Journal of Biological Control, 24 (3): 231–237, 2010

Research Article

Development and evaluation of wettable powder and oil based formulations of *Nomuraea rileyi* (Farlow) Samson against *Helicoverpa armigera* (Hübner) and *Spodoptera litura* (Fabricius)

D. R. MALLIKARJUNA*, R. K. PATIL, Y. H. SUJAY and G. K. RAMEGOWDA
Department of Agricultural Entomology, College of Agriculture, University of Agricultural Sciences, Dharwad 580 005, Karnataka, India.
**Corresponding author E–mail*: morphosis77@gmail.com

ABSTRACT : *Nomuraea rileyi* (Farlow) Samson is a potential entomopathogenic fungus against lepidopteran pests. This was formulated as wettable powder and oil-based formulations to increase its efficiency in the field by using different carrier materials and oils and these were evaluated in the laboratory against two important noctuid pests, *Helicoverpa armigera* (Hübner) and *Spodoptera litura* (Fabricius). Among the wettable powder formulations of *N. rileyi*, *viz*., bentonite + glucose (7: 1), talc + glucose (7: 1), bentonite + sucrose (7: 1) and talc + sucrose (7: 1) recorded 87.0, 74.0, 72.0, 83.0 and 75.0 per cent mortality in *S. litura* and 79.0, 70.0, 66.0 and 88.0 per cent in *H. armigera*, respectively. The oil-based formulations (tank mix) with pongamia oil, sunflower oil, sesame oil and groundnut oil recorded 74.0, 90.0, 83.0 and 87.0 per cent mortality in *S. litura* and 73.0, 89.0, 87.0 and 87.0 per cent in *H. armigera*, respectively.

KEY WORDS: Formulations, *Helicoverpa armigera*, *Nomuraea rileyi*, oil-based formulations, *Spodoptera litura*

(Article chronicle: Received: 01.03.2010; Sent for revision: 01.05.2010; Accepted: 19.07.2010)

INTRODUCTION

The gram pod borer, *Helicoverpa armigera* (Hübner) and tobacco leaf eating caterpillar, *Spodoptera litura* (Fabricius), are cosmopolitan and polyphagous pests. The gram pod borer attacks more than 182 host plants belonging to 47 botanical families in the Indian sub-continent and it is now estimated to feed on more than 200 plant species (Pawar, 1998). Pulse crops are heavily infested by the pest, with total pod damage up to 45 per cent and yield loss up to 60-90 per cent in India (Anon., 1994). *Spodoptera litura* is next only to *H. armigera* in economic importance at national level. Biopesticides used for pest management are environmentally safe, selective, specific in their action and easily biodegradable. They can be used in combination with other control measures in integrated pest management programs.

Apart from viruses and bacteria, fungi also infect insects. The pathogenicity of fungi towards insects has been mainly attributed to various hydrolytic enzymes, such as chitinases, proteases and lipases. Among the entomopathogenic fungi, *Nomuraea rileyi* (Farlow) Samson seems to be promising because of its widespread occurrence and relative abundance due to its wide host range which includes all the major caterpillar pests. It is also commonly known that *N. rileyi* induces extensive epizootics in caterpillar pests on groundnut, cabbage, clover, soybean and velvet beans and is a potential candidate for use as a microbial insecticide (Ignoffo, 1981). In India, its epizootics occur in rainy season (Phadke *et al.*, 1978; Lingappa *et al.,* 2000).

The formulation of fungi still awaits a serious effort in formulation technology. Efforts with entomopathogenic fungi tend to be concentrated on conidial formulation (Pereira and Roberts, 1990). In the process of exploring formulations of *N. rileyi* as a cost-effective and ecofriendly tool in the pest management of lepidopteran pests, the present investigation was carried out for the development and evaluation of formulations of *N. rileyi* against *S. litura* and *H. armigera.*

MATERIALS AND METHODS

The experiments were conducted during 2004-06 in the Department of Agricultural Entomology, at the main campus of the University of Agricultural Sciences, Dharwad. For mass production of *N. rileyi*, the procedure developed by Lingappa and Patil (2002) was followed.

Development of wettable powder formulations

Dried conidial powder of *N. rileyi* cultured on broken rice grains (10g) was mixed with 90g of each of fifteen carrier materials (Table 2). Before mixing, these carrier materials were sieved through sieves (355 mesh) to maintain uniformity in particle size of conidial powder and the carrier material. These carrier materials were sterilized in an autoclave at 121°C and 15 psi for 30 min and mixed with conidial powder and carboxy methyl cellulose was added uniformly to all treatments at 0.1% by weight.

Development of oil formulations

One gram of conidial powder of *N. rileyi* obtained from broken rice culture (2.13×10^9 spores ml^{-1}) was mixed with nine ml of autoclaved and cooled oils (listed in Table 1) containing Tween – 80 (0.1%). The conidial load was adjusted to 2.13×10^8 conidia ml^{-1} by adding the respective oil + Tween 80 mixture.

In vitro *evaluation of formulations of* N. rileyi *on* S. litura

Different formulations of *N. rileyi* were evaluated against third instar larvae. Castor leaves were cut into circular discs of Petri plate (10 cm) size. The surface area of the leaf disc was calculated. The spray solution was assessed for the number of spores present in one ml. The leaf disc was dipped in the spray fluid. The amount of fluid retained on the disc was measured. The spore load per square centimeter was calculated. The larvae were made to crawl on the leaf disc and feed. The wettable powder based formulations containing 2.13×10^8 conidia ml^{-1} were assayed against third instar larvae of *S. litura*. Observations were made from the first day after application for up to ten days. The larval mortality due to *N. rileyi* was expressed in per cent using Abbott's formula.

In vitro *evaluation of formulations of* N. rileyi *on* H. armigera

Concentrations of formulations with 10^8 conidia ml^{-1} were prepared using freshly prepared oil based formulations. Twenty freshly moulted third instar larvae of *H. armigera* were sprayed to wetness with the help of a hand automizer in a glass Petri plate lined with butter paper and allowed to crawl in the Petri plates for 5 minutes. These larvae were transferred into multicavity trays to avoid cannibalism and provided with soaked bengal gram seeds individually. Daily observations on the mortality of larvae due to *N. rileyi* were made from the first day for ten days after treatment. Per cent larval mortality due to different treatments was computed.

RESULTS AND DISCUSSION

The data pertaining to per cent mortality of *H. armigera* due to different treatments of *N. rileyi* are presented in Table 1. Mortality of the third instar larvae commenced on the second day after treatment and it increased with advancement of days and the exposure period. On the third day after treatment, *N. rileyi* conidia formulated in different oils resulted in 7.8 per cent mortality and reached maximum of 76.4 per cent on the tenth day after treatment, irrespective of formulations. Among formulations, *N. rileyi* formulated in sunflower oil caused 89.0 per cent mortality ten days after treatment, followed by groundnut oil and sesame oil formulations, with 87.0 per cent mortality, which were on par with each other and also with glycerol. The lowest per cent mortality was recorded in diesel formulation (64.0%), which was found to be the least effective. It is apparent from the present study and earlier reports that vegetable oils synergize the pathogen, but cannot provide good storability and are detrimental to the conidia. Higher efficacy of oil based formulation might be due to prevention of the desiccation of the conidia which helped in longer survival period and better penetration of peg into the integument (Burges, 1988). These results are in agreement with Nagaraja (2005) who also reported that *N. rileyi* formulated with sunflower oil recorded 93.2 per cent cumulative mortality against 3rd instar larvae of *H. armigera*.

In the experiment with different carrier materials, bentonite + sucrose (7:1) recorded highest corrected cumulative mortality (88.0%), followed by talc + sucrose and bentonite formulations (Table 2). The various flour-based formulations recorded the least mortality. Better performance of bentonite + sucrose (7:1) may be due to the adhesive nature of clays which helps in better contact of conidia formulated with clay and sucrose which provide nutrition to the organism. The formulation with gram flour + wheat flour (1:5) might have failed to provide better contact with target site of the insect. The present findings are in conformity with those of Nagaraja (2005) who reported talc based WP formulation caused 87.2 per cent cumulative mortality under laboratory conditions against *H. armigera*.

The mean cumulative mortality due to conidia of *N. rileyi* in oil formulation to *S. litura* was low for up to 5 days after treatment, ranging from 23.0-36.0% irrespective of the formulation (Table 3). The highest mortality was recorded in the formulation with sunflower oil (90.0%) ten days after treatment, followed by groundnut oil (87.0%) and sesame oil (83.0%). In other formulations, per cent mortality ranged from 64.0-77.0%. The present findings of the investigation are confirm the findings of Nagaraj (2005), who reported that sunflower oil based formulation of *N. rileyi* was superior to other treatments, causing 95.0 per cent mortality of *S. litura* laboratory condition. Vimaladevi *et al.* (2002) reported that conidia of *N. rileyi* + sunflower oil + Triton-x –100 recorded 88.9 per cent mortality on 9th day after exposure under laboratory conditions.

The wettable powder formulations of *N. rileyi* gave low mortality even for up to 7 days after treatment (Table 4). The rate of mortality increased consistently on

Table 1. ***In vitro*** **evaluation of oil based formulations of** ***N. rileyi*** **@ 2.13 x 10^8 conidia g^{-1} against** ***H. armigera***

Formulation	Corrected cumulative mortality of *H. armigera* (third instar)								
	2 DAT	3 DAT	4 DAT	5 DAT	6 DAT	7 DAT	8 DAT	9 DAT	10 DAT
1. Castor oil	0.00^{d} (1.00)	6.00^{d} (14.02)	17.00^{c} (24.30)	28.00^{cd} (31.93)	39.0^{bcd} (38.65)	47.00^{c} (45.02)	54.00^{b} (47.32)	66.00^{b} (54.38)	73.00^{bc} (58.81)
2. Coconut oil	1.00^{c} (3.38)	5.00^{f} (12.92)	14.00^{d} (21.92)	23.00^{e} (28.58)	34.00^{d} (35.66)	42.00^{ef} (40.41)	54.00^{b} (47.32)	59.00^{cd} (50.22)	66.00^{cd} (54.38)
3. Diesel	0.00^{d} (1.00)	2.00^{g} (5.67)	10.00^{e} (18.44)	18.00^{f} (25.05)	28.00^{e} (31.93)	41.00^{f} (39.83)	52.00^{d} (46.16)	58.00^{d} (49.63)	64.00^{d} (53.15)
4. Glycerol	2.00^{b} (5.67)	8.00^{d} (16.23)	18.00^{c} (25.05)	29.00^{bc} (32.57)	41.00^{bc} (39.83)	52.00^{c} (46.16)	61.00^{b} (51.39)	77.00^{a} (61.40)	85.00^{a} (67.47)
5. Groundnut oil	3.00^{a} (8.17)	10.00^{e} (18.44)	23.00^{b} (28.58)	36.00^{a} (36.87)	49.00^{a} (44.44)	60.00^{ab} (50.80)	68.00^{a} (55.58)	80.00^{a} (63.46)	87.00^{a} (68.98)
6. Neem oil	3.00^{a} (8.17)	11.00^{b} (19.31)	18.00^{c} (25.05)	30.00^{bc} (33.19)	37.00^{cd} (37.45)	46.00^{de} (42.72)	57.0^{b} (45.59)	69.00^{b} (56.23)	78.00^{b} (62.08)
7. Pongamia oil	1.00^{c} (3.38)	6.00^{e} (14.02)	14.00^{d} (21.92)	25.00^{de} (30.01)	36.00^{cd} (36.87)	45.00^{def} (42.15)	57.00^{bc} (45.59)	69.00^{bc} (53.80)	73.00^{b} (58.78)
8. Pundi oil	0.00^{d} (1.00)	6.00^{e} (14.02)	13.00^{d} (21.05)	19.00^{f} (25.81)	29.00^{e} (32.57)	35.00^{g} (36.28)	49.00^{d} (44.44)	55.00^{d} (47.89)	62.00^{d} (51.97)
9. Sesame oil	1.00^{c} (3.38)	10.00^{c} (18.44)	22.00^{b} (27.94)	32.00^{b} (34.44)	43.00^{b} (40.99)	56.00^{bc} (48.47)	68.00^{a} (55.58)	77.00^{a} (61.40)	87.00^{a} (68.98)
10. Sunflower oil	2.00^{b} (5.67)	14.00^{a} (21.92)	28.00^{a} (31.93)	39.00^{a} (38.65)	51.00^{a} (45.59)	63.00^{a} (52.56)	72.00^{a} (58.09)	81.00^{a} (64.26)	89.00^{c} (70.72)
CD (0.01)	0.32	0.75	1.44	2.20	3.01	2.58	3.37	3.77	4.45
SEM±	0.08	0.20	0.38	0.58	0.79	0.69	0.89	0.99	1.17
CV 1%	4.41	2.85	3.43	4.09	4.61	3.47	3.91	3.94	4.25

DAT – Days after treatment; figures in parentheses are arcsine transformed values; means followed by the same letter in a column do not differ significantly by DMRT (P = 0.01)

Table 2. ***In vitro*** **evaluation of wettable powder formulations of** ***N. rileyi*** **@ 2.13×10^{8} conidia g^{-1} against** ***H. armigera***

Formulation	Corrected cumulative mortality of *H. armigera* (third instar)								
	2 DAT	3 DAT	4 DAT	5 DAT	6 DAT	7 DAT	8 DAT	9 DAT	10 DAT
1. Aluminium silicate	2.00^{e} (5.56)	8.00^{c} (16.23)	18.00^{b} (25.05)	29.00^{ab} (32.57)	39.00^{a} (38.65)	48.00^{ab} (43.87)	58.00^{abc} (49.63)	65.00^{c} (53.75)	73.00^{d} (58.74)
2. Bentonite	2.00^{e} (5.56)	11.00^{b} (19.31)	22.00^{a} (27.94)	29.00^{ab} (32.57)	41.00^{a} (39.83)	49.00^{ab} (44.44)	60.00^{ab} (50.82)	69.00^{b} (56.25)	79.00^{bc} (62.77)
3. Bentonite + Glucose (7:1)	0.00^{g} (1.00)	3.00^{f} (7.55)	13.00^{ef} (21.05)	22.00^{def} (27.94)	28.00^{bc} (31.93)	41.00^{ef} (39.83)	50.00^{def} (49.02)	60.00^{d} (50.82)	70.00^{def} (56.81)
4. Bentonite + Lactose (7:1)	4.00^{c} (8.85)	9.00^{c} (17.33)	17.00^{bc} (24.30)	24.00^{cde} (29.32)	32.00^{b} (34.41)	45.00^{cd} (42.14)	54.00^{cde} (47.31)	64.00^{c} (53.15)	75.00^{cd} (60.03)
5. Bentonite + Maltose (7:1)	1.00^{f} (3.18)	4.00^{e} (8.85)	15.00^{cde} (22.67)	21.00^{ef} (27.25)	32.00^{b} (34.41)	43.00^{de} (40.99)	54.00^{cde} (47.31)	64.00^{c} (53.15)	72.00^{de} (58.13)
6. Bentonite + Sucrose (7:1)	5.00^{a} (12.92)	13.00^{a} (21.05)	24.00^{a} (29.27)	31.00^{a} (33.80)	39.00^{a} (38.65)	49.00^{a} (44.44)	63.00^{a} (52.56)	77.00^{a} (61.40)	88.00^{a} (69.85)
7. Corn flour	2.00^{e} (5.56)	5.00^{d} (12.92)	11.00^{g} (19.31)	20.00^{f} (26.57)	28.00^{bc} (31.93)	41.00^{ef} (39.83)	52.00^{def} (46.16)	60.00^{d} (50.82)	66.00^{fg} (54.36)
8. Crude formulation	3.00^{d} (7.55)	8.00^{c} (16.23)	15.00^{cd} (22.67)	26.00^{bc} (30.65)	33.00^{b} (35.05)	47.00^{bc} (43.29)	60.00^{ab} (50.80)	71.00^{b} (57.85)	74.00^{d} (59.37)
9. Gram flour + wheat flour (1:5)	1.00^{f} (3.18)	5.00^{d} (12.92)	15.00^{cd} (22.67)	20.00^{f} (26.32)	26.00^{c} (30.01)	39.00^{f} (38.65)	48.00^{f} (43.88)	55.00^{e} (47.89)	64.00^{g} (53.15)
10. Sorghum flour	0.00^{g} (1.00)	4.00^{e} (8.85)	19.00^{b} (25.81)	19.00^{f} (25.81)	29.00^{bc} (32.57)	39.00^{f} (38.65)	49.00^{ef} (44.44)	59.00^{d} (50.21)	66.00^{fg} (54.36)
11. Talc	0.00^{g} (1.00)	3.00^{f} (7.55)	9.00^{h} (17.33)	20.00^{f} (26.32)	28.0^{bc} (31.93)	40.00^{f} (39.25)	52.00^{def} (46.16)	61.00^{cd} (50.82)	70.00^{def} (56.89)
12. Talc + Glucose (7:1)	1.00^{f} (3.18)	5.00^{d} (12.92)	12.00^{fg} (20.18)	21.00^{ef} (27.25)	30.00^{bc} (3.22)	39.00^{f} (38.65)	50.00^{def} (45.02)	59.00^{d} (50.21)	66.00^{fg} (54.36)
13. Talc + Lactose (7:1)	1.00^{f} (3.18)	5.00^{d} (12.92)	11.00^{g} (19.31)	21.00^{ef} (27.25)	28.00^{bc} (31.93)	42.00^{de} (40.03)	49.00^{ef} (44.44)	60.00^{d} (50.82)	67.00^{efg} (54.96)
14. Talc + Maltose (7:1)	1.00^{f} (3.18)	8.00^{c} (16.23)	14.00^{de} (21.92)	22.00^{def} (27.94)	30.00^{bc} (33.22)	41.00^{ef} (39.43)	55.00^{bcd} (47.89)	65.00^{c} (53.75)	74.00^{d} (59.38)
15. Talc + Sucrose (7:1)	4.00^{c} (8.85)	9.00^{c} (17.33)	17.00^{bc} (24.30)	26.00^{cd} (30.01)	38.00^{a} (38.06)	49.00^{ab} (44.44)	61.00^{a} (51.32)	69.00^{b} (56.25)	80.00^{b} (63.46)
CD (0.01)	0.82	1.15	1.58	2.29	2.82	1.51	2.94	2.17	3.05
SEM±	0.10	0.31	0.42	0.61	0.76	0.40	0.79	0.58	0.81
CV 1%	4.49	4.88	4.12	4.70	4.94	2.19	3.70	2.45	3.10

DAT – Days after treatment; figures in parentheses are arcsine transformed values; means followed by the same letter in a column do not differ significantly by DMRT (P = 0.01)

Table 3. *In vitro* evaluation of oil based formulations of *N. rileyi* @ 2.13×10^{8} conidia g^{-1} against *S. litura*

Formulation	Corrected cumulative mortality of *S. litura* (third instar)								
	2 DAT	3 DAT	4 DAT	5 DAT	6 DAT	7 DAT	8 DAT	9 DAT	10 DAT
1. Castor oil	1.00^{d}	8.00^{d}	17.00^{cd}	25.00^{cd}	35.00^{de}	45.00^{de}	55.00^{c}	64.00^{cde}	76.00^{cd}
	(3.38)	(16.23)	(24.30)	(30.01)	(36.28)	(42.15)	(47.89)	(53.15)	(60.71)
2. Coconut oil	2.00^{c}	10.00^{c}	17.00^{cd}	23.00^{d}	36.00^{cd}	45.00^{de}	54.00^{c}	63.00^{de}	70.00^{de}
	(5.76)	(18.44)	(24.30)	(28.63)	(36.87)	(42.15)	(47.31)	(52.56)	(56.87)
3. Diesel	1.00^{d}	8.00^{d}	10.00^{d}	23.00^{d}	32.0^{e}	43.00^{de}	49.00^{d}	58.00^{f}	64.00^{e}
	(3.38)	(16.23)	(22.79)	(28.63)	(34.44)	(40.99)	(44.44)	(49.63)	(53.19)
4. Glycerol	2.00^{c}	10.00^{c}	16.00^{cd}	28.0^{bc}	40.00^{b}	51.00^{c}	61.00^{b}	68.00^{c}	77.00^{c}
	(5.76)	(18.44)	(23.54)	(31.93)	(39.25)	(45.59)	(51.38)	(55.58)	(61.40)
5. Groundnut oil	4.00^{b}	12.00^{b}	23.00^{ab}	36.00^{a}	45.00^{a}	57.00^{ab}	68.00^{a}	77.00^{ab}	87.00^{ab}
	(10.53)	(20.18)	(27.25)	(35.05)	(42.15)	(49.05)	(55.58)	(61.40)	(69.10)
6. Neem oil	2.00^{c}	10.00^{c}	21.00^{b}	27.00^{cd}	39.00^{bc}	46.00^{d}	56.00^{c}	67.00^{cd}	74.00^{cd}
	(5.76)	(18.44)	(25.05)	(31.29)	(38.65)	(42.72)	(48.47)	(54.97)	(59.38)
7. Pongamia oil	1.00^{d}	8.00^{d}	18.00^{c}	27.00^{cd}	35.00^{de}	46.00^{d}	55.00^{c}	65.00^{cde}	74.00^{cd}
	(3.38)	(16.23)	(24.38)	(31.29)	(36.28)	(42.72)	(47.89)	(53.75)	(59.38)
8 Pundi oil	1.00^{d}	8.00^{d}	17.00^{cd}	27.00^{cd}	38.00^{bcd}	43.00^{e}	54.00^{c}	62.00^{ef}	70.00^{de}
	(3.38)	(16.23)	(24.30)	(31.29)	(38.06)	(40.99)	(47.31)	(51.97)	(56.87)
9. Sesame oil	3.00^{bc}	11.00^{bc}	22.00^{b}	32.00^{b}	46.00^{a}	54.00^{bc}	62.00^{b}	74.00^{b}	83.00^{b}
	(8.15)	(19.31)	(27.94)	(34.44)	(42.15)	(47.31)	(51.87)	(59.38)	(65.79)
10. Sunflower oil	4.00^{a}	14.00^{a}	25.00^{a}	36.00^{a}	46.00^{a}	58.00^{a}	70.00^{a}	79.00^{a}	90.00^{a}
	(10.53)	(21.92)	(30.01)	(36.87)	(42.15)	(49.63)	(56.81)	(62.77)	(71.60)
CD (0.01)	0.52	1.20	1.95	2.65	1.75	2.20	2.28	2.58	3.98
SEM±	0.14	0.32	0.51	0.70	0.46	0.58	0.60	0.68	1.05
CV 1%	4.97	3.89	4.46	4.88	2.67	2.91	2.68	2.74	3.81

DAT – Days after treatment; figures in parentheses are arcsine transformed values; means followed by the same letters in a column do not differ significantly by DMRT ($P = 0.01$)

Table 4. ***In vitro*** **evaluation of wettable powder formulation of *N. rileyi* @ 2.13×10^{8} conidia g^{-1} against *S. litura***

Formulation	Corrected cumulative mortality of *S. litura* (third instar)								
	2 DAT	3 DAT	4 DAT	5 DAT	6 DAT	7 DAT	8 DAT	9 DAT	10 DAT
1. Aluminium silicate	0.00^{d}	4.00^{e}	10.00^{hi}	20.00^{efg}	31.00^{cde}	45.00^{cd}	55.00^{b}	66.00^{b}	77.00^{bc}
	(1.00)	(10.52)	(18.44)	(26.50)	(33.80)	(42.15)	(47.90)	(54.99)	(61.51)
2. Bentonite	4.00^{a}	11.00^{a}	20.00^{b}	32.00^{a}	43.00^{bc}	55.00^{a}	65.00^{a}	75.00^{a}	83.00^{ab}
	(10.52)	(19.31)	(26.57)	(34.14)	(40.97)	(47.90)	(53.79)	(60.11)	(65.72)
3. Bentonite + Glucose (7:1)	0.00^{d}	3.00^{f}	10.00^{hi}	18.00^{g}	27.00^{ef}	39.00^{de}	52.00^{bc}	62.00^{bcd}	74.00^{cd}
	(1.00)	(8.15)	(13.44)	(25.05)	(31.29)	(38.64)	(46.16)	(51.97)	(59.46)
4. Bentonite + Lactose (7:1)	1.00^{c}	6.00^{c}	16.00^{c}	24.00^{bcd}	32.00^{b-e}	46.00c	55.00^{b}	66.00^{bc}	75.00^{cd}
	(3.38)	(14.02)	(23.54)	(29.92)	(34.41)	(42.2)	(47.90)	(54.40)	(60.11)
5. Bentonite + Maltose (7:1)	1.00^{c}	5.00^{d}	12.00^{fg}	23.00^{cde}	33.00^{bcd}	43.00^{cde}	53.00^{bc}	65.00^{bcd}	73.00^{cd}
	(3.38)	(12.92)	(20.18)	(28.56)	(35.02)	(40.97)	(46.74)	(53.80)	(58.85)
6. Bentonite + Sucrose (7:1)	2.00^{b}	11.00^{a}	22.00^{a}	32.00^{a}	42.00^{a}	53.00^{ab}	66.00^{a}	76.00^{a}	87.00^{a}
	(5.76)	(19.31)	(27.94)	(34.14)	(40.39)	(46.74)	(54.3)	(60.71)	(68.98)
7. Corn flour	1.00^{c}	6.00^{c}	13.00^{ef}	22.00^{c-f}	35.00^{bc}	46.00^{c}	52.00^{bc}	58.00^{d}	67.00^{d}
	(3.38)	(14.02)	(20.93)	(27.63)	(36.24)	(42.72)	(46.16)	(49.30)	(55.04)
8. Crude formulation	1.00^{c}	6.00^{c}	14.00^{de}	23.00^{c-f}	35.00^{f}	45.00^{cd}	55.00^{b}	67.00^{b}	74.00^{cd}
	(3.38)	(14.02)	(21.80)	(28.56)	(36.24)	(42.15)	(47.90)	(54.97)	(59.38)
9. Gram flour + wheat flour (1:5)	0.00^{d}	2.00^{g}	10.00^{hi}	19.00^{fg}	25.00^{def}	32.00^{f}	41.00^{d}	50.00^{e}	57.00e
	(1.00)	(5.76)	(18.44)	(25.81)	(30.10)	(34.41)	(39.25)	(45.02)	(49.05)
10. Sorghum flour	0.00^{d}	1.00^{h}	9.00^{i}	18.00g	29.00^{ef}	37.00^{ef}	46.00^{cd}	50.00^{cd}	67.00^{d}
	(1.00)	(3.38)	(17.33)	(25.05)	(32.57)	(37.46)	(42.72)	(50.21)	(54.99)
11. Talc	1.00^{c}	7.00^{b}	16.00^{c}	25.00^{bc}	37.00^{bc}	47.00^{bc}	57.00^{b}	65.00^{bcd}	77.00^{bc}
	(3.38)	(15.12)	(23.54)	(30.01)	(37.46)	(43.29)	(49.05)	(53.77)	(61.40)
12. Talc + Glucose (7:1)	1.00^{c}	6.00^{c}	15.00^{cd}	23.00^{cde}	36.00^{bc}	43.00^{cde}	53.00^{bc}	62.00^{bcd}	72.00^{cd}
	(3.38)	(14.02)	(22.67)	(28.56)	(36.87)	(40.99)	(46.74)	(51.99)	(58.09)
13. Talc + Lactose (7:1)	1.00^{c}	4.00^{e}	12.00^{fg}	21.00^{d-g}	35.00^{bcd}	44.0^{cd}	54.00^{b}	62.00^{bcd}	71.00^{cd}
	(3.38)	(10.52)	(20.18)	(27.19)	(36.28)	(41.56)	(47.32)	(51.99)	(57.45)
14. Talc + Maltose (7:1)	1.00^{c}	5.00^{d}	12.00^{gh}	22.00^{c-f}	33.00^{bcd}	44.00^{cd}	52.00^{bc}	62.00^{bcd}	71.00^{cd}
	(3.38)	(12.92)	(20.18)	(27.94)	(35.66)	(41.56)	(46.74)	(51.99)	(57.45)
15. Talc + Sucrose (7:1)	2.00^{b}	6.00^{c}	16.00^{c}	27.00^{b}	36.00^{bc}	46.00^{c}	56.00^{b}	67.00^{b}	75.00^{cd}
	(5.76)	(14.02)	(23.54)	(31.29)	(36.87)	(42.72)	(48.47)	(54.97)	(60.07)
CD (0.01)	0.26	0.70	1.14	2.31	2.89	3.44	3.92	4.04	4.61
SEM±	0.07	0.19	0.31	0.62	0.77	0.92	1.05	1.08	1.23
CV 1%	4.49	3.33	3.17	4.81	4.91	4.92	4.94	4.52	4.65

DAT – Days after treatment; figures in parentheses are arcsine transformed values; means followed by the same letters in a column do not differ significantly by DMRT (P = 0.01) increase in exposure period and attained maximum for bentonite + sucrose 87.0% on the tenth day. The various flour based formulations gave the least mortality. The present findings are in confirmation with the studies of Wiwat (2004), who reported WP formulations of *N. rileyi* with bentonite + sucrose (1:7:7), bentonite + soil (1:7:7), bentonite and aluminium silicate were better than fresh conidia in infectivity of mycosis by recording the lowest LC_{50} values against *S. litura*. Ramegowda and Nagaraj (2005) also reported the talc-based WP formulation of *N. rileyi* recorded 82% mortality of *S. litura* compared to the other formulations tested.

ACKNOWLEDGEMENT

The authors are thankful to the University of Agricultural Sciences, Dharwad, for providing necessary facilities for the investigations.

REFERENCES

Anonymous, 1994. ICRISAT *Annual Report for 1993–94*. Hydrabad, India.

Burgess, H. D. 1998. *Formulation of microbial bio-pesticides*, Kluwer Academic Publishers, London, UK, 412 pp.

Ignoffo, 1981. The fungus *Nomuraea rileyi* as a microbial insecticide, pp. 513–536. In: Burges, H. D. (Ed.). *Microbial control of pests and plant diseases,* 1970–80, Academic Press, New York, USA.

Lingappa, S. and Patil, R.K. 2002. *Nomuraea rileyi – a potential mycoinsecticide*. University of Agricultural Sciences, Dharwad, Karnataka, 30 p.

Lingappa, S., Patil, R. K. and Hegde, R. 2000. Seasonal occurrence of *Nomuraea rileyi* (Farlow) Samson in crop ecosystem in the transitional tract of Karnataka, pp. 264–265. In: *National Seminar on Oilseeds and Oil Research and Development Needs in the Millennium*, February 2–4, 2000, DOR, Hyderabad,

Nagaraja, S. D. 2005. Effect of formulations of *Nomuraea rileyi* (Farlow) Samson and spray equipments in the management of tobacco caterpillar in groundnut and pod borer in chickpea ecosystem. M.Sc. (Agri.) Thesis, University of Agricultural Sciences, Dharwad, Karnataka, India.

Pawar, R. C. S. 1998. *Helicoverpa*, a national problem that needs a national policy and commitment for its management. *Pestology*, **22**: 51–57.

Pereira, R. M. and Roberts, D. W. 1990. Dry mycelium preparation of entomopathogenic fungi, *Metarhizium anisopliae* and *Beauveria bassiana*. *Journal of Invertebrate Pathology*, **56**: 39–46.

Phadke, C. H., Rao, V. G. and Pawar, S. K. 1978. Natural outbreak of the muscardine fungus *Nomuraea rileyi* (Farlow) Samson on leaf eating caterpillar, *Spodoptera exigua* Hb. in Maharashtra. *Current Science*, **22**: 476.

Ramegowda, G. K. 2005. Aerobiology, epizootiology and utilization of *Nomuraea rileyi* (Farlow) Samson. Ph.D. Thesis, University of Agricultural Sciences, Dharwad, Karnataka.

Vimaladevi, P. S., Prasad, Y. G., and Chowdary, A. 2002. Effect of drying and formulation of conidia on virulence of the entomofungal pathogen *Nomuraea rileyi* (Farlow) Samson. *Journal of Biological Control*, **16**: 43–48.

Wiwat, C. 2004. Development of *Nomuraea rileyi* based biopesticide for controlling lepidopteran larvae. Ph. D. Thesis, Mahidol University, Malaysia.