to the ufra disease. There is an urgent need for ufra resistant varieties, but until recently no resistant variety has been found in high yielding varieties. The application of furadan 5G at 1 kg ai/ha in soils at the time of land preparation would be quite effective for reducing the ufra disease.

Conclusion

On the basis of these results, we conclude that 3 granular nematicides (sunfuran 5G, edfuran 5G and forwafuran 5G at 1 kg ai/ha) could be cost-effective for the manage-ment of ufra disease. In the rain-fed ecosystem, we cannot manage water due to heavy rainfall. Therefore, we need to find out suitable liquid nematicide(s) to combat this disease. We believe that the entries those showed highly resistant reactions to *D. angustus* could be used as parent material(s) for hybridization program to develop ufra resistant rice variety. We also believe that the Scientists of South-East Asia would greatly be benefited to use the highly resistant sources for the management of devastating ufra disease of rice.

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