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False smut of rice, a new emerging disease in tarai region of Uttarakhand: Its eco-friendly management through essential oils

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Abstract
False smut of rice earlier considered as minor disease has become one of the major diseases in rice growing areas. Present investigation was carried out to evaluate the efficacy of different essential oils against false smut disease of rice under field conditions. Research findings over two crop seasons, suggests that of the different essential oils tested two foliar sprays of neem essential oil @ 2ml/liter was found to be the best in managing the disease and in improving the grain yield. The treatment provided 16.33 per cent control of the disease and 7.93 per cent increase in grain yield. The treatment also avoided 7.53 per cent loss in grain yield. Moreover, treatment has been found to be safe as no phytotoxicity symptoms was observed.

Keywords: False smut, ustilaginoidea virens, rice, *Oryza sativa*

Introduction
Rice (*Oryza sativa* L.) is one of the most important food crops of the Asia, cultivated by more than 100 countries and is a major part of the food for nearly half of the world's population. During 2018 crop year, rice was cultivated on an area of about 167.3 million hectares worldwide with a production of about 495.9 million tones (Shahbandeh 2020) [29]. During 2018, India is the second largest producer with 116.42 million metric tons and was estimated to harvest a rice area of about 43.8 million hectares (Shahbandeh 2020) [29]. Although, India had largest area under rice cultivation but its productivity is much less compared to its neighbor China. Its productivity is greatly affected by several biotic and abiotic causes. Biotic factors include insect-pests and diseases caused by fungi, bacteria, viruses, phytoplasmas and nematodes. However, among the fungal disease, false smut caused by *Ustilaginoidea virens* (Cooke) (Takahashi, 1896) [35] earlier considered as a minor disease of rice is now becoming one of the most emerging diseases causing serious yield losses worldwide (Abbas *et al*. 2014) [1] and has been reported as an epidemic disease (Rush *et al*. 2000, Singh and Pophaly, 2010) [25, 31]. The disease has been reported from Japan, China, North and South America, Southeast Asian countries, Myanmar, Sri Lanka, Fiji, and Africa. False smut is also known as Lakshmi disease and was believed to be an indication of a bumper harvest.
The disease (caused by *Ustilaginoidea virens* (Cooke) Takahashi, teleomorph *Claviceps oryza sativa* (Hashioka)) was first reported from Tirunelveli in Tamil Nadu, India (Cooke, 1878) [6]. Most recently *Villosiclava virens* has been proposed as the new teleomorph stage of the fungus (Tanaka *et al*. 2008) [36]. The disease manifests at after panicle emergence. The affected grain converts into yellowish-green velvety spore balls. The spore balls are smooth at first and are yellow covered by a membrane but as the membrane bursts the color appears to be orange/yellow. When cut open, the ball is white in the center with three outer layers (Sciumbato and Street, 2000) [27]. Depending upon the disease severity and varieties grown the yield loss caused by disease estimated to vary from 0.2-49 per cent (Kumari and Kumar 2015, Doden and Singh 1996, Singh 1998, Atia 2004, Ladhalakshmi *et al*. 2012, Baruah *et al*. 1992, Singh *et al*. 1992, Biswas 2001) [18, 7, 32, 3, 19, 4, 33, 5]. Besides causing serious yield losses *Ustilaginoidea virens* is reported to produce two mycotoxins i.e. ustiloxins and ustilaginoidins causing poisoning to humans and domestic animals (Koiso *et al*. 1994, Zhou *et al*. 2012) [9, 37]. High yielding varieties and hybrids are severely affected by false smut and are badly affected by high fertility levels in an irrigated ecosystem. Occurrence of this disease in severe form is correlated with susceptibility of high yielding varieties and hybrids supported by high nitrogen inputs (Savary *et al*. 2004, Ladhalakshmi 2012) [26, 19].
Since it is a relatively newer disease in many parts, the systematic screening has not been taken up and even if conducted they are mainly based on natural disease incidence in the field

which is highly influenced by the environmental conditions. Since the disease affects the grains directly spraying of fungicides particularly at later stages of crop may have chance of residue problems. Use of essential oils is one of the eco-friendly strategies for the management of diseases. The antimicrobial properties of plant oils against sheath blight (Sehajpal *et al*. 2009) [28] and seed-borne fungi of rice (Nguefack *et al*. 2008) [22], fungal pathogens of cinnamon (Alrajhi 2014) [2] and late blight of tomato (Soylu *et al*. 2006) [34] have been proved. However, no information is available about the efficacy of essential oils against false smut of rice. Therefore, keeping these aspects in mind use of essential oils can be one of the best options for disease management, particularly in the context of organic farming.

Materials and Methods

The Experiment was carried out at N.E.B. Crop Research Centre of G.B. Pant University of Agriculture and Technology, Pantnagar during *kharif* 2018 and 2019 crop seasons to evaluate the efficacy of selected essential oils against false smut of rice. The trials were laid out in a Randomized Block Design (RBD) with three replications and ten treatments *viz*., T_1 - Citronella oil @ 2.0ml/l; T_2-Eucalyptus oil @ 2.0ml/l; T_3- Cedar wood oil @ 2.0ml/l; T_4-Nirgundi oil @ 2.0ml/l; T_5-Lemon grass oil @2.0ml/l; T_6-Clove oil @2.0ml/l; T_7-Neem essential oil @2.0ml/l; T_8-Emulsifier @2.0ml/l; T_9-Carbendazim @0.6g/l and T_{10}-Control.

The seedlings of susceptible pre-released hybrid UPRH 191 were transplanted on 31st July, 2018 and 19th July, 2019 with 20cm row to row and 10cm plant to plant spacing in 5 x 5 meter plots. The crop was raised as per the recommended package of practices and protective irrigation was given as and when required. The crop was spray inoculated on 24th Sept, 2018 and 12th Oct, 2019. The spore balls collected from infected plants were vigorously agitated in sterilized water in a bucket and a sticker was also added to it so that spores can easily stick on to the flowers. The essential oils were sprayed twice first at 2 days after inoculation and second 7 days later, using a hand operated knapsack sprayer fitted with hollow cone nozzle and water volume of 500 lit/ha was maintained. During 2018, crop was sprayed on 26th Sept and 3rd Oct, while, in 2019, on 21st Oct and 28th Oct, 2019. The observations on false smut incidence (% infected panicles/ m^2) was recorded 10 days before harvesting from 1 m^2 area at random in each plot (Anonymous 1996b). Finally, per cent disease control was calculated to assess the effectivity of essential oils (Kumar *et al*. 2016a&b; Pandey *et al*. 2016) [13, 14, 23].

The observations on phytotoxicity symptoms namely; viz; epinasty, hyponasty, chlorosis, necrosis, stunting, wilting etc. were recorded as per CIB guidelines using a rating scale of 0 – 10 (Muthukumar and Udhayakumar 2015; Kumar 2018; 2020a&b) [20, 15, 16, 17] where, 0= no phytotoxicity, 1= 1-10% phytotoxicity, 2=11-20% phytotoxicity, 3=21-30% phytotoxicity, 4=31-40% phytotoxicity, 5=41-50% phytotoxicity, 6=51-60% phytotoxicity, 7=61-70% phytotoxicity, 8=71-80% phytotoxicity, 9=81-90% phytotoxicity and 10= 91-100% phytotoxicity. Visual observations were recorded at 1, 3, 7 and 10 days after spray of test products.

The crop was harvested at maturity and grain yield was recorded on plot basis and further converted into hectare basis. Per cent increase in yield and avoidable loss in yield were calculated on the basis of pooled mean of two crop seasons. Increase in grain yield and avoidable yield loss (AYL) due to false smut were calculated using grain yield data using following formulae:

Increase in grain yield (%) = [(Yt-Yc)/Yc] x 100

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

Where, Yt = yield in treatment, Yc = yield in control, Yp = Yield under protected condition and Yu = Yield under unprotected condition (Kumar 2011, 2012, 2013; Nagaraja *et al*. 2012) [10, 11, 12, 21].

Statistical Analysis

The data collected were statistically analyzed using analysis of variance (ANOVA) for randomized block design with the help of STPR-1 statistical programme developed by Department of Mathematics and Statistics, College of Basic Sciences and Humanities, G.B. Pant University of Agriculture and Technology, Pantnagar. In case of significant result of F test, critical difference at 5% level of probability was taken for comparison between treatment means (Gomez and Gomez 1984) [8].

Results and Discussion

Field experiments were conducted at Norman E. Borlaug Crop Research Centre, Pantnagar during *Kharif* 2018 and 2019 to find out the efficacy of essential against false smut of rice.

Effect of Essential Oils against False Smut of Rice

The data pertinent to false smut incidence during 2018 and 2019 crop seasons is presented in table 1. The false smut incidence during 2018 ranged between 20.38 and 30.57 per cent while in 2019 it ranged between 21.20 and 30.01 per cent. During both the years' highest incidence was recorded in untreated control while lowest with carbendazim @ 0.6g/litre. To evaluate the efficacy of different essential oils the data from two seasons were pooled. The pooled analysis (table1) also revealed that of the various treatments spraying of carbendazim @ 0.6g/litre recorded lowest incidence (20.79%) of the false smut. However, among the different essential oils, two spraying of neem oil, first at 2 days after inoculation and second 7 days later was found to be the best recorded 26.24 per cent incidence of the disease and provided 16.33 per cent control of the disease over untreated control.

Effect of Essential Oils on Grain Yield of Rice

The crop was harvested at maturity and grain yield was recorded on plot basis and further converted into hectare basis (Table 2). The yield during 2018 ranged between 5401.00 and 6218.00 kg/ha while in 2019 it ranged between 5428.00 and 6094.67 kg/ha. During both the years' lowest yield was recorded in untreated control while highest with carbendazim @ 0.6g/litre. Like disease incidence the yield data from two seasons were pooled to evaluate the effect of essential oils on grain yield of rice. The pooled analysis (table 2) revealed that of the various treatments spraying of carbendazim @ 0.6g/litre recorded highest grain yield (6156.33 kg/ha). However, among the different essential oils, two spraying of Neem oil, first at 2 days after inoculation and second 7 days later proved to be the best recorded 5843.83 kg/ha grain yield. The treatment provided 7.93 per cent increase in grain yield and avoided 7.35 per cent loss in grain yield.

Evaluation of Phtytoxicity of Essential Oils on Rice

The data pertinent to phytotoxicity symptoms namely; epinasty, hyponasty, chlorosis, necrosis, stunting, wilting etc.

are presented in table 3. The plants were observed for the presenece of phytotoxicity symptoms at 1, 3, 7 and 10 days after application of essential soils. It is evident from the results that none of the essential oil showed phytotoxicity symptoms.

Based on the present study it can be concluded that spraying of neem essential oil was found to be the best in managing the false smut disease and also in improving the grain yield compared to untreated control. Complete inhibition in growth of *Ustilaginoidea virens* with lemon grass oil (*Cymbopogon flexuous),* cinnamon oil (*Cinnamomum zeylanicum*) and palmarosa oil (*Cymbopogon martinii*) has been reported under *in-vitro* conditions (Raji *et al*. 2016) [24]. Similarly, Nguefack *et al*. (2008) [22] reported the antimicrobial property of cinnamon oil (*Cymbopogon citratus*) against rice pathogens *Alternaria padwickii, Bipolaris oryzae* and *Fusarium moniliforme*. Likewise, inhibition of mycelial growth of *Sarocladium oryzae in vitro* and reduction in sheath rot severity in field by citronella oil was reported (Sharma *et al*. 2013) [13].

However, no report is available in literature on the efficacy of neem essential oil against the false smut disease of rice. Therefore, it should be considered as first record.

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Table 1: Effect of essential oils on incidence of false smut disease of rice.

Treatments	Dose	Infected panicles/m2 (%)			Disease control (%)
		2018	2019	Pooled	
T1-Citronella oil	2.0 ml/l	28.86	31.19	30.03	4.25
T2- Eucalyptus oil	2.0 ml/l	28.57	30.20	29.38	6.30
T3- Cedar wood oil	2.0 ml/l	28.17	30.80	29.49	5.98
T4-Nirgundi oil	2.0 ml/l	28.58	30.53	29.56	5.75
T5-Lemon grass oil	2.0 ml/l	29.31	30.01	29.66	5.43
T6-Clove oil	2.0 ml/l	29.77	30.42	30.09	4.04
T7-Neem essential oil	2.0 ml/l	24.92	27.56	26.24	16.33
T8-Emulsifier	2.0 ml/l	29.80	30.01	29.91	4.64
T9-Carbendazim	0.6g/l	20.38	21.20	20.79	33.69
T10-Control	-	30.57	32.16	31.36	-
Sem		0.80	0.73	0.43	
CD at 5%		2.38	2.21	1.27	

Table 2: Effect of essential oils on grain yield of rice.

Treatments	Dose	Grain yield (kg/ha)			Increase in yield (%)	Avoidable yield loss (%)
		2018	2019	Pooled		
T1-Citronella oil	2.0 ml/l	5569.33	5525.33	5547.33	2.45	2.39
T2- Eucalyptus oil	2.0 ml/l	5563.33	5569.00	5566.17	2.80	2.72
T3- Cedar wood oil	2.0 ml/l	5648.67	5554.33	5601.50	3.45	3.34
T4-Nirgundi oil	2.0 ml/l	5454.67	5549.67	5502.17	1.62	1.59
T5-Lemon grass oil	2.0 ml/l	5686.33	5575.33	5630.83	4.00	3.84
T6-Clove oil	2.0 ml/l	5585.67	5529.67	5557.67	2.64	2.58
T7-Neem essential oil	2.0 ml/l	5894.67	5793.00	5843.83	7.93	7.35
T8-Emulsifier	2.0 ml/l	5654.33	5577.00	5615.67	3.72	3.58
T9-Carbendazim	0.6g/l	6218.00	6094.67	6156.33	13.70	12.05
T10-Control	-	5401.00	5428.00	5414.50	-	-
Sem		46.81	47.96	36.78		
CD at 5%		139.07	142.50	109.29		

Table 3: Evaluation of phytotoxicity of selected essential oils on rice (2018 and 2019).

Treatment	Days of observation after spray	Phytotoxicity Symptoms					
		Epinasty	Hyponasty	Chlorosis	Necrosis	Stunting	Wilting
Untreated control (water spray)	1st day	0	0	0	0	0	0
	3rd day	0	0	0	0	0	0
	7th day	0	0	0	0	0	0
	10th day	0	0	0	0	0	0
T1-Citronella oil	1st day	0	0	0	0	0	0
	3rd day	0	0	0	0	0	0
	7th day	0	0	0	0	0	0
	10th day	0	0	0	0	0	0
T2- Eucalyptus oil	1st day	0	0	0	0	0	0
	3rd day	0	0	0	0	0	0
	7th day	0	0	0	0	0	0
	10th day	0	0	0	0	0	0
T3- Cedar wood oil	1st day	0	0	0	0	0	0
	3rd day	0	0	0	0	0	0
	7th day	0	0	0	0	0	0

	10th day	0	0	0	0	0	0
T4-Nirgundi oil	1st day	0	0	0	0	0	0
	3rd day	0	0	0	0	0	0
	7th day	0	0	0	0	0	0
	10th day	0	0	0	0	0	0
T5-Lemon grass oil	1st day	0	0	0	0	0	0
	3rd day	0	0	0	0	0	0
	7th day	0	0	0	0	0	0
	10th day	0	0	0	0	0	0
T6-Clove oil	1st day	0	0	0	0	0	0
	3rd day	0	0	0	0	0	0
	7th day	0	0	0	0	0	0
	10th day	0	0	0	0	0	0
T7-Neem essential oil	1st day	0	0	0	0	0	0
	3rd day	0	0	0	0	0	0
	7th day	0	0	0	0	0	0
	10th day	0	0	0	0	0	0
T8-Emulsifier	1st day	0	0	0	0	0	0
	3rd day	0	0	0	0	0	0
	7th day	0	0	0	0	0	0
	10th day	0	0	0	0	0	0
T9-Carbendazim	1st day	0	0	0	0	0	0
	3rd day	0	0	0	0	0	0
	7th day	0	0	0	0	0	0
	10th day	0	0	0	0	0	0
Sem		NS	NS	NS	NS	NS	NS
CD at 5%		NS	NS	NS	NS	NS	NS

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