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Relative efficacy of *Bacillus thuringiensis* against *Spodoptera litura* (Fab.) on Okra grown under differential organic manure application

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Abstract
Okra, *Abelmoschus esculentus* have an important place among *kharif* vegetable crops grown in all the states of India and has appreciable nutritional and economic value. This crop is used as boiled vegetable and is rich in minerals and vitamins. Field experiment on the influence of *Bacillus thuringiensis kurstaki* (Dipel 8L) against *Spodoptera litura* (Fab.) in okra managed through organic treatments was conducted during Kharif 2016 and 2017 at the Organic Farming Research Centre, OFRC, SKUAST-J, Chatha.. *Bacillus thuringiensis* var. *kurstaki* (*B.t.*) is the most commonly used bio-pesticide globally. A field experiment was conducted using ten organic nutrient treatments in variety Jammu Okra -05 (Seli Special) during *Kharif* 2016 and repeated in *Kharif* 2017 at Organic Farming Research Centre, Chatha, SKUAST-J. *B.t.k.* was applied at the rate of 1.0 L/ha sprayed at 15 days interval. The relative efficacy of bio-pesticide, *Bacillus thuringiensis kurstaki* @ 2g/L was evaluated against *S. litura* at different days *viz*. 3rd, 5th and 7th days after spray, in ten different organic manure applications with Farm Yard Manure (FYM), Vermi-compost (VC), Poultry Manure (PM) and Neem Cake (NC) alone, as well as their different combinations. Results revealed that maximum reduction of larval population was recorded in the okra crop grown on 12 kg Farm Yard Manure + 1.75 kg Poultry Manure, followed by FYM + Neem Cake.

Keywords: *Bacillus thrunigenesis, Spodoptera litura* (Fab.) *Abelmoschus esculentus,* organic nutrient management

Introduction
Plants supplied with nutrients from organic sources, biological materials have been reported to be more resistant to insects as compared to those grown with chemical fertilizers [1]. Workers are also of the view that pest outbreaks are likely to be reduced with organic farming practices, because of the establishment and maintenance of healthy soils in such fields [2. 3]. Recent researches have proved the plants resistance to insect-pest and diseases is related to the biological, physical and chemical properties of the soil [4, 5]. Signalling between soil and plants have also been reported to be mediated by soil organic matter, which may help in pest management [6, 7, 8].
Farming practices that results in nutritional imbalances in plants have been reported to lower pest resistance [9]. Soil nutrient availability besides affecting the amount of plant damage from herbivores, also affects the plant ability to recover from such damage [10]. Soil fertility status also impacts the physiological susceptibility of crop plants to insect-pest either by affecting the individual plant resistance to hervibores attack or by altering plant acceptability to them.
Okra, *Abelmoschus esculentus* have an important place among kharif vegetable crops grown in all the states of India and has appreciable nutritional and economic value. Okra is used as a boiled vegetable; it is rich in minerals and vitamins. Okra is principally infested with okra fruit and shoot borer (*Earias vitella* and *Earias insulana*) *Helicoverpa armigera, Spodoptera litura,* jassids, whiteflies, etc. *Spodoptera litura* is becoming serious presently on several important crop plants including okra. The larva of *S. litura* is hairless, variable in colour (young larvae are light green, the later in stars are dark green to brown on their backs, lighter underneath); sides of body with dark and light longitudinal bands; dorsal side with two dark semi-lunar spots laterally on each segment, except for the prothorax; spots on the first and eighth abdominal segments larger than others, interrupting the lateral lines on the first segment. Though the markings are variable, a bright-yellow stripe along the length of the dorsal surface

Is characteristic of *S. litura* larvae. *Bacillus thuringiensis* var. *kurstaki* (*B.T.*) is the most commonly used bio-pesticide globally. It releases toxins which damage the mid gut of the pest, eventually killing it. Main sources for the production of *B.T.* preparations are the strains of the subspecies *kurstaki*, *galeriae* and *dendrolimus*. It is a natural occurring, soil bacteria that has been used since 1950 to manage natural insects. It consists of a spore, which gives it persistence and a protein crystal within the spore, which is toxic to the target insects. They are particularly effective against the lepidopterous pests for pest control in cotton, rice and vegetables. Control of diamondback moth and *Helicoverpa* on cotton, pigeon-pea, and tomato by application of *Bacillus thuringiensis* has been reported [11]. Considering these facts an experiment was designed to assess the relative efficacy of *Bacillus thuringiensis* var. *kurstaki* against *S. litura* on okra grown under differential organic manure application.

Materials and Methods

To check bio-efficacy of *B.T.* against *S. litura* on okra managed through different organic inputs, field experiment was conducted on variety Seli Special (Jammu Okra -05) during Kharif 2016 and repeated in Kharif 2017 at the Organic Farming Research Centre, Chatha, and SKUAST-J in. This variety is medium tall in height with shorter internodes. Fruits are tender and dark green fruits with five ridges. This variety is recommended for the region and shows field tolerance to YVMV. However, pod borer is serious in this variety due to its tenderness. The experiment was conducted in three replications with ten treatments having plot size (3x4m^2) with row to row and plant to plant spacing of 45 x 60 cm^2, respectively. Initial dosages were kept with 24 kg/plot. Bio-pesticide, *Bacillus thuringiensis kurstaki* was sprayed @ 2g/L and *S. litura* population counts were made both pre-spray and post-spray at different days *viz*. 3rd, 5th and 7th days after spray, in all the ten different organic treatments with Farm Yard Manure (FYM), Vermi-compost (VC), Poultry Manure (PM) and Neem Cake (NC) alone, as well as their different combinations (Applied as per Package of Practices for Organic Crop Production - Adhoc Recommendation, SKUAST-Jammu, 2018). *B.T.* was applied twice at 15 days interval initiating first spray in the last week of April when the pest infestation started *viz*; 30 April and 15 May during Kharif 2016 and 2017, respectively. Sowing of the crop was done on 30th March, 2016 and 28th March, 2017 respectively.

Method of recording observations

The larval mortality counts were recorded after third, fifth and seventh days after spray. The observation on mortality of larvae due to *B.T.* was expressed as percent mortality using the following formula

$$\text{Per cent mortality} = \frac{\text{No. of larvae dead}}{\text{Total no. of larvae treated}} \times 100$$

Results and Discussion

All the organic amendments applied basally at the time of sowing recorded good management of *S. litura*, when sprayed with *B.T.*, upto seven days of spray during both the years (Table 1, 2 and 3). During *Kharif*, 2016 *B.t.* when sprayed against *S. litura* recorded highest percent reduction (90.19%) in 1.2 kg Neem cake + 1.75 kg Poultry manure applied plots after 7th Day after spray. This This was followed by 12 kg FYM + 1.75 kg Poultry Manure applied plots (85.67%), 12 kg FYM + 1.75 kg Neem Cake (81.72%) and 4 kg Vermicompost + 1.2 kg Neem Cake applied plots (81.72%) (Table 1). After three days of spray, all the treatments recorded percent reduction in *S. litura* population ranging from 29.16 to 44.44%. However, there were no significant differences among the various treatments after the 3rd day. The differences in responses among the various treatments became evident only after 5th day of spray.

Likewise, during *Kharif*, 2017, significantly highest reduction in *S. litura* larval population was recorded in 1.2 kg FYM + 1.75 kg PM applied plots (88.33%) and 12 kg FYM + 1.7 kg PM applied plots (86.67%); followed by 12 kg FYM + 1.2 kg NC (81.67%) and 4 kg VC + 1.2 kg NC (80.00%) applied plots, after seven days of *B.t.* spray (Table 2). Pooled data too, recorded similarly, as evident from Table 3. Okra crop treated with 1.2 kg NC + 1.75 kg PM and sprayed with *B.T.* recorded the highest reduction in *S. litura* larval population (89.26% after seven days of spray, as shown in the pooled table. This was followed by the crop treated with 12 kg FYM + 1.75 kg PM, 12 kg FYM + 1.2 kg NC and 4kg VC + 1.2 kg NC and sprayed with *B.t.* reduction in *S. litura* larval population was 81.42%, 81.70% and 80.86% respectively in these three treatments after seven days of spray.

Bioefficacy of *B.t.* in these treatments was may be due to the fact that the crop showed vigorous growth, that was able to tolerate the pest injury [1]. Supporting our results organic sources F.Y.M. and Vermi-compost to support lower fruit borer infestation in okra as compare to N.P.K. supplied through inorganic sources which supported higher fruit borer infestation have been reported [12]. Application of organic amendment (Castor cake, neem cake, poultry manure, sheep manure and sewage sludge) along with 75% dose of nitrogen was also found to be better in reducing the sucking pest population in cotton as compared with a full dose of nitrogen [13]. Lowest infestation of brinjal fruit and shoot borer (14.3%) in Neem cake @ 1.7 tonnes/ha applied plots was reported [14].

This pest has developed resistance against all insecticides which were used in crops. To control this pest under organic management in an environmentally friendly way, bio-pesticides or agents are being used in place of chemical pesticides [15]. Stem fly infestation in vegetable pea was significantly reduced in plants grown on Vermi-compost prepared from different organic sources, when applied in combination with DAP [16]. Significantly lowest whitefly population in brinjal was recorded in plots treated with various organic manures [17]. Corroborating our studies, few workers have reported application of neem cake, to reduce various insect-pest population in different crops [18, 19, 20, 21]. In accordance with our study, researchers have showed that application of organic fertilizers positively influenced rice plant growth and minimized the outbreak of insect-pest (Brown plant hopper, stem borer and leaf folder) and diseases (Blast and Sheath blight) [22]. Low BPH populations in organic amendments treated plots have also been recorded [23]. The main reason attributed to low BPH populations was low nitrogen content in those rice plants. Several authors have recorded a decrease in pest resistance in response to increase in soluble nitrogen levels in plant tissues by applying chemical fertilizers in different crop plants [24, 25, 6]. However, excessive nitrogen levels are rarely a problem in an organic production system [26]. Contradicting this study, in a very recent work, application of cattle manure increased pest and disease damages in maize by attracting diverse groups of insects [27]. This resulted in increased vector borne diseases like maize streak in organic fertilized plots [28, 29]. They suggested an increase in wheat development in organic fertilized plots which acted as a probable source of inoculums of maize streak virus. Likewise, a worker observed maize stem borers to be marginally more prevalent in fertilized crops than in unfertilized crops [30]. In a previous study, similar results in maize intercropped with peanut at high or low levels of fertilizers with good or bad weeding was recorded [31].

Though *B.T.* acts slowly as compared to conventional insecticides, but is as effective as any of the other insecticide, besides being safe. It can be thus safely accommodated in any Integrated Pest Management program for management of *Spodoptera* in okra, when grown organically.

Table 1: Reduction in *Spodoptera litura* larvae population in okra after *B.T.* spray during Kharif, 2016

S.No.	Treatments	Per cent reduction in larval population		
		3rd DAS	**5th DAS**	**7th DAS**
1.	1.2 kg NC+ 1.75 kg PM	30.55 (33.49)	53.89 (42.27)	90.19 (72.18)
2.	4 kg VC+1.2 kg NC	44.44 (41.74)	63.34 (52.75)	81.72 (64.77)
3.	4 kg V.C+1.75 kg P.M	41.67 (39.98)	52.67 (46.52)	70.56 (57.15)
4.	12 kg FYM+ 1.2 kg N.C	38.89 (38.49)	63.89 (53.18)	81.72 (64.77)
5.	12 kg FYM+ 1.75 kg PM	29.16 (32.64)	73.39 (59.04)	85.67 (71.57)
6.	2.4 kg Neem Cake	29.55 (32.86)	50.78 (45.43)	72.96 (58.68)
7.	3.5 kg PM	36.11 (36.74)	73.39 (59.01)	76.17 (60.77)
8.	8 kg VC	31.44 (34.03)	55.56 (48.18)	65.06 (53.77)
9.	24 kg FYM	37.00 (37.27)	53.33 (46.90)	61.11 (51.43)
10.	CONTROL	30.51 (33.46)	59.11 (50.24)	76.89 (61.25)
	C.D.	(N.S.)	(6.99)	(10.44)
	S.E.(m)	(3.70)	(2.33)	(3.49)

Figures in parenthesis are arc sine transformed value
DAS=Days after Spray

Table 2: Reduction in *Spodoptera litura* larvae population in okra after *B.T.* spray during Kharif, 2017

S.No.	Treatments	Per cent reduction in larval population		
		3rd DAS	**5th DAS**	**7th DAS**
1.	1.2 kg NC+ 1.75 kg PM	31.67 (34.13)	43.33 (41.15)	88.33 (70.09)
2.	4 kg VC+1.2 kg NC	39.67 (39.00)	60.67 (51.16)	80.00 (63.52)
3.	4 kg VC+1.75 kg PM	28.33 (32.13)	73.33 (59.03)	73.33 (58.91)
4.	12 kg FYM+ 1.2 kg NC	43.67 (41.32)	65.33 (53.94)	81.67 (64.78)
5.	12 kg FYM+ 1.75 kg PM	46.00 (42.65)	73.33 (58.97)	86.67 (69.52)
6.	2.4 kg Neem Cake	39.00 (38.59)	58.67 (49.97)	63.33 (52.72)
7.	3.5 kg PM	41.67 (40.09)	58.33 (49.80)	60.00 (50.77)
8.	8 kg VC	33.33 (35.10)	52.33 (46.32)	69.67 (56.64)
9.	24 kg FYM	30.67 (33.58)	51.67 (45.94)	74.67 (59.83)
10.	CONTROL	31.67 (34.13)	59.00 (50.19)	77.00 (61.34)
	C.D.	(N.S.)	(5.67)	(7.15)
	S.E.(m)	(2.70)	(1.89)	(2.39)

Figures in parenthesis are arc sine transformed value
DAS=Days after Spray

Table 3: Reduction in *Spodoptera litura* larvae population in okra after *B.T.* spray (Pooled data of 2016 and 2017)

S.No.	Treatments	Per cent reduction in larval population		
		3rd DAS	**5th DAS**	**7th DAS**
1.	1.2 kg NC+ 1.75 kg PM	33.11 (33.88)	48.61 (44.18)	89.26 (71.22)
2.	4 kg VC+1.2 kg NC	42.06 (40.41)	62.00 (51.93)	80.86 (64.07)
3.	4 kg VC+1.75 kg PM	28.75 (32.36)	73.36 (58.93)	79.50 (63.44)
4.	12 kg FYM+ 1.2 kg NC	41.28 (39.95)	64.61 (53.57)	81.70 (64.71)
5.	12 kg FYM+ 1.75 kg PM	41.06 (39.76)	73.36 (59.09)	81.42 (64.58)
6.	2.4 kg Neem Cake	35.22 (36.37)	57.11 (49.07)	64.19 (53.25)
7.	3.5 kg PM	39.34 (38.77)	55.83 (48.35)	60.56 (51.09)
8.	8 kg VC	37.50 (37.59)	52.50 (46.42)	70.11 (56.89)
9.	24 kg FYM	29.59 (32.91)	51.23 (45.69)	73.82 (59.28)
10.	CONTROL	30.37 (33.39)	59.06 (50.22)	76.94 (61.34)
	C.D.	(N.S.)	(6.21)	(6.52)
	S.E.(m)	(2.35)	(2.07)	(2.18)

Figures in parenthesis are arc sine transformed value
DAS=Days after Spray

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