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Compatibility of new species of entomopathogenic nematode, *Steinernema dharanaii* Kulkarni *et al*., 2012 (Nematoda: Rhabditida: Steinernematidae) from India with some modern biopesticides

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***Abstract*—** *The paper reports the compatibility of Infective Juveniles (IJs) ofnew species of entomopathogenic nematode, Steinernema dharanaii (TFRIEPN-15) was evaluated against some new generation biopesticides (9 products comprising of 5 botanical pesticides, Neem Gold®, Neem oil®, Agropest Bt. ®, Derisome®, Ozomite®, 3 microbial pesticides, Bioprahar®, Conserve® , Delfine®) and 1 Insect Growth Regulator (Cigna®). The freshly harvested Infective Juveniles (IJs) were exposed to the desired concentration of the biopesticides, which normally ranged from concentration lower to higher concentration specific to the type of biopesticides for 72 hours and data on the survival in IJs was recorded. The iinfectivity of the surviving IJs was also tested in laboratory against the wax moth larvae, Galleria mellonella.*

The results showed that the EPNs survival on highest concentration of different biopesticides such as, Neemgold 2.0% survival 84.76%, Neem oil 1.0% survival 86.28%, Spinosad 1.5% survival 91.63%,Agropest Bt. 2.0% survival 94.16, Bioprahar 2.0% survival 93.60%, Cigna 2.0% survival 75.94%, Derisome 0.3% survival 71.55%, Delfin 0.10% survival 42.69 and Ozomites 0.2% survival 44.95% respectively.

The results indicated no detrimental effect on the survival, infectivity and progeny production of EPN, Steinernema dharanaii (TFRIEPN-15), which were exposed recommended lower to highest concentration of the nine selected biopesticides. The experimental results discussed in the paper are important considering the future possibility of combination treatments against the major forest insect pests under Integrated Pest Management (IPM) programme.

***Keywords*—Compatibility, Infective Juveniles, Steinernema, Biological control, biopesticides, forest insect pests, IPM.**

I. INTRODCUTION

Entomopathogenic nematodes (*Steinernema* and *Heterorhabditis*) are microbial biopesticides capable of controlling a variety of economically important insect pests of forestry, agriculture, plantation crops, household, veterinary and turf grass (Klein, 1990;Karunakaran, et al., 1999;Hussainiet al., 2003;Grewal et al., 2005ab; Bedding, 2006;Kulkarni et al., 2008, 2017; Paunikar et al., 2010;Lacy & Georgis, 2012;Shapiro-Ilan et al., 2014;Paunikar &Kulkarni, 2019abc). These nematodes are obligate parasites of insects that kill their hosts with the aid of bacteria carried in the nematode's alimentary canal (Poinar, 1990; Koppenhofer & Kaya, 2001). The third-stage Infective Juvenile (IJs) nematode, the only free-living stage, enters the host via natural openings, i.e., mouth, anus, spiracles (Kaya,1985; Poinar, 1990), or occasionally through the insect

cuticle (Bedding and Molyneux, 1982). The nematodes then release their symbiotic bacteria, which are the primary agents responsible for killing the host within 24 to 72 hours (Gaugler & Kaya 1990; Adams & Nguyen,2002). After the nematodes complete one to three generations within the insect cadaver, infective juveniles exit to find new hosts (Poinar, 1990). These nematodes possess a number of attractive qualities as biocontrol agents including a durable infective stage, host-seeking ability, quick mortality of targeted insect, safety to mammals and other nontarget organisms, suitability to mass production (Akhurst, 1990;Ehlers & Hokkanen, 1996;Grewal, 2002;Jagdale &Grewal, 2008;Shapiro-Ilan, et al., 2012; Paunikar, 2014;Hussaini, 20017;Devi, 2018). The one of the most important attributes of entomopathogenic nematodes are to compatibility/tolerance to number of biopesticides, insecticides herbicides, acaricides, nematicides, fertilizers and pathogens (Hara &Kaya 1983;Rovesti et al., 1988; Georgis & Kaya, 1998;Gupta & Siddiqui,1999;De Nardo & Grewal, 2003;Koppenhofer &Grewal 2005;Kulkarni et al., 2009;Rodova, 2010;Paunikar et al., 2012;Laznik & Tredan, 2014; Chavan *et al.*, 2018; Devi, 2019). There are several biological controls agents like predators/parasites and others natural enemies kills by chemical insecticides, some biopesticides and fungicides (Schmutterer,1997; Ruberson, et al., 2004; Xia, et al., 2008; Gill & Garg, 2014). Therefore, use of their biocontrol potential restricts against variety of insect pests.

But, the number of studies has been conducted on agrochemicals including biopesticidesand EPNs interaction showing tolerance, lethal or sub lethal effects on survival and virulence or synergistic effects on the Infective Juveniles (IJs) of several species of EPNs around the world including in India (Koppenhöfer & Kaya, 1998: Stark, 1996: Hussaini et al., 2001; Bedding, 2006;Laramliana & Yadav 2009: Rodova 2011;Laznik, et al., 2012, Kulkarni et al., 2013;Paunikar, 2014;Anis & Ganguly 2016; Rahil et al., 2017). However, the compatibility varies with the species, strain, agrochemical formulation and applications dose (Koppenhoffer & Grewal, 2005). These qualities of EPNs make its excellent biological control agents over other biocontrol agents and encouraged to use against variety of insect pests of soil and cryptic habitat in India and abroad (Karunakaran et al., 1992;Kaya & Gaugler, 1993; Koppenhöfer et al., 2002;Sankaranarayanan, et al., 2006; Shapiro-Illan et al., 2012;Lacy et al., 2015;Kulkarni, 2014,2017; Paunikar & Kulkarni, 2020ab).

Therefore, the paper reports compatibility of native EPN, *Steinernema dharanaii* Kulkarni et al., 2012(TFRIEPN-15) with some new generation biopesticides products. The IJs of this native EPN, exposed tonine selected biopesticides formulations for their compatibility, ability to infect and reproduce.

II. MATERIALS AND METHODS

The new species of entomopathogenic nematode, *Steinernema dharanaii* were isolated and identified from forest floor of central India by Kulkarni et al. (2012a). This native species isused in this study method of Dutky et al., 1964; Kulkarni et al., 2012b was used for cultured EPNs on last instar larvae of the greater wax moth, *Galleria mellonella* L. (Lepidoptera: Pyralidae). The White trap technique as described by White (1927) was used for harvesting nematodes progeny (Infective Juveniles "IJs") at 27±1 ^{0}C. A stock suspension of the IJs in sterilized water was stored at 10^0 C for 2 weeks until used.

2.1Biopesticides

For evaluating compatibility of EPNs with biopesticides products listed Table A were procured from the local markets of Jabalpur (Madhya Pradesh) and Nagpur (Maharashtra). The selection was restricted to the most commonly used and /or new products, which are being experimented or are, used commonly in forestry and agriculture against various group of insect pests.

Table. A. Details of biopesticides compatibility experiments

Active compound of Insecticides / Biopesticides	**Registered Biopesticides**	**Concentrations tested**
Neem Formulation	Neem Gold®	0.50 to 2%
Neem	Neem oil	0.12 to 1.0%
Bacteria, *Photorhabdus* luminescence spp.Formulation	Bioprahar®	0.050 to 2.0%
Botanical combination	Agropest Bt®	0.50 to 1.5%

Actinomycete, Spinosad formulation	Conserve®45.0% EC,	0.050 to 0.2%
Botanical combination	Derisome®	0.05 to 0.3%
IGR, Lufenuron	Cigna®5.4% W/w EC,	0.50 to 2.0%
Mit-018 Botanical Combination	Ozomite®	0.03 to 0.2%
Bacillus thuringiensis	Delfine® WG	0.25 to 0.10%

The stock solutions of different chemical insecticides and biopesticides were prepared in distilled water in and shaken thoroughly, out of which 2 ml of solution in 5 ml beaker for the test was used. The fifty IJs of EPNs were exposed to the pesticide solution. Pure distilled water was used as a control. The beakers were kept at room temperature (27±1 ^{0}C) in a tray covered to avoid direct to exposure to light. Each treatment was replicated five times. The mortality/survival was checked after 24, 48 and 72 h, by counting survival/mortality of IJs in each replication and the control under the stereomicroscope. The nematodes that did not move even when prodded, were considered dead.

Confirmation of pathogenicity and virulence of EPNs suspended some biopesticide suspension were rinsed with sterile water three times to remove the rest of the biopesticide.

Nematodes were left for 72 hrs in distilled water. The alive infective juveniles (24 IJs Larva-1) of *S. dharanaii* (TFRIEPN-15) were released into Petri dish (10 cm x 1.5 cm depth) lined moistened with filter paper on ten larvae of waxmoth. Petri dishes were kept at room temperature (27±1 ^{0}C) in darkness. Each treatment had three replications and clear nematode suspension served as a control. The larval mortality was checked on the 24, 48 and 72 hrs. The experiment was repeated thrice before compilation of data and statistical analysis.

III. STATISTICAL ANALYSES

Data on surviving infective juveniles was used to calculate mean percentage survival and subjected to Analysis of Variance (ANOVA) after transforming it to angular values (Gomez & Gomez, 1984). The multiple comparison of means was done using the Ryan, Eniot-Gabriel &Welsch (REGW) procedure (Quinn & Keough, 2002), using statistical software GenStat Discovery Version 3 and data presented.

VI. RESULTS

4.1 Neem Gold®

The investigations on the compatibility of EPN, *Steinernema* sp. (nr.) TFRIEPN-15 with available market product of neem (Neem gold®) revealed IJs of EPNs to be highly compatible with the neem product. Even at the highest concentration of 2.0 %, IJs showed 84.76% survival after 72 hrs of exposure to Neem gold as compared to survival in control being 97.73% (P<0.05) ($F_{(P<0.001)}$= 11.05, *df* = 15, ($F_{(P<0.001)}SE_{(d)}\pm$ = 2.60, $LSD_{(P<0.05)}$ = 5.54), which corresponded to the 13.25% (P<0.05) ($F_{(P<0.001)}$= 15.87, *df* = 16, $SE_{(d)}\pm$ = 2.49, $LSD_{(P<0.05)}$ = 5.31) toxicity over control. The results with the lowest dose of 0.5 (97.51% survival corresponding to only 0.19% toxicity over control) were statistically at par (P>0.05) with the control. Detailed result has been presented as Table1).

4.2 Neem oil®

Similar to the commercial neem product Neem gold®, IJs when exposed for 72 hrs to the highest tested concentration of 1.0%, IJs showed 86.28% survival as compared to 99.24% (P<0.05)($F_{(P<0.001)}$ = 4.36, *df* = 15, $SE_{(d)}\pm$ = 4.67, $LSD_{(P<0.05)}$ = 9.95) in control, corresponding toxicity over control being 13.04% (P<0.05)($F_{(0.001)}$ = 6.87, *df* = 16, $SE_{(d)}\pm$ = 10.09, $LSD_{(P<0.05)}$ = 21.24). (Table2).

4.3 Actinomycete (Spinosad) product, Conserve® 45.0% EC

Infective Juveniles when exposed to Actinomycete (Spinosad) product, Conserve® at the highest tested concentration of 1.5%, showed 91.63% survival after 72 hrs as compared to 98.41% (P<0.05) in control ($F_{(P<0.001)}$ = 10.85, *df* = 11, $SE_{(d)}\pm$ = 2.03, $LSD_{(P<0.05)}$ = 4.48), corresponding to toxicity over control being 6.87% (P<0.05)($F_{(P<0.001)}$ = 37.40, *df* = 12, $SE_{(d)}\pm$ = 1.52, $LSD_{(P<0.05)}$ = 3.31) (Table3).

4.4 Agropest Bt®.

A botanical combination product (Agropest Bt®.) the highest tested concentration of 2.0%, allowed 94.16% survival after 72 hrs of exposure as compared to 99.31% (P<0.05)($F_{(P<0.001)}$ = 12.75, *df* = 15, $SE_{(d)\pm}$ = 2.083, $LSD_{(P<0.05)}$ = 4.439) in control, corresponding to toxicity over control being 5.17%

($_{P<0.05}$)($F_{(0.001)}$ = 37.07, *df* = 16, $SE_{(d)}$± = 1.304, $LSD_{(P<0.05)}$ = 2.764) (Table4).

4.5 Bioprahar®

The commercial botanical product (Bioprahar®) at the highest tested concentration of 2.0%, allowed 93.60% survival of IJs after 72 hrs of exposure as compared to 99.26% (P<0.05) ($F_{(P<0.001)}$ =9.68, *df* = 15, $SE_{(d)}$± = 2.131, $LSD_{(P<0.05)}$ = 4.543) in control, corresponding to toxicity over control being 5.69% (P<0.05) ($F_{(P<0.001)}$ = 22.36, *df* = 16, $SE_{(d)}$± = 1.612, $LSD_{(P<0.05)}$ = 3.417) (Table 5).

4.6 Cigna®

Insect Growth Regulator Product (IGR) (Cigna®**)** at the highest tested concentration of 2.0%, IJs showed 75.94% survival after 72 hrs of exposure to Cigna as compared to 97.53% (P<0.05)($F_{(P<0.001)}$ = 32.77, *df*= 11, $SE_{(d)}$± = 2.276, $LSD_{(P<0.05)}$ = 5.009) in control, corresponding to toxicity over control being 22.11% (P<0.05) ($F_{(P<0.001)}$ = 39.80, *df* = 12, $SE_{(d)}$± = 2.576, $LSD_{(P<0.05)}$ = 5.612) (Table 6).

4.7 Derisome®

The commercial botanical combination (Derisome®**)** at the highest tested concentration of 0.3%, IJs showed 71.55% survival after 72 hrs of exposure as compared to 98.10% (P<0.05) ($F_{(P<0.001)}$ = 22.58, *df* = 15, $SE_{(d)}$± = 3.016, $LSD_{(P<0.05)}$ = 6.429) in control, corresponding to toxicity over control being 26.99% (P<0.05)($F_{(P<0.001)}$= 52.50, *df*= 16, $SE_{(d)}$± = 2.521, $LSD_{(P<0.05)}$ = 5.344). The IJs exposed even at the lowest concentration above 0.5% showed significant (P<0.05) reduction in capacity of progeny production, as compared to control ($F_{(P<0.001)}$ = 7.15, *df* = 16, $SE_{(d)}$± = 12.43, $LSD_{(P<0.05)}$ = 26.36). There was significant increase in the mortality in IJs, when data on IJs survival was compared with the survival recorded after 24, 48 and 72 hrs for each concentration (Table 7).

4.8 Delfine Bt.®

The commercial Bacilius thuringiensis, product (Delfine Bt.®**)** at the highest tested concentration of 0.10%, IJs showed 42.69% survival after 72 hrs of exposure to Delfine Bt as compared to 94.42% (P<0.05)($F_{(P<0.001)}$ = 14.33, *df* = 11, $SE_{(d)}$± = 5.94, $LSD_{(P<0.05)}$ = 13.08) in control, corresponding to toxicity over control being 54.88% (P<0.05)($F_{(P<0.001)}$ = 87.13, df = 12, $SE_{(d)}$± = 3.22, $LSD_{(P<0.05)}$ = 7.02). The IJs exposed to Delfine Bt at and above 0.1% showed significant (P<0.05) reduction in capacity of progeny production, as compared to control ($F_{(P<0.001)}$ = 12.41, *df* = 12, $SE_{(d)}$± = 12.83, $LSD_{(P<0.05)}$ = 27.97) (Table8).Compared to other biopesticides there was significant effect even after 24 hrs of exposure (P<0.05) even at the lowest concentration of 0.25% .Days of exposure had significant effect on survival of IJs.

4.9 Ozomite ®

Botanical combination Ozomite®, at the highest tested concentration of 0.2%, IJs showed 44.95% survival after 72 hrs of exposure to Ozomite as compared to 98.31% (P<0.05) ($F_{(P<0.001)}$ = 40.76, *df* = 15, $SE_{(d)}$± = 3.89, $LSD_{(P<0.05)}$ = 8.28) in control, corresponding to toxicity over control being 54.16% (P<0.05)($F_{(P<0.001)}$ = 52.90, *df* = 16, $SE_{(d)}$± = 3.80, $LSD_{(P<0.05)}$ = 35.01) (Table 9).

Table 1: Compatibility of TFRIEPN-15 with Neem product, Neem Gold®

Concentration (in %)	***Mean Survival (in%)***			***Mean Toxicity over control (in%)***		
	24 hours*	***48 hours***	***72 hours***	***24 hours***	***48 hours***	***72 hours***
0.5	99.58^{ab} (88.38)	98.34^{ab} (84.36)	97.51^{ab} (82.09)	0.419^{ab} (1.66)	0.55^{ab} (3.94)	0.19^{ab} (3.89)
1.0	98.07^{bc} (82.95)	94.43^{bc} (76.93)	92.81^{c} (74.74)	1.92^{b} (7.08)	4.54^{c} (12.01)	5.02^{c} (12.47)
1.5	96.29^{cd} (80.35)	93.59^{cd} (75.74)	90.85^{cd} (72.54)	3.70^{c} (9.69)	5.34^{c} (12.31)	6.95^{cd} (15.11)
2.0	91.87^{d} (73.94)	89.72^{d} (71.50)	84.76^{d} (67.26)	8.12^{d} (16.10)	9.28^{d} (17.53)	13.25^{e} (21.03)
Distilled water (Untreated)	100.00^{a} (90.04)	98.91^{a} (86.30)	97.73^{a}	*0.00^{a}* *(0.00)*	*0.00^{a}* *(0.00)*	*0.00^{a}* *(0.00)*

			(82.36)	*(0.00)*		
$F_{(P<0.001)}$	8.10	*8.10*	*11.05*	*8.10*	*8.10*	*15.87*
df	*15*	*15*	*15*	*16*	*16*	*16*
$SE_{(d)}\pm$	3.12	3.12	2.60	3.12	3.12	2.49
$LSD_{(P<0.05)}$	6.66	6.66	5.54	6.66	6.66	5.31

** The values in parentheses are Arcsin√n transformed values of original proportions.*

$ The mean values of initial population were taken as covariate at the time of ANOVA of mean survival after 72 hrs.

Table. 2. Compatibility of TFRIEPN-15 with Neem oil.

Concentration (in %)	***Mean Survival (in %)***			***Mean Toxicity over control (in %)***		
	24 hours	***48 hours***	***72 hours***	***24 hours***	***48 hours***	***72 hours***
0.12	99.24^{ab} (86.90)	98.69^{ab} (87.08)	97.00^{ab} (81.52)	0.75^{ab} (3.14)	1.30^{ab} (2.96)	2.69^{ab} (8.18)
0.25	97.26^{c} (81.60)	96.46^{c} (79.69)	95.23^{bc} (77.80)	2.73^{c} (8.44)	3.53^{c} (10.34)	4.03^{bc} (11.11)
0.50	93.83^{d} (75.72)	92.28^{d} (73.99)	90.98^{cd} (72.73)	6.16^{cd} (14.32)	7.72^{cd} (16.04)	8.00^{cd} (16.15)
1.00	90.11^{de} (72.11)	88.21^{de} (70.18)	86.28^{de} (70.85)	9.88^{de} (17.93)	11.79^{de} (19.85)	13.04^{de} (18.47)
Distilled water (Untreated)	100.00^{a} (90.04)	100.00^{a} (90.04)	99.24^{a} (86.88)	*0.00* ^{a} *(0.00)*	*0.00* ^{a} *(0.00)*	*0.00*^{a} *(0.00)*
$F_{(P<0.001)}$	34.20	26.95	4.36	31.18	19.51	6.87
Df	*15*	*15*	*15*	*16*	*16*	*16*
$SE_{(d)}\pm$	2.00	2.36	4.67	2.0	2.69	4.44
$LSD_{(P<0.05)}$	4.26	5.04	9.95	4.38	5.71	9.42

** The values in parentheses are Arcsin√n transformed values of original proportions.*

$ The mean values of initial population were taken as covariate at the time of ANOVA of mean survival after 72 hrs.

Table3: Compatibility of TFRIEPN-15 with Actinomycete (Spinosad) product, Conserve® 45% EC

Concentration (in %)	Mean Survival (in%)			Mean Toxicity over control (in%)		
	24 hours	48 hours	72 hours	24 hours	48 hours	72 hours
0.5	98.91^{ab} (86.30)	97.96^{ab} (83.78)	96.75^{ab} (79.88)	1.09^{ab} (3.74)	1.69^{ab} (4.94)	2.01^{ab} (7.25)
1.0	98.41^{bc} (83.59)	95.57^{bc} (77.98)	94.19^{bc} (76.23)	1.59^{bc} (6.45)	3.31^{c} (10.33)	4.25^{c} (11.49)
1.5	95.36^{c} (77.81)	93.45^{c} (75.34)	91.63^{c} (73.29)	4.63^{c} (12.23)	5.429^{cd} (12.80)	6.87^{d} (15.14)
Distilled water (Untreated)	100.00^{a} (90.04)	98.86^{a} (86.23)	98.41^{a} (84.46)	0.00^{a} (0.00)	0.00a (0.00)	0.00^{a} (0.00)
$F_{(P<0.001)}$	7.61	5.48	10.85	9.14	19.05	37.40
df	11	11	11	12	12	12
$SE_{(d)}\pm$	2.543	2.784	2.037	2.409	1.914	1.523
LSD (P<0.05)	5.59	6.12	4.48	5.24	4.17	3.31

** The values in parentheses are Arcsin√n transformed values of original proportions.*

$ The mean values of initial population were taken as covariate at the time of ANOVA of mean survival after 72 hrs.

Table 4: Compatibility of TFRIEPN-15 with Botanical combination Agropest-Bt. ®

Concentration (in %)	Mean Survival (in%)			Mean Toxicity over control (in%)		
	24 hours	48 hours	72 hours	24 hours	48 hours	72 hours
0.5	100.00^{ab} (90.04)	99.56^{ab} (98.06)	98.50^{ab} (84.63)	0.00^{ab} (0.00)	0.44^{ab} (1.72)	0.82^{ab} (3.31)
1.0	99.36^{bc} (87.15)	98.33^{c} (83.92)	96.21^{c} (79.16)	0.63^{b} (2.89)	1.94^{c} (6.13)	3.44^{c} (9.39)
1.5	(97.60) ^{d} (81.17)	96.84^{cd} (79.99)	94.72^{cd} (76.91)	2.40^{c} (8.88)	3.16^{cd} (10.10)	4.62^{d} (12.35)
2.0	96.28^{d} (79.13)	95.37^{d} (77.83)	94.16^{d} (76.24)	3.72^{cd} (10.90)	4.63^{d} (12.20)	5.17^{d} (12.79)
Distilled water (Untreated)	100.00^{a} (90.04)	100.00^{a} (90.04)	99.31^{a} (87.90)	0.00^{a} (0.00)	0.00^{a} (0.00)	0.00^{a} (0.00)
$F_{(P<0.001)}$	36.27	14.47	12.75	29.91	13.85	37.07
df	15	15	15	16	16	16
$SE_{(d)}\pm$	1.195	1.945	2.083	1.315	1.987	1.304

LSD $_{(P<0.05)}$	2.54	4.14	4.43	2.78	4.21	2.76

** The values in parentheses are Arcsin√n transformed values of original proportions.*

$ The mean values of initial population were taken as covariate at the time of ANOVA of mean survival after 72 hrs.

Table 5: Compatibility of TFRIEPN-15 with commercial symbiotic bacterial product Bioprahar®

Concentration (in %)	Mean Survival (in %)			Mean Toxicity over control (in%)		
	24 hours	48 hours	72 hours	24 hours	48 hours	72 hours
0.50	100.00^{ab} (90.04)	99.29^{ab} (86.99)	98.98^{ab} (85.55)	0.00^{a} (0.00)	0.70^{ab} (3.04)	0.38^{ab} (2.05)
1.00	99.62^{bc} (88.46)	98.61^{bc} (84.85)	97.83^{bc} (82.52)	0.37^{ab} (1.58)	1.38^{c} (5.19)	1.44^{bc} (5.60)
1.50	98.37^{d} (83.49)	96.80^{cd} (79.98)	96.13^{cd} (78.73)	1.63^{c} (6.55)	3.19^{cd} (10.06)	3.14^{cd} (9.86)
2.00	97.36^{de} (80.83)	95.93^{d} (78.76)	93.60^{d} (75.53)	2.63^{cd} (9.21)	4.07^{d} (11.28)	5.69^{d} (13.41)
Distilled water (Untreated)	100.00^{a} (90.04)	100.00^{a} (90.04)	99.26^{a} (86.93)	0.00a (0.00)	0.00^{a} (0.00)	0.00a (0.00)
$F_{(P<0.001)}$	16.03	11.26	9.68	16.49	11.01	22.36
df	15	15	15	16	16	16
$SE_{(d)}\pm$	1.490	1.949	2.131	1.459	2.018	1.612
LSD $_{(P<0.05)}$	3.17	4.15	4.54	3.09	4.27	3.41

** The values in parentheses are Arcsin√n transformed values of original proportions.*

$ The mean values of initial population were taken as covariate at the time of ANOVA of mean survival after 72 hrs.

Table 6: Compatibility of TFRIEPN-15 with IGR Lufenuron Cigna® 5.4% W/w EC

Concentration (in %)	Mean Survival (in %)			Mean Toxicity over control (in %)		
	24 hours	48 hours	72 hours	24 hours	48 hours	72 hours
0.50	98.51^{ab} (85.76)	95.73^{b} (78.61)	92.06^{b} (74.29)	1.48^{ab} (4.27)	2.87^{b} (8.64)	5.57^{b} (11.96)
1.00	94.41^{c} (76.69)	92.36^{bc} (74.23)	90.82^{b} (72.65)	5.58^{c} (13.35)	6.27^{bc} (14.40)	7.05^{bc} (13.76)
2.00	88.21^{cd} (70.24)	83.62^{d} (66.26)	75.94^{c} (60.68)	11.78^{cd} (19.80)	15.11^{cd} (22.74)	22.11^{d} (28.02)

Distilled water (Untreated)	100.00[a] (90.04)	98.53[a] (84.68)	97.53[a] (82.10)	0.00[a] (0.00)	0.00[a] (0.00)	0.00[a] (0.00)
$F_{(P<0.001)}$	20.50	39.90	32.77	21.26	35.01	39.80
df	11	11	11	12	12	12
$SE_{(d)}\pm$	2.816	1.782	2.276	2.735	2.290	2.576
LSD (P<0.05)	6.19	3.92	5.00	5.95	4.98	5.61

** The values in parentheses are Arcsin√n transformed values of original proportions.*

$ The mean values of initial population were taken as covariate at the time of ANOVA of mean survival after 72 hrs.

Table 7: Compatibility of EPN-15 with Botanical Combination Derisome®

Concentration (in %)	Mean Survival (in %)			Mean Toxicity over control (in%)		
	24 hours	48 hours	72 hours	24 hours	48 hours	72 hours
0.5	96.35[b] (79.18)	92.25[b] (74.15)	89.84[b] (71.52)	3.64[b] (10.86)	6.67[b] (14.46)	8.40[b] (16.77)
0.1	92.13b[c] (73.82)	89.30[bc] (71.08)	85.80[bc] (68.15)	7.86[c] (16.21)	9.64[c] (17.85)	12.49$_c$ (20.32)
0.2	90.92[cd] (72.66)	82.72[c] (65.57)	73.49[d] (59.14)	9.07[d] (17.38)	16.30[d] (23.68)	25.05[d] (29.93)
0.3	84.14[d] (66.71)	76.23[d] (60.95)	71.55[de] (57.88)	15.85[e] (23.33)	22.85[e] (28.42)	26.99[de] (31.18)
Distilled water (Untreated)	100.00[a] (90.04)	98.86[a] (85.29)	98.10[a] (83.07)	0.00[a] (0.00)	0.00[a] (0.00)	0.00[a] (0.00)
$F_{(P<0.001)}$	45.72	35.08	22.58	44.92	90.52	52.50
df	15	15	15	16	16	16
$SE_{(d)\pm}$	1.799	1.656	3.016	1.801	1.725	2.521
LSD (P<0.05)	3.83	2.34	6.42	3.81	3.65	5.34

** The values in parentheses are Arcsin√n transformed values of original proportions.*

$ The mean values of initial population were taken as covariate at the time of ANOVA of mean survival after 72 hrs.

Table 8: Compatibility of TFRIEPN-15 with Bacilius thuringiensis Delfine® Bt.WG

Concentration (in %)	Mean Survival (in%)			Mean Toxicity over control (in%)		
	24 hours	48 hours	72 hours	24 hours	48 hours	72 hours
0.25	86.30[b] (68.58)	74.65[b] (60.04)	56.57[b] (48.82)	12.24[b] (20.09)	22.37[b] (27.88)	39.97[b] (39.17)

0.50	76.76^{bc} (61.42)	61.38^{c} (51.64)	47.48b^{c} (43.51)	21.9^{c} (27.62)	36.28^{c} (37.01)	49.82^{bc} (44.95)
0.10	67.75^{cd} (55.51)	54.46^{cd} (47.59)	42.69^{c} (40.76)	31.08^{d} (33.77)	43.53^{d} (41.29)	54.88^{c} (47.84)
Distilled water (Untreated)	98.40^{a} (85.45)	96.27^{a} (80.39)	94.42^{a} (76.74)	0.00^{a} (0.00)	0.00^{a} (0.00)	0.00^{a} (0.00)
$F_{(P<0.001)}$	31.80	54.13	14.33	71.30	103.82	87.13
df	11	11	11	12	12	12
$SE_{(d)}\pm$	3.29	2.832	5.94	2.460	2.576	3.22
LSD $_{(P<0.05)}$	7.24	6.23	13.08	5.36	5.613	7.02

** The values in parentheses are Arcsin√n transformed values of original proportions.*

$ The mean values of initial population were taken as covariate at the time of ANOVA of mean survival after 72 hrs.

Table 9: Compatibility of TFRIEPN-15 with Botanical combination, Ozomite®

Concentration (in %)	**Mean Survival (in %)**			**Mean Toxicity over control (in%)**		
	24 hours	**48 hours**	**72 hours**	**24 hours**	**48 hours**	**72 hours**
0.03	98.87^{b} (85.32)	97.60^{ab} (82.17)	96.81^{ab} (80.98)	1.12^{b} (4.71)	1.62^{b} (5.52)	1.97^{ab} (7.14)
0.05	96.43^{c} (80.54)	93.85^{c} (75.91)	90.68^{bc} (72.41)	3.56^{c} (9.50)	5.32^{c} (13.07)	7.71^{c} (15.54)
0.1	89.89^{d} (71.81)	80.91^{d} (64.57)	71.16^{d} (57.95)	10.11^{cd} (18.23)	18.34^{d} (24.88)	27.49^{d} (31.03)
0.2	73.68^{e} (59.17)	58.39^{e} (50.01)	44.95^{e} (42.03)	26.31^{d} (30.87)	41.05^{e} (39.68)	54.16^{e} (47.50)
Distilled water (Untreated)	100.00^{a} (90.04)	99.12^{a} (86.65)	98.31^{a} (84.32)	0.00^{a} (0.00)	0.00^{a} (0.00)	0.00^{a} (0.00)
$F_{(P<0.001)}$	58.06	61.32	40.76	57.76	46.42	52.90
df	15	15	15	16	16	16
$SE_{(d)}\pm$	2.260	2.629	3.89	2.271	3.30	3.80
LSD $_{(P<0.05)}$	4.81	5.60	8.28	4.815	3.30	8.05

** The values in parentheses are Arcsin√n transformed values of original proportions.*

$ The mean values of initial population were taken as covariate at the time of ANOVA of mean survival after 72 hrs.

VII. DISCUSSION

The EPN, *Steinernema dharanaii (*TFRIEPN-15) was highly compatible with the biopesticidal products like actinomycete (spinosad) product, conserve® 45.0% EC, botanical products like neem, agropest Bt®, ozomite®. The commercial microbial product (bioprahar®). The moderate level of tolerance was observed to the commercial botanical combination (derisome®), the commercial Bacilius thuringiensis, product (delfine Bt.®) and ozomite®.

In most of the earlier reports most of the EPNs populations have been reported tolerant to biopesticidal products, *viz.*, botanical (nemmarin) to *S. masoodi*, *S. seemae*, *S. carpocapsae* and *S. mushtaqi* Rashid &Ali (2012); neem product (neemsuraksha®) to two native populations of *Steinernema* sp. (SSL2)(PDBCEN 13.21, PDBC EN 14.10 and three *H. indica* IPDBC EN 13.22, PDBC EN 14.3, PDBC EN 7.71) (Hussaini et al., 2001);Krishnayya &Grewal(2002) studied the effect of neem and fungicides on viability and virulence of entomopathogenic nematodes, *S. feltiae*. They evaluated the effects of different formulations of neem and selected fungicides commonly used in greenhouses on *S. feltiae* which is used for the control of fungus gnats.*S. carpocapsae* to neem product (azadirachtin) Koppenhofer&Grewal (2005); *S. carpocapsae* (PDBC strain) to some biopesticides like agropest Bt., actinomycete (spinosad) product (conserve®) and neem formulation (Kulkarni et al., 2009); EPN, *H. indica*to three fungal pathogens (*M. anisopliae*, *B. bassiana* and *T. viride*), one antagonistic bacteria (*P. fluorescence*), and two neem based biopesticides (neem and nimor) (Sankar et al., 2009); Badr El et al. (2009) studied the combined effect of entomopathogenic nematodes, *S. carpocapsae* and *H. bacteriophora* with two biopesticides: spinosad and proclaim were more effective than nematodes when used separately. *H. indica* to neem oil, agropest Bt. derisome, ozomite and two microbial pesticides, bioprahar and conserve and one Insect growth regulator, Cigna (Paunikar et al., 2012). However, negative effect of actinomycete product of Spinosad has been reported by Elizabeth et al. (2003) on *S. feltiae*. Kulkarni et al. (2013) investigated compatibility of entomopathogenic nematode, *Steinernema carpocapsae* with three biopesticides (Neemgold, Spinosad and Agropest Bt.) in lower to highest doses. The actinomycete Spinosad product (Conserve~) also allowed 87.20% survival at the lowest concentration. and the highest concentration of 0.20 survive 77.20. The formulation (Neemgold®) was tested in 0.5% to 2.00% concentration range. The highest concentration of 2.00% allowed 69.60% survival followed by 80.80% at the concentration of 1.5%, 87.20% survival at 1.00% and 92.40 % survival at the lowest tested concentration of 0.5%. They found that the combination of six Botanicals, viz., *Jatropha* extract, *Pongamia* extract, Custard apple extract, Kitinase and digestive enzyme (Agropest *bt.* ®), allowed survival of only 42.40% IJs, exposed to the highest concentration of 0.3%, which was statistically at par *(P>0.05)* with next lower concentration (0.2%). The lowest concentration of 0.05% allowed survival of 84.0%. Recently, Raheel et al. (2017) also studied the compatibility of four species of EPNs *Steinernema feltiae*, *S. asiaticum*, *Heterorhabditis bacteriophora* and *H. indica* with biopesticides spinosad (0.45 g/L), azadirachtin (1.5 ml/L), abamectin (1.25 ml/L), emamectin (0.20 ml/L), lambda-cyhalothrin (0.15 ml/L) and radiant (1.5 g/L) against *Galleria mellonella*. They found that. Azadirachtin and lambda-cyhalothrin proved to be compatible with all the EPNs species.

VIII. CONCLUSION

The results indicated that the most of the biopesticides compatible with new species of entomopathogenic nematode, *Steinernema dharanaii* (TFRIEPN-15) from higher to lower doses and possibilities of their combination treatment under IPM not only against forestry but also agricultural importance insect pests.

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