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CP Mallapur
Department of Agricultural Entomology, College of Agriculture, Dharwad University of Agricultural Sciences, Dharwad Karnataka, India

Anjan Kumar Naik
Department of Agricultural Entomology, College of Agriculture, Dharwad University of Agricultural Sciences, Dharwad Karnataka, India

Sireesh Hagari
Department of Agricultural Entomology, College of Agriculture, Dharwad University of Agricultural Sciences, Dharwad Karnataka, India

Praveen T
Department of Agricultural Entomology, College of Agriculture, Dharwad University of Agricultural Sciences, Dharwad Karnataka, India

RK Patil
Department of Agricultural Entomology, College of Agriculture, Dharwad University of Agricultural Sciences, Dharwad Karnataka, India

S Lingappa
Former Director of Research University of Agricultural Sciences, Dharwad Karnataka, India

Correspondence
CP Mallapur
Department of Agricultural Entomology, College of Agriculture, Dharwad University of Agricultural Sciences, Dharwad Karnataka, India

Potentiality of *Nomuraea rileyi* (Farlow) Samson against the fall armyworm, *Spodoptera frugiperda* (J E Smith) infesting maize

CP Mallapur, Anjan Kumar Naik, Sireesh Hagari, Praveen T, RK Patil and S Lingappa

Abstract
Fall armyworm is an invasive insect pest on maize which is causing huge loss to maize cultivators in Northern Karnataka. The field survey conducted in these areas during *kharif* 2018 indicated that the entomopathogenic fungi, *Nomuraea rileyi* is natural occurring on *Spodoptera frugiperda* with its infection ranging from 1.87 percent in Vijaypur to 18.30 percent in Dharwad district while, the percent damage of fall armyworm on maize ranged between 12.42 in Uttar Kannada and 65.73 percent in Dharwad district. Further, three large scale field evaluation studies conducted on this pathogen against the fall armyworm in maize revealed 58.91 to 62.87 percent reduction of pest infestation in these localities. Similarly, the larval and leaf injury reduction after 15 days of spraying *N. rileyi* ranged from 62.50 to 66.46 and 66.84 to 73.05 percent, respectively. The studies indicated the high potentiality of *N. rileyi* in combating the notorious invasive pest, *S. frugiperda.* This is the first report from India with respect to efficacy of *N. rileyi* against *S. frugiperda* under field conditions.

Keywords: Fall armyworm, *Spodoptera frugiperda*, *Nomuraea rileyi*, maize

Introduction
Maize (*Zea mays*) is an important cereal crop in many developed and developing countries. It is widely used for animal feed and industrial raw material in the developed countries where as in the developing countries it is used generally for feed purpose [1]. In Indian agriculture, maize occupies a prominent position and each part of the maize plant is put to one or the other use and nothing goes as waste. Throughout the country, cultivation of maize is spread over an area of 96.33 million hectares with a production of 258.99 million tonnes and with a productivity of 2.69 tonnes per hectare. In Karnataka state, maize is cultivated over an area of 13.70 million hectares with a production and productivity of 33.14 million tonnes and 2.42 tonnes per hectare, respectively [2].

Now a day, the maize production is hindered by several biotic and abiotic factors. Prominent abiotic factors such as irregular rain fall, moisture stress and market price fluctuation and biotic factors like insect pests and diseases are affecting the crop production to a great extent [18]. In addition to these miseries, invasion of fall armyworm, *S. frugiperda* to India has further worsened the maize production making the farmers helpless. Fall armyworm reported to be feeding on more than 80 plant species from 23 families [15]. The pest has been reported in India during July 2018 from Karnataka [14]. It has become a serious pest on maize within a short time of its invasion with the pest infestation ranging between 6.00 to 100 percent on maize [11]. Fall Armyworm (FAW) in Africa has the potential to cause maize yield losses in a range from 8.3 to 20.6m tonnes per annum representing potential losses ranging between US $ 2,481m and US $ 6,187m [6].

The farmers use a range of management tactics in American and African subcontinent, including host plant resistance, insecticide applications and biological control [7, 30, 14, 16]. However, ecofriendly management practices help to reduce the pesticide usage and reduce the hazardous effect on the environment [8]. reported four species of entomopathogens on fall armyworm belonging to classes, Zygomycetes (Entomophthorales) and Hyphomycetes (*Beauveria bassiana, Nomuraea rileyi*, and *Hirsutella* sp.). Unlike insect pathogenic bacteria and viruses, the fungi have a capability to invade by producing proteolytic enzymes and there by penetrating the cuticle of their host [3] and have potentiality to cause epizootics during

favorable environmental conditions. *Nomuraea rileyi* is an evident entomopathogenic fungus which causes natural infection on various lepidopteran pests. The fungus has already been reported on *S. frugiperda* from Karnataka, India [19]. In the present study, efforts have been made to know the natural incidence of *N. rileyi* on fall armyworm and its utilization as effective tool to manage the pest.

2. Materials and Methods

2.1 Incidence of fall armyworm and natural occurrence of *Nomuraea rileyi* in major maize growing areas of Northern Karnataka

Roving survey was carried out in major maize growing areas of different taluks in Northern Karnataka covering Dharwad, Haveri, Belagavi, Bagalkot, Gadag, Uttar Kannada and Vijaypur districts during *kharif*, 2018. Major maize growing areas from each district were identified and surveyed for the incidence of fall armyworm and the natural occurrence of *N. rileyi*.

From each taluk, six farmer's fields were selected and in each field, twenty plants at ten random spots were selected. Observations on pest infestation, larval population and number of larvae infected with *Nomuraea rileyi* were recorded on these selected plants and interpreted in terms of percentage. The percent pest infestation and incidence of *N. rileyi* were calculated by using the following formulae.

$$\text{Percent infestation} = \frac{\text{Number of plants damaged}}{\text{Total number of plants observed}} \text{X } 100$$

$$\text{Percent incidence of } N.\ rileyi = \frac{\text{Number of larvae infected by } N.\ rileyi}{\text{Total number of larvae observed}} \text{X } 100$$

2.2 Large scale evaluation of *Nomuraea rileyi* on *Spodoptera frugiperda* infesting Maize

Large scale evaluation of *Nomuraea rileyi* against fall armyworm on maize was conducted on the farmer's field at different locations to know the efficacy of the entomopathegenic fungus. Locations were selected based upon the environmental conditions and availability of irrigation facility which play a vital role in virulence and self-perpetuation of *N. rileyi*. These trials were carried out on large area (minimum of one acre each) at three locations *viz.* Main Agricultural Research Station, UAS, Dharwad, Garag village in Dharwad district and Mamdapur village in Belagavi district.

Nearly 30-40 days old maize crop which was severely damaged by the fall armyworm in these locations were imposed with the *N. rileyi* formulation obtained from Institute of Organic Farming, UAS, Dharwad @ 2 g/l using the knapsack sprayer by directing the spray onto the leaf whorls. The observations were made on 20 plants at ten spots each selected randomly in each field. Number of plants damaged by fall armyworm, larval population and leaf damage (on visual basis) were recorded one day before and 15 days after spray and percent reduction values were calculated. The data were averaged and compared to study the efficacy of *N. rileyi.*

3. Results and Discussion

3.1 Incidence of fall armyworm and natural occurrence of *Nomuraea rileyi* in major maize growing areas of Northern Karnataka

The fall armyworm incidence in major maize growing areas of northern Karnataka ranged between 12.42 and 65.73 percent. In Belagavi district the highest incidence was noticed in Gokak (70.75%) taluk while, the least was recorded in Nippani (47.75%). In the other taluks, the pest infestation was to the tune of 68.00, 57.00, 55.25, 49.50, 64.75, 67.50 and 60.50 percent, respectively in Kittur, Ramadurga, Mudalagi, Savadatti, Chikkodi, Hukkeri and Belagavi. The percent incidence of *N. rileyi* on fall armyworm varied between 3.56 and 24.54 in Belagavi district with the maximum incidence in Hukkeri (24.54%) followed by Chikkodi (23.44%) taluks. Whereas, the least incidence was recorded in Nippani (3.56%) followed by Ramdurga (9.93%) taluk (Table 1).

Dharwad taluk of Dharwad district recorded maximum percent infestation of *N. rileyi* (23.86%) on the fall armyworm. However, incidence of fall armyworm and *N. rileyi* ranged from 50.50 to 74.17 and 7.53 to 23.86 percent, respectively in different taluks of Dharwad district. In Haveri district, Byadagi taluk recorded the highest incidence of *N. rileyi* (19.28%) with 63.00 percent infestation of fall armyworm. However, the incidence of fall armyworm and *N. rileyi* were to the extent of 41.00, 75.00, 11.75, 14.50 and 16.82, 11.89, 9.82, 7.78 percent, respectively in Hangal, Haveri, Hirekerur and Ranebennur taluks.

In Bagalkot district, the highest (91.75%) incidence of fall armyworm was recorded in Bagalkot taluk with 3.51 percent occurrence of *N. rileyi*. Whereas, the percent damage by fall armyworm in Mudhol, Jamakhandi, Bilgi and Badami taluks was recorded at 51.25, 53.00, 38.25 and 45.50 with 3.13, 6.08, 6.49 and 1.66 percent infection by *N. rileyi* on the fall armyworm. Interestingly, at Hunagund taluk, no incidence of *N. rileyi* was observed although the fall armyworm incidence was to the tune of 50.00 percent. Among the different taluks surveyed from Vijaypur district, the incidence of *N. rileyi* was observed only in Nidagundi taluk (5.61%). However, the fall armyworm incidence was observed in all the taluks surveyed which ranged from 20.00 to 37.00 percent.

Among the four taluks of Uttar Kannada district surveyed, the highest incidence of fall armyworm (19.00%) and *N. rileyi* (16.67%) were recorded in Haliyal taluk. Whereas, in Mundagod, Dandeli and Sirsi taluks, the incidence of fall armyworm and *N. rileyi* ranged from 10.17, 14.50 and 6.00 percent and 10.06, 11.11 and 12.50 percent, respectively. Incidence of *N. rileyi* (2.35%) was highest in Ron among various taluks surveyed in Gadag district. This was followed by Gadag (2.14%), Shirahatti (0.68%), Mundaragi (0.62%) and Naragund (0.45%) taluks. The incidence of fall armyworm in the entire district ranged from 45.00 to 57.00 percent.

The district wise average figures from table 2 indicated the fall armyworm damage ranged from 12.42 percent (Uttar Kannada) to 65.73 percent (Dharwad) with the larval population of 12.08 (Uttar Kannada) to 74.10 (Gadag) larvae per 200 plants, respectively. In Belagavi, 60.11 percent infestation of fall armyworm and 14.56 percent incidence of *N. rileyi* was recorded. Whereas, in Bagalkot, 54.96 percent infestation of *S. frugiperda* and 3.48 percent incidence of *N. rileyi* were recorded.

Similarly, in Vijaypur, 28.83 percent incidence of *S. frugiperda* and 1.87 percent of *N. rileyi* were observed. In Haveri, Gadag and Uttar Kannada districts, the infestation of fall armyworm was recorded at 41.15, 50.30 and 12.42 percent with 13.29, 1.25 and 11.75 percent incidence of *N. rileyi*, respectively. Except Uttar Kannada, all districts witnessed almost similar incidence of fall armyworm with

minute variations (Table 2).

Similarly, the infection of *S. frugiperda* by *N. rileyi* averaged at 1.25 to 18.30 percent. However, the maximum natural incidence of *N. rileyi* was observed in Dharwad district (18.30%) followed by Belagavi (14.70%), Haveri (13.29%) and Uttar Kannada (11.75%). This may be attributed to the humid conditions prevailing during *kharif* season in these districts. On the contrary, lower incidence of *N. rileyi* was observed in Bagalkot (3.48%) and Vijaypur (1.87%) districts while, the least incidence was noticed in Gadag (1.25%) district owing to high temperature coupled with low humidity prevailing in these areas which are detrimental to the entomopathogenic fungi, *N. rileyi* in order to cause natural infection and epizootics.

The potentiality of *N. rileyi* on many lepidopteran insects has been well documented by previous workers but however, its efficacy on *S. frugiperda* are lacking [9]. observed 14 percent natural incidence of *N. rileyi* on *Helicoverpa armigera*. During the present study, the infestation of *N. rileyi* on *S. frugiperda* varied across different districts which may be due to varied environmental conditions such as rain fall, temperature and relative humidity. These findings are corroborating with the reports of [12, 21, 5] who stated that temperature, rainfall and relative humidity showed positive correlation on disease occurrence. Similarly, rainfall and moisture condition play a major role in disease development on *Spodoptera litura* [17]. Weather parameters particularly temperature, humidity and rainfall play a significant role in the incidence, distribution, prevalence and efficacy of entomopathogenic fungi [13, 4]. In Andhra Pradesh 36.9 percent infection of *N. rileyi* on *S. litura* in ground nut field was observed [23, 22]. Unlike chemical approaches, the entomopathogenic fungi can self-perpetuate where in, the farmers will be provided with an added advantage of avoiding repeated spraying which would save time, labour and money as well it can safeguard the environment as it is an eco-friendly approach. Occurrence of these high incidences might be due to rainfall and high humidity which favoured the growth and multiplication of the fungus and further the rain splashes aided the spores in reaching the leaf surfaces where the insects were found to be feeding resulting into primary infection. Study also revealed that weather variable *viz*., rainfall and relative humidity had significant positive relation with perpetuating the entomopathogenic fungus. This is the first report from India on the field efficacy of *N. rileyi* against *S. frugiperda* (Fig. 1 to 4).

3.2 Large scale evaluation of *Nomuraea rileyi* on *Spodoptera frugiperda* infesting maize

Before spray, the infestation of fall armyworm on maize at different locations was almost similar which ranged from 77.05 to 83.50 percent. Similarly, number of larvae and leaf injury ranged from 14.55 to 15.60 larvae /20 plants and 65.00 to 69.67 percent, respectively (Table 3).

However, the data recorded at 15 days after *N. rileyi* spray revealed that the infestation by fall armyworm was 30.50, 31.00 and 33.50 percent at Dharwad, Garag and Mamdapur locations with 60.42, 62.87 and 58.92 percent reduction, respectively. Similarly, average number of larvae and leaf injury varied from 5.10 to 5.85 larvae / 20 plants and 18.78 to 21.56 percent with a reduction of 62.50 to 66.46 and 66.84 to 73.05 percent, respectively. The study clearly indicated that *N. rileyi* (IOF strain) is a potential biocontrol agent to mitigate the damage caused by fall armyworm. The foliar spray and soil application of 2 $X10^8$ cfu/ml conidial formulation of *N. rileyi* were equally effective against the mortality of the larvae of *S. litura* [24]. This entomopathegenic fungus has the ability to perpetuate and cause natural epizootics on fall armyworm if congenial environmental conditions particularly normal temperature and high humidity prevail in the field. Providing frequent irrigation will aid the farmers to create congenial environmental conditions by bringing down the temperature and increasing the relative humidity.

Table 1: Incidence of *Nomuraea rileyi* on fall armyworm, *Spodoptera frugiperda* in major maize growing areas of Northern Karnataka

District	Taluk	Pest infestation (%)	Number of larvae /200 plants	Number of larvae infected by *N. rileyi* /200 plants	Natural incidence of *Nomuraea rileyi* (%)
Belagavi	Savadatti	49.50	58.50	7.49	12.81
	Gokak	70.75	64.50	10.77	16.69
	Mudalagi	55.25	78.00	8.04	10.31
	Hukkeri	67.50	60.50	14.85	24.54
	Chikkodi	64.75	64.00	15.00	23.44
	Nippani	47.75	56.50	2.01	3.56
	Belagavi	60.50	59.50	8.01	13.47
	Ramdurg	57.00	87.00	8.64	9.93
	Kittur	68.00	68.00	12.57	18.49
	Average	60.11	66.28	9.71	14.70
Uttar Kannada	Mundgod	10.17	10.33	1.04	10.06
	Haliyal	19.00	12.00	2.00	16.67
	Dandeli	14.50	18.00	2.00	11.11
	Sirsi	6.00	8.00	1.00	12.50
	Average	12.42	12.08	1.51	11.75
Bagalkot	Mudhol	51.25	62.00	1.94	3.13
	Jamkhandi	53.00	67.50	4.10	6.08
	Biligi	38.25	36.00	2.34	6.49
	Bagalkot	91.75	113.50	3.98	3.51
	Hungund	50.00	63.50	0.00	0.00
	Badami	45.50	60.50	1.00	1.66
	Average	54.96	67.17	2.23	3.48
Vijaypur	Nidagundi	29.50	44.50	2.50	5.61
	Muddebihal	37.00	63.50	0.00	0.00

	Basavana Bagewadi	20.00	38.50	0.00	0.00
	Average	28.83	48.83	0.83	1.87
Dharwad	Dharwad	74.17	67.00	15.99	23.86
	Kalghatagi	50.50	57.00	9.56	16.78
	Hubballi	71.00	34.00	7.76	22.81
	Kundgol	72.50	44.50	9.13	20.52
	Navalgung	60.50	62.50	4.71	7.53
	Average	65.73	53.00	9.43	18.30
Haveri	Hanagal	41.00	58.00	9.76	16.82
	Byadagi	63.00	69.33	13.37	19.28
	Haveri	75.50	85.80	10.20	11.89
	Hirekerur	11.75	15.00	1.47	9.82
	Ranebennur	14.50	14.00	1.09	7.78
	Average	41.15	48.43	7.18	13.29
Gadag	Gadag	45.00	78.00	1.67	2.14
	Rona	57.00	67.50	1.59	2.35
	Shirahatti	51.00	60.50	0.41	0.68
	Naragund	51.75	84.50	0.38	0.45
	Mundaragi	46.75	80.00	0.50	0.62
	Average	50.30	74.10	0.91	1.25

Table 2: District wise incidence of *Nomuraea rileyi* on fall armyworm, *Spodoptera frugiperda* on maize

Districts	Pest infestation (%)	Number of larvae /200 plants	Number of larvae infected by *N. rileyi* /200 plants	Natural incidence of *Nomuraea rileyi* (%)
Belagavi	60.11	66.28	9.71	14.70
Bagalkot	54.96	67.17	2.23	3.48
Vijaypur	28.83	48.83	0.83	1.87
Dharwad	65.73	53.00	9.43	18.30
Uttar Kannada	12.42	12.08	1.51	11.75
Haveri	41.15	48.43	7.18	13.29
Gadag	50.30	74.10	0.91	1.25
Overall average	44.79	52.84	4.54	9.23

Table 3: Large scale evaluation of *Nomuraea rileyi* on *Spodoptera frugiperda* infesting maize

Location	Pest infestation (%)		Percent reduction of infestation	No of larvae per 20 plants		Larval reduction (%)	Leaf injury (%)		Reduction of leaf injury (%)
	1 DBS	15 DAS		1 DBS	15 DAS		1 DBS	15 DAS	
MARS, Dharwad	15.40	6.10	60.39	16.20	6.85	57.72	65.00	21.56	66.84
Garag, Dharwad	16.70	6.20	62.87	12.90	4.50	65.12	69.67	18.78	73.05
Mamadapur, Belagavi	16.31	6.70	58.91	16.10	5.40	66.46	66.26	18.93	71.43

*DBS: day before spray DAS: Days after spray

Fig 1: Nomuraea rileyi infected fall armyworm larvae on silk

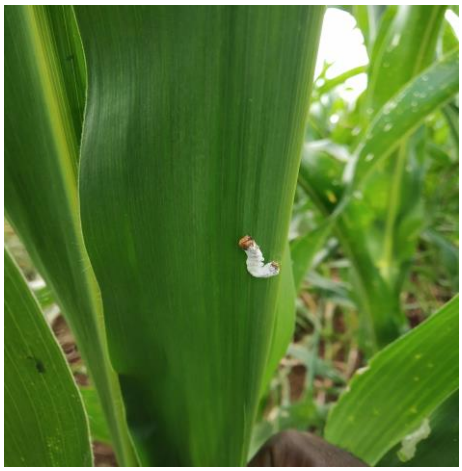

Fig 2: Nomuraea rileyi infected fall armyworm larvae on maize leaf.

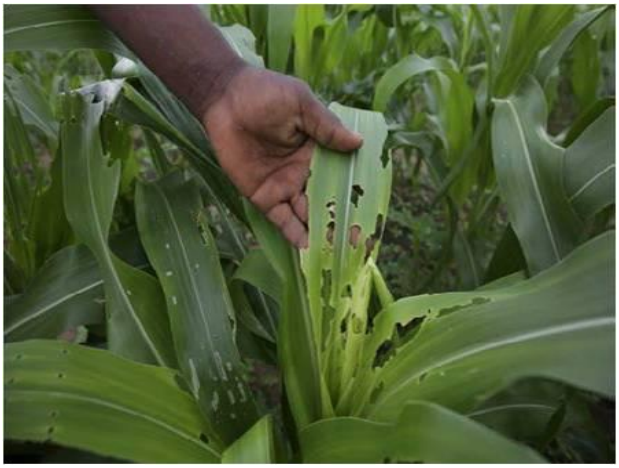

Fig 3: Fall armyworm damage on maize

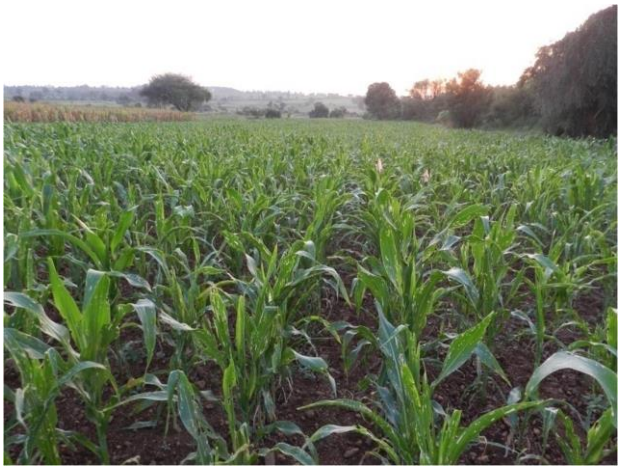

Fig 4: Maize crop severely damaged by fall armyworm

4. Conclusion

India is tropical country where environment is congenial for the insect pest occurrence and also their natural enemies. Based on the present investigations, it may be concluded that *N. rileyi* application can be one of the potential tool to combat the invasive notorious pest, *S. frugiperda.* This pathogen fungus being compatible with other ecofriendly management practices, it is self-perpetuating and highly cost effective under favorable environmental conditions. However, further studies are required on enhancement of efficacy of *N. rileyi* in order to witness its potential benefits in the management of fall armyworm.

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