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Outbreak of falciparum malaria in submerged villages of Narayanganj PHC, district Mandla due to Narmada Irrigation Project, Central India (Madhya Pradesh)

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On receipt of a report about high prevalence of malaria and deaths in submerged villages of Narayanganj Primary Health Centre (PHC) of district Mandla, Central India (Madhya Pradesh) due to Bargidam in October–November 1996, an investigation into the causes was carried out in 20 villages. Blood smears from fever cases and contacts of deceased patients were collected. Slide positivity rate was over 70%, of which more than 90% was *Plasmodium falciparum*. Mass blood surveys of infant and pregnant women revealed 39% and 62% parasite prevalence rate respectively. More than 80% children (2–9 yrs) had enlarged spleen. Such high malaria prevalence appeared to be maintained by *Anopheles culicifacies* and *An. fluviatilis* which could not be suppressed by intensive surveillance, prompt radical treatment with 1500 mg chloroquine and 45 mg primaquine and two rounds of special focal spray with DDT in October 1996 and January 1997. There is, therefore, an urgent need to develop suitable malaria control strategy by replacement of insecticides in conjunction with prompt and effective radical treatment.

NARMADA, an inter-state monsoon river, is the fifth largest river of India. Since bulk of the runoff water is generated during the monsoon months (June–September) and that too in a few spells of intense and heavy rainfall, conservation of water is important to meet the ever-growing water needs of the society, as more than 80 lakh population of Madhya Pradesh (Central India) lives along Narmada river and its tributaries. To utilize Narmada waters, it is proposed to construct a series of projects for irrigation and power generation. Bargi is the first completed hydro-electric-cum-irrigation project on river Narmada in Jabalpur district in the series. The dam is 826.9 m in length and 68.9 m in height. The water reservoir is 14556 km^2 and command area is 2.544 lakh ha. The construction of this multipurpose dam (1974–1988) has resulted in the submergence of 162 villages of three districts, viz. Jabalpur, Mandla and Seoni. Water has been stored in this dam to full capacity since 1990. In October–November 1996, there were reports of 109 deaths due to clinical malaria in some submergence villages of district Mandla. An investigation into the cause of deaths was carried out in 20 villages of Narayanganj Primary Health Centre (PHC) from November 1996 to March 1997. Results of this study are presented in this paper.

The whole region is a cobweb of peaks of the Maikal hills, which forms a broad plateaus of about 2200 km^2, mostly forest inhabited by tribals. Since the region is a hilly-tract, its elevation is very irregular which renders the whole area highly undulating. The region is best known for the magnificent forests of sal (*Shorea robusta*) and teak (*Tectona grandis*) as seen in Figure 1. Study villages are sandwiched between forest and dam reservoir as shown in Figure 2. Wild life was rare but lion, tiger, bison, etc are still present in the jungle and seen occasionally in villages. These villages are generally located on the slopes of hillocks or on hill

Figure 1. A completely submerged village, Bhanpur showing undulating terrain, scattered housing and forest.

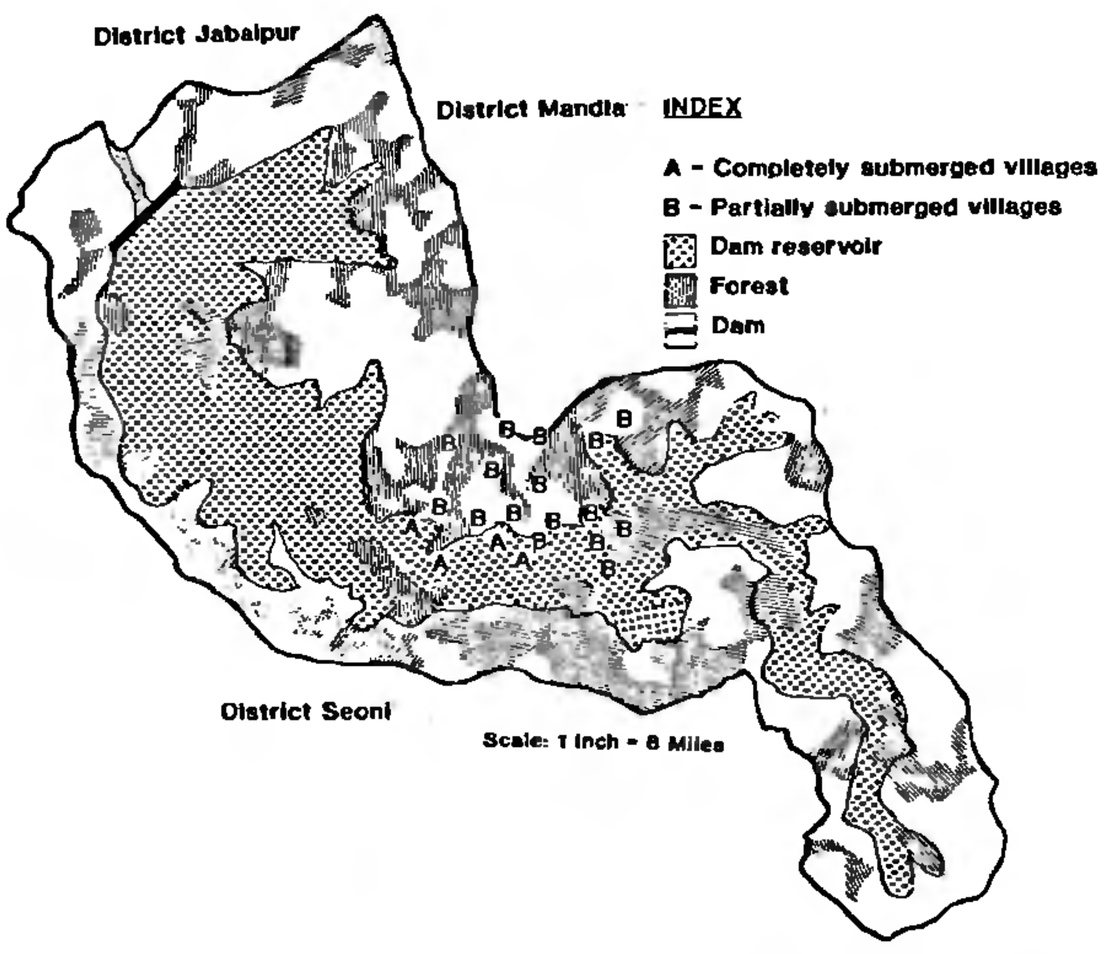

Figure 2. Map of Narmada irrigation project showing Bargidam and study villages.

tops adjoining perennial streams about 5–25 km from State highway. These are inhabited by tribals (85–100% Gond), whose main occupation is agriculture. People live clustered together in a small area popularly known as tola (hamlets). Dwellings are small, one-room huts made of wood and mud. The cattle is kept either in a fenced area attached with the huts or cattle and other domestic animals are harboured in human dwellings. The medical facilities in the study area are non-existent. The rainy season is from June to September with an average annual rainfall of 1500–1800 mm. Road communication is very poor and during rainy season these villages are approachable only by a primitive wooden boat prepared locally.

Blood smears were collected from all fever cases and people with history of fever. Blood smears were stained with JSB[1] and examined in field to provide prompt malaria treatment. As per National Malaria Eradication Programme (NMEP), adult patients with *P. falciparum* infection were given three tablets of pyralfin fansidar (1500 mg sulfadoxine + 75 mg pyrimethamine) + 45 mg primaquine (single dose). Children were given proportionately low dosages. Pregnant women were given only 1500 mg chloroquine. *P. vivax* cases were administered 600 mg chloroquine followed by 75 mg primaquine (15 mg daily for five days). Mass blood surveys of infants (< 1 yr) and pregnant women were undertaken as both are highly susceptive to malaria. Both were not given primaquine. Since both infants and pregnant women are high-risk groups, follow-ups were also made to assess the magnitude of the problem and impact of antimalarial measures. Spleen enlargement was determined by Hackett's method[2] in children between 2 and 9 years' age.

Mosquito collections were made twice in the months of December and March from the 2 villages. Anophelines resting inside 4 fixed houses located in different parts of the villages (2 human dwellings and 2 cattle sheds) were sampled during early morning (0600 h) for 15 min at each place as per standard techniques[3]. The same collectors caught mosquitoes with flash lights and mouth aspirators at each village.

Mosquitoes were also collected by CDC light traps from two villages (other than those selected for indoor resting collections) in December and March. Traps were always placed at a constant height of 5.5 ft, at fixed locations, indoors in human dwellings and outdoors near occupied human dwellings (6 inside and 6 outside). Each trap was emptied manually at hourly intervals until morning. The human dwellings were without windows but have many eaves, holes and large cracks in the walls and roofs. The catch house had been treated with DDT (1 g/m^2) in October 1996 and with DDT and pyrethrum space spray in January 1997. All the houses in these experiments were occupied during the nights of observations. Mosquitoes collected every hour were kept in labelled test tubes and identified in the laboratory using standard keys[4,5]. *Anopheles culicifacies* and *An. fluviatilis* were dissected for the presence of sporozoites in salivary glands. Larval surveys were carried out in streams, rocky pools and pits, seepages, dam water and hoof prints, etc.

Systematic meteorological records were not available, as the only weather recording station is in Mandla – about 100 km from the study villages. Thus, humidity and temperature were recorded at the collection site. Minimum and maximum temperatures during December and March are in the range of 0.5–21°C and 8–34°C, respectively. Before undertaking investigations, previous years' data for the six affected sections was obtained from the District Malaria Officer/Block Medical Officer of the PHC which are summarized in Table 1. It was revealed that the affected villages were under

Table 1. Section-wise (population of 6 affected sections is 18,715 in 1997 as per NMEP) malaria incidence of submergence area of Narayanganj PHC

Year	Blood slide examination (BSE)	Positive for malaria parasite (+ve)	*Plasmodium vivax* (Pv)	*Plasmodium falciparum* (Pf)	Slide positivity rate (SPR)	Slide *falciparum* rate (SFR)	*Plasmodium falciparum* percentage (Pf%)
1985	354	3	3	0	0.9	0.0	0.0
1986	715	0	0	0	0.0	0.0	0.0
1987	808	3	0	3	0.4	0.4	100.0
1988	1163	61	49	12	5.2	1.0	19.7
1989	1037	46	22	24	4.4	2.3	52.2
1990	1008	16	16	0	1.6	0.0	0.0
1991	795	8	1	7	1.0	0.9	87.5
1992	1545	112	13	99	7.3	6.4	88.4
1993	1403	124	31	93	8.8	6.6	75.0
1994	699	0	0	0	0.0	0.0	0.0
1995	1283	37	14	23	2.9	1.8	62.2

Source: Block Medical Officer, Narayanganj, Mandla.

Table 2. Monthly point prevalence surveys in submergence villages (4 completely and 16 partially submerged villages) of Narayanganj PHC

		Children (<14 yrs)						Adults (>14 yrs)					
Month	Villages	BSE	+ve	Pv	Pf	SPR	Pf%	BSE	+ve	Pv	Pf	SPR	Pf%
November	9	250	210	15	195	84.0	92.9	379	290	3	287	76.5	99.0
December	15	272	210	19	191	72.2	91.0	536	335	11	324	62.5	96.7
January	8	46	33	2	31	71.7	93.9	158	105	13	92	66.5	87.6
March	6	43	28	8	20	65.1	71.4	73	43	18	25	58.9	58.1
Total	38	611	481	44	437	78.7	90.8	1146	773	45	728	67.4	94.2

regular DDT spray until 1993. However, due to shortage of DDT in 1994 these were sprayed with 3 rounds of BHC, while in 1995 these villages were not sprayed with any insecticide as the reported API was less than 2.

The following additional measures were implemented by State health authorities to check malaria. One special round of DDT (1 g/m^2) was sprayed in all the 52 affected villages in October–November. Additional surveillance workers, supervisors and technicians were posted in the field by establishing field laboratory for strengthening surveillance, prompt diagnosis and radical treatment (with 1500 mg chloroquine and 45 mg primaquine). Headquarters of one medical officer was changed temporarily from Mandla to Singodha, one of the worst-affected completely submerged villages. A team of medical specialists was also deputed in the affected area. Furthermore, additional Drug Distribution Centres (DDCs) and Fever Treatment Depot (FTDs) were opened and there were frequent visits of supervisory staff and senior officers for impact assessment.

In all, 1757 blood smears were collected from fever cases, of which 611 were of children. Table 2 showed that 1254 blood smears were positive for malaria, of which 481 were of children. The slide positivity rate (SPR) was 71.4% and slide *falciparum* rate (SFR) was 66.3% (13% were gametocyte carriers). Only 441 children were examined for spleen enlargement, of which 359 had enlarged spleen (81.5%). The average enlarged spleen rate was 1.97. Most children (59.5%) with enlarged spleen were invariably positive for malaria parasite. Further during investigation in November, four deaths were reported from one Baiga hamlet of village Bijegaon. Table 3 revealed that in all 46 residents of this hamlet, 45 blood smears were collected, of which 42 were positive for *P. falciparum* (Pf). Similarly, death of two young children, one male child (1½ yrs) from village Patha and one female child (1½ yrs) from village Dehara and death of one woman (55 yrs) from village Manegaon was brought into the notice of the research team during December. Table 3 showed that blood smears of almost all available family members of all three families were positive for *P. falciparum*. Records showed that the woman of village Manegaon was positive for *P. falciparum* and had taken presumptive treatment but died before taking radical treatment. Thus the most likely cause of these deaths was probably malaria.

Further, an *in vivo* test on 46 *P. falciparum* cases was carried out to find the susceptibility after treatment with fansidar. Two cases were found resistant (one each of

Table 3. Results of blood smear examination of the family members of the deceased of village Bijegaon, Patha, Manegaon and Dehara

Age groups (in yrs)	Bijegaon (Baigatola)				Patha				Manegaon				Dehara			
	BSE	+ve	Pf	SFR	BSE	+ve	Pf	SFR	BSE	+ve	Pf	SFR	BSE	+ve	Pf	SFR
0–1	2	2	2	100.00	–	–	–		–	–	–		–	–	–	
>1–4	4	4	4	100.00	1	1	1	100.00	–	–	–		1	1	1	100.0
5–9	7	7	7	100.00	1	1	1	100.00	2	2	2	100.00	–	–	–	
10–14	13	13	13	100.00	–	–	–		1	1	1	100.00	–	–	–	
14–Above	19	16	16	84.21	3	3	3	100.00	3	3	3	100.00	4	3	3	75.0
Total	45	42	42	93.30	5	5	5	100.00	6	6	6	100.00	5	4	4	80.0

Table 4. Month-wise mass survey of infants in 17 submergence villages of Narayanganj PHC

Month	Blood slide examination (BSE)	Positive for malaria parasite (+ve)	*Plasmodium vivax* (Pv)	*Plasmodium falciparum* (Pf)	Slide positivity rate (SPR)	Slide *falciparum* rate (SFR)	*Plasmodium falciparum* percentage (Pf%)
December	161	78	18	60	48.4	37.3	76.9
January	112	46	16	30	41.1	26.8	65.2
February	54	16	2	14	29.6	25.9	87.5
March	52	7	1	6	13.5	11.5	85.7
Total	379	147	37	110	38.8	29.0	74.8

RI and RII level) against fansidar during the 28th day follow-up. Mean sulfadoxine concentration in plasma of sensitive cases was 60.59 µg/ml while that of the two resistant cases were 58.74 and 69.08 µg/ml respectively (Dua, personal communication). Results showed that in two cases parasitaemia recurred/persisted despite higher sulfadoxine concentration than therapeutical level. However, further studies are required to confirm the existence of *P. falciparum* resistance to fansidar in this area.

Table 4 showed that in mass blood surveys of infants, 379 blood smears were collected from 17 villages, of which 147 infants were carrying malaria parasite, 37 *P. vivax* (Pv) and 110 *P. falciparum*. Out of 124 infants found positive in December–January, only 80 could be followed in February, of which two Pf positive infants died and 45 others were again positive for malaria (9 *P. vivax* and 36 *P. falciparum*).

In the mass survey of pregnant women in 20 villages, 137 blood smears were made, of which 85 were malaria positive (9 *P. vivax* and 76 *P. falciparum*). Out of 76 *P. falciparum*, 22 were carrying gametocytes along with rings. Majority of them (55%) were in third trimester, and their followup revealed that out of 44 deliveries, still-birth occurred in one case, four neonate died and two neonate were found infected with *P. falciparum* on day 10 and day 21 in the month of March. While out of 28 pregnant women of the second trimester, abortion was recorded in 4 cases.

Table 5 summarizes the results of mosquito collection by hand catches (indoor resting), which revealed the presence of 6 species of anophelines of which two were efficient vectors, i.e. *An. culicifacies* and *An. fluviatilis*.

Table 5. Mean indoor resting density (Man Hour density, PMH) anophelines in submergence villages of Narayanganj PHC after foc spray of DDT (November and January) and Pyrethrum space spr (January)

Species	Density (PMH)			
	December 1996		March 1997	
	Human dwellings	Cattle sheds	Human dwellings	Cattle sheds
An. culicifacies	0.5	35.0	3.0	51.0
An. fluviatilis	0.0	0.0	0.5	0.5
An. annularis	0.5	5.0	0.0	13.0
An. pallidus	0.0	0.0	0.0	8.0
An. theobaldi	0.0	2.0	0.5	5.5
An. subpictus	0.0	1.5	0.0	0.0
An. vagus	0.0	1.5	0.0	0.0

Table 6. Light trap catches (outdoor/indoor) in submergenc villages of Narayanganj PHC

Species	No. of anophelines per trap			
	Outdoor		Indoor	
	December	March	December	March
An. culicifacies	3.0	13.0	1.5	5.0
An. fluviatilis	0.5	0.5	0.0	1.6
An. annularis	5.0	8.5	1.5	0.6
An. pallidus	1.5	3.0	0.0	0.0
An. theobaldi	0.0	2.0	0.0	0.0
An. splendidus	2.0	0.0	0.0	0.0

Table 6 showed light trap catches during Decembe and March. Analysis of results revealed that the peak hour activities (indoor/outdoor) of both the vectors were

between 1800 and 1900 h during December and almost nil after 2200 h. In March, peak activities were recorded between 1900 and 2000 h and very few mosquitoes were caught after 2200 h.

Out of 283 *An. culicifacies* and 9 *An. fluviatilis* dissected, in the months of December and March, neither species was found positive for sporozoite. Both the species were found breeding in stream, stream bed pools, seepages, rocky pits, etc. Besides, both the species have established their breeding in receding dam water which was used for agriculture as shown in Figure 3 though the main reservoir was free of larval breeding.

The epidemiological study of the outbreak from 24 November to 24 March has revealed the following. There was a complete breakdown of surveillance in these villages, as a result annual parasite incidence was consistently low since 1985 and in the year 1994 not a single malaria case was detected from these outbreak-affected sections. Hence these villages were not sprayed in 1995–96 routinely. The record further showed that the prevalence of malaria was almost negligible from January to August 1996 just prior to this outbreak in September. Therefore in October–November, M.P. government had undertaken focal spray in 52 villages. In view of smaller villages and hamlets, all the houses were sprayed including all neighbouring villages. The administration of fever radical treatment was initiated from October by establishing a field laboratory, DDCs and FTDs, etc. In view of the seriousness of the outbreak, villages were sprayed with DDT again in January 1997 followed by pyrethrum space spray. However, almost all *Anopheles* species showed an increasing trend in March which may be due to favourable weather conditions during this time of the year. Thus the low density of anopheline in December was not the result of spraying but due to the extreme cold weather. This was substantiated by the fact that in adjoining PHC Bizadandi, *An. culicifacies* was highly resistant to both DDT and HCH[6].

Figure 3. Hamlet of completely submerged village, Patha showing utilization of receding dam water for agriculture. The nearness of houses to the dam resevoir is also evident. This photograph was taken during May, the hottest month of the year.

Enquiries indicated that the incidence of fever in the area was at its peak about 6–8 weeks prior to the starting of the investigation. Absenteeism in schools was 98–100%. Further, very high infant parasite rates indicate active malaria transmission during this period, the coldest winter months of the year (Dec.–Jan.). The high prevalence of malaria in pregnant women also showed the magnitude of the malaria transmission in the area. However, this finding of active transmission is not corroborated by the entomological results as during these months no infective mosquito was found. Meteorologically these were not favourable months for malaria as the average temperature was below 10°C from November to January. Therefore, further intensive research is required about vector behaviour and transmission dynamics.

Investigations further revealed that almost all the fever cases had taken radical treatment (chloroquine and primaquine) but again majority of these cases suffered from malaria. Resistance in *P. falciparum* against chloroquine has been known in Bizadandi, Mandla, (adjacent PHC of Narayanganj) since 1988 (ref. 7) and a rapid decline in the sensitivity of *P. falciparum* to chloroquine was recorded recently[8]. It is likely that perhaps because of chloroquine resistance, the intensive surveillance and prompt treatment failed to produce any reduction in malaria prevalence and high fever rate in these villages as well. Further, it is well known that malaria incidence particularly *P. falciparum* is very high in tribal forested area[9,10], which is very difficult to control[11–13]. Since the study area is hilly with difficult terrain, most of the people infected with the malaria parasite remain undetected. The immensity of the operational difficulties and vigilance required can be judged from the fact that one village Dehara (population, 727) consists of 52 hamlets (2–8 houses). Likewise, majority of villages are thinly populated with scattered housing divided in geographically discrete 4–15 hamlets. Furthermore, with the completion of the dam, there was about 20–30% increase in the existing population of some villages because of resettlement of villagers from the completely submerged areas, consequent to which there was formation of new hamlets along with import of different strains of parasite with people of different endemicity. Introduction of different strains into such an area where malariogenic potential is high and which is not approachable for 4–5 months, may be likened to the introduction of dry wood into smouldering fire.

The problem is further compounded by the fact that agriculture is rainfed and a single crop is raised. In some villages which are under complete submergence, people have not left the villages despite receiving compensation/dues from the government in lieu of their

land/houses, because of the availability of naturally fertile, irrigated soil (when the water recedes after rain), which produces maximum of profit with minimum of labour. Moreover, because of the dam, the general water level in wells, streams and its tributaries was also raised, thereby increasing the breeding potential of vectors manifold. People have made their huts on the top of the hill, even though the dam reservoir is just a few feet away from their huts during rainy season and the whole area becomes highly unhygienic and infested with snakes, crabs, spiders, leeches, etc. To control malaria in these villages, special efforts are required such as, surveillance should be tightened throughout the year and prompt single dose treatment with fansidar/pyralfin (sulfadoxine and pyrimethamine) should be given. For this purpose, rapid and accurate new diagnostic tools such as the antigen detection dipstick/ICT may be used[14,15]. Further, health education should be given top priority so that the community may understand the importance of prompt diagnosis and treatment in prevention of deaths, human suffering and spread of transmission. Villages should be sprayed with an effective insecticide such as deltamethrin or insecticide-impregnated curtains should be given, as experience had shown that in tribal villages, where insecticide-treated bed nets were not effective because of socio-economic and cultural factors[16], insecticide-treated curtains were quite effective (Singh, personal communication). People should also be encouraged to use personal protection methods such as skin repellent or neem oil on exposed body parts during outdoor sleeping[17]. A more lasting solution of the problem is to shift these villages to some other area away from the dam reservoir.

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Evaluation of mycobacillin formulation for the control of rice blast disease

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Field trials on the control of blast disease of rice indicate that the disease was controlled to the extent of 96% by mycobacillin formulation as against 90%, 72%, 72%, 76% and 48% by Hinosan, Agrozim, Fuji, Topsin, S-1901 and mycobacillin respectively. Efficacy of mycobacillin is thus greatly enhanced by formulation.

MYCOBACILLIN, an antifungal tridecapeptide, was isolated from the culture filtrate of *Bacillus subtilis* B_3 (ref. 1). Since its isolation, it has been of much interest in our laboratory for a number of studies including those on chemistry[1–3], biosynthesis *in vivo* and *in vitro*[4,5], genetic analysis of mycobacillin pathway[6], mode of action of the antibiotic including its use as a membrane probe in release and uptake[7–9], and finally its physiological role in the sporulation of the producer organism[10–12]. We observed that mycobacillin has only a limited use as a drug against dermatophytes[13]. The compound, however, appears to be very effective against plant pathogens particularly *Pyricularia oryzae* (Cav.). The minimum inhibitory concentration (MIC) of the antibiotic against *P. oryzae* (Cav.) is 10 µg/ml (ref. 14). The brown leaf spot disease of rice caused by *Drechslera oryzae* Van Breda de Haan (Syn. *Helminthosporium oryzae*) has already been reported to be controlled to the extent of 55% by foliar spray in the laboratory scale experiments[15]. Subsequent experiments showed that mycobacillin is active only topically[16]. Hence, a formulation was developed according to the method of Bhattacharya *et al.*[17] with the adjuvants (% by g/v), glycerol 1, tween-20 1, methyl cellosolve 1 and indole-3-acetic acid