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Comparative efficacy of native *Bacillus thuringiensis* strains in two different sprayable formulations against *Spodoptera litura* in groundnut

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Abstract
A total of 203 *B. thuringiensis* strains were collected from 925 soil samples covering different soil environments of Chittoor, Kadapa and Nellore districts of Andhra Pradesh. These strains were bioassayed against *Spodoptera litura* in laboratory studies and identified 28 potential strains which were developed into solid and liquid formulations to test against *S. litura* under field studies. The results revealed that, *S. litura* larval population ranged from 7.0 to 22.5 No/metre row and it was low in three strains F493 (7 larva/m row), F504 (7.5 larva/m row), C33 (7.5 larva/m row) which were superior over the other strains as well on par with standard check HD-1 (7.5 larva/m row). In untreated control a larval population 22.5 larva/m row was recorded. The defoliation at 7 days after spray was low in F493 (14.93%) and HD-1 (16.87%) which were superior over the other treatments, whereas, in untreated control the damage was 40.15%. The same strains were effective in liquid formulations which were equivalent with HD-1. Highest pod yield was recorded in HD-1, F493 and F504 treated plots. From the present studies, it is again proved that, *B.thuringiensis* based biopesticides are effective in controlling *S.litura* and solid formulations were effective compared to liquid formulations.

Keywords: Environmental samples, *Bacillus thuringiensis*, *Spodoptera litura*, Groundnut

Introduction
Biological control is an important component of integrated pest management (IPM) in which microbial biocontrol agents play a pivotal role in the control of insect pests. The use of microorganisms has assumed a prominent position among the options that seek to control insect pests without the use of chemicals and with high specific toxicity applied in agro-ecosystems. This is being strengthened with the statement of Cheng *et al.* [1] who reported that, in recent years production of chemical pesticides decreased by 2 per cent per year, whereas production of biopesticides increased at the annual rate of 20 per cent.

Over 100 bacteria have been identified as insect pathogens, among which *Bacillus thuringiensis* Berliner (*Bt*) has got maximum importance as a microbial biocontrol agent (Muhammad *et al*.) [2]. *B. thuringiensis* stands out representing approximately 95 per cent of microorganisms used in biological control of agricultural pests in different cultures, which accounts for 1.3 per cent of total pesticides (Ramanujam *et al*.) [3]. *B.thuringiensis* is a Gram-positive, rod shaped bacterium, aerobic and facultative anearobic, motile bacteria which is capable of producing insecticidal crystal proteins (ICPs) during the stationary phase of its life cycle. Along with crystal proteins, this organism also capable of producing insecticidal proteins during the vegetative stage, which were termed as vegetative insecticidal proteins (VIPs). These proteins are responsible for insecticidal activity against different insect species belongs to lepidoptera, coleoptera, diptera, hymenoptera, *etc*., *B. thuringiensis* is proved to be a successful biocontrol agent, because of its host spectrum, various forms of utility in pest management programmes such as development of transgenic crop plants with the utilization of insecticidal *cry* genes. Each and every strain is unique in its host spectrum which might be because of diversified production of insecticidal proteins either crystal or vegetaive proteins which resulted in huge collections of *B. thuringiensis* strains worldwide. This further led to identify more than 700 insecticidal crystal protein encoding *cry* genes (Crickmore *et al*.) [4]. Intensive studies are being conducted under *in vitro* and *in vivo* conditions against various insect pests to identify virulent strains.

At the same time, the strains identified as effective in laboratory studies against certain pests may not equally good when they tested under field conditions against the same pest. For maintaining more or less equal efficacy of the strains under laboratory as well in field conditions, the formulations with suitable carrier materials are equally important. Earlier researchers identified certain nutritional recipe *viz*., barley based solid media and liquid MGM broth for the multiplication and development of solid and liquid formulations of *B.thuringiensis* with low cost and easy to maintain. The present studies were conducted in search of *B.thuringiensis* strains effective against *Spodoptera litura* on groundnut crop in two different formulations for identifying effective strain at field conditions.

Materials and Methods

The studies were conducted in the Department of Entomology, Institute of Frontier Technology and experimental fields of Regional Agricultural Research Station, Tirupati, Andhra Pradesh, India during 2015-16 and 2016-17. Twenty eight native *B.thuringiensis* strains along with standard strain HD1 were developed into solid and liquid formulations for testing against *S.litura* under field conditions in groundnut.

Preparation of *B.thuringiensis* solid formulations

Twenty eight native *B. thuringiensis* strains, HD1 (positive reference) and control (negative reference) were selected for field evaluation which were effective against *S. litura* in laboratory bioassay. Barley based media was used as solid formulation for growth and multiplication of *B.thuringiensis* strains (Vimaladevi *et al*.) [5].

Preparation: Powdered Barley (5g) was taken in a 250 ml conical flask. The other ingredients (Table.1) were dissolved separately in 50 ml distilled water and this was added to barley powder and pH of the medium was adjusted to 7.2. Flasks containing media were sterilized at 15 psi for 20 minutes, cooled and inoculated with 2 per cent (v/v) of *B. thuringiensis* strains multiplied on Luria broth and incubated for 48h at 30°C on a shaker at 200 rpm. The medium in flasks was centrifuged, the pellet was dried in a laminar air flow and used for field application.

Table 1: Composition of solid media preparation of solid formulations of native *B. thuringiensis* strains

Components	Quantity
Barley	5 g
Yeast extract	63 mg
$CaCl_2$	24 mg
$MgSO_4$	60 mg
K_2HPO_4	50 mg
KH_2PO_4	50 mg
Water	50 ml

Preparation of liquid formulations

Forty milli litre MGM broth (Table.2) was taken in a 250 mL conical flask. Flasks containing media were sterilized at 15 psi pressure for 20 minutes cooled and inoculated with native *Bt* strains, along with reference strain (HD-1) and incubated for 72 hrs in shaker at 200 rpm. This medium was taken @ 1 mL L^{-1} for field application.

Table 2: Composition of MGM (Modified glucose medium) broth for preparation of liquid formulations of native *B. thuringiensis* strains (Aronson *et al*.) [6]

Ingredient	Quantity (g or mL L^{-1} of water)
Tris HCl (pH 7.6) 0.01 M	1.58
$CuSO_4$. $7H_2O$	0.05
$FeSO_4$. $7H_2O$	0.005
$ZnSO_4$. $7H_2O$	0.005
$MnSO_4$. H_2O	0.5
$MgSO_4$. $7H_2O$	2.0
$Cacl_2$. $2H_2O$	0.8
KH_2PO_4	5.0
$(NH4)_2SO_4$	20.0
Yeast extract	20.0
Glucose	10.0

Field trials were laid during post monsoon period during 2015-16 and 2016-17 for testing the efficacy of solid and liquid formulations of some of the native *B. thuringiensis* strains which were studied in lab studies and proven as effective against *S. litura*. A total of thirty plots in two replications was sown in randomized block design each separately for solid and liquid formulations. Groundnut crop was sown as per the agronomic practices formulated by ANGRAU and the plant protection was not taken till the crop received *S.litura* population above the threshold levels and defoliation crossed 25 per cent.

B. thuringiensis formulations containing spore, cells and crystal suspensions of solid and liquid formulations were prepared by following standard procedures (Vimaladevi *et al*.; Aronson *et al*.) [5, 6]. The formulations were sprayed at a dose of 1g or 1ml per litre when the defoliation in groundnut was exceeded economic threshold level (25%). The composition of spray fluid containing mixture of robin blue @ 1ml/l as UV protectant, jaggery @ 2g/l as feeding additive, *Bt* @1g/l in solid formulation and @1ml/l in liquid formulation was sprayed when *S. litura* larva appeared and foliage damage exceeded 25 per cent *i.e.* at 60 days after sowing. Triton-X @ 2mlL^{-1} was added as emulsifying agent.

No. of treatments: 30
Replications: 2 Design: RBD

T1	C33	T11	K18	T21	F287
T2	C44	T12	K83	T22	F297
T3	C59	T13	N3	T23	F468
T4	C63	T14	N30	T24	F487
T5	C79	T15	N44	T25	F493
T6	C92	T16	N48	T26	F504
T7	C97	T17	N58	T27	K10
T8	C105	T18	N93	T28	K6
T9	C134	T19	N115	T29	HD-1
T10	C212	T20	N141	T30	Control

In each plot pre-treatment data was recorded as, number of larvae/ m row, total number of leaves and damaged leaves from randomly selected five plants. Each treatment was imposed with 1 litre *B.thuringiensis* suspension at a dose of 1 ml. Post treatment counts of larvae per meter row at 3 and 7 days after spraying was recorded. Number of damaged leaves for 5 randomly selected plants was also recorded at 7 and 14 days after treatment in both solid and liquid formulations applied plots separately. The pod yield (kg/ha) and haulm yield (kg/ha) were recorded after harvesting of the crop. The data was computed and was statistically analyzed for ANOVA using SPSS.

Results and Discussion

Field Evaluation of Native strains of *B. thuringiensis* in Solid Formulations against *S. litura* in Groundnut

Larval population: Pre-count one day before treatment was ranged from 16.5 to 24.5 No./1 m row in different plots laid for evaluating solid formulations of native *Bt* strains. The population was reduced after application of *Bt* formulation and third day after treatment, the population was ranged from 7.0 to 22.5 No./ 1 m row. The mean population was low in treatments F493 (7.0 larva/m row), F504 (7.5 larva/m row), C33 (7.5 larva/m row) and HD-1 (7.5 larva/m row) which were statistically superior over the other strains as well as untreated control (22.5 larva/m row). The other treatments, C44 (8.5 larva/m row) and C97 (8.5 larva/m row) were next in the order of efficacy. The larval count was reduced in all treatments except untreated control at 7 days after spray. The lowest larval population was recorded in HD-1 (4.5 larva/m row), followed by F504 (5.0 larva/m row) and F493 (5.5 larva/m row). In untreated control, the larval population was 24.0 larva/m row.

Foliar damage: Foliar damage was recorded from different plots one day before spray, 7 and 14 days after spray. One day before spray, the foliar damage due to *S. litura* was ranged from 33.70 to 47.91 per cent. At seven days after spray, the foliar damage in groundnut was ranged from 14.93 to 40.15 per cent in different plots treated with solid formulations of *B.thuringiensis* strains. F493 was found as effective treatment with the lowest foliar damage of 14.93 per cent followed by standard check HD-1(16.87%) which were superior over the other treatments and statistically on par with each other. The other treatments, F287 (17.64%), C44 (17.74%), F487 (17.78%), F504 (17.84%), C212 (18.63%), C79 (18.77%), C33 (18.90%), K6 (18.95%) and C97 (19.00%) were also statistically on par with F493 and HD-1 strains. The other treatments (K83, K18, N115, N44, F297, N141, C63, N3, N48, C105, F468, C59, N93, C92, C134, N30, K10 and N58) were moderately effective with per cent defoliation of 19.62 to 26.67 per cent. In untreated control, the damage was 40.15 per cent.

At Fourteen days after spray, foliar damage was ranged from 14.10 to 48.63 per cent in various plots. Treatment with F493 (14.10%) and F504 (15.43%) was superior over the other treatments and on par with HD-1 (15.65%). The treatments in their order of efficacy were C33 (16.78%), C44 (17.64%), C79 (17.77%), C97 (17.46%) were also statistically on par with each other and standard check HD-1. The foliar damage was reduced in other *Bt* treated plots also at a considerable level, but there was not much variation in their efficacy levels at 14 days after treatment compared to 7 days after treatment, whereas, the foliar damage was 48.63 per cent in untreated control (Table.3).

Pod and haulm yield: The pod yield in solid formulations of *B. thuringiensis* strains was in the range of 1024.0 to 1862.5 kg /ha. The treatment with F493 (1857.5kg/ha) and F504 (1825 kg ha^{-1}) were as effective as standard check HD-1 (1862.5 kg/ ha) which were statistically on par with each other and also with other treatments C105 (1768.5 kg/ha), C79 (1747.5 kg/ha), C59 (1723.5 kg/ ha), F468 (1711.5 kg/ ha), N141 (1667.5 kg/ ha), K83 (1650.0 kg/ ha), N30 (1633.5 kg/ ha), F487 (1562.5 kg/ ha), F287 (1562.0 kg/ ha), C33 (1548.0 kg/ ha), C97 (1520.0 kg/ ha), K18 (1517.5 kg/ ha) and N93 (1500.0 kg/ ha). In untreated control, pod yield was 1024.0 kg/ ha (Table. 3). Haulm yield ranged from 1525.0 to 4270.0 kg/ ha in different plots treated with solid formulations of *B.thuringiensis*. Highest haulm yield was recorded in plot treatment with HD-1 (4270.0 kg/ ha), followed by the other treatments F504 (3975.0 kg/ ha), F493 (3925.0 kg/ ha), F468 (3922.5 kg/ ha), N44 (3882.5 kg/ ha) and C97 (3860.0 kg/ ha) (Table 3).

Field Evaluation of Native strains of *B.thuringiensis* in Liquid Formulations against *S. litura* in Groundnut

Larval population: The larval count was ranged from 16.0 to 27.0 No./1 m row in different plots one day before treatment. Third day after treatment, the larval population was ranged from 8.5 to 21.5 No./ 1m row and lowest population was recorded in standard strain HD-1 (8.5 larva/ m row), followed by F493 (9.0 larva/m row). The next best treatments in the order of efficacy were F468 (9.5 larva/m row), C33 (9.5 larva/m row), N48 (9.5 larva/m row), C59 (10.0 larva/m row), F504 (10 larva/m row). In untreated control, the larval population per meter row was 21.5 No. The larval population at 7 days after spray was ranged from 6.0 to 23.5 larvae/ m row and in plot treated with HD-1 lowest population (6.0 larvae/ m row) was recorded, followed by F493 (7.0 larvae/m row). In untreated control, larval population was 23.5 larvae/ m row (Table 4).

Foliar damage: One day before spray, the foliar damage caused by *S. litura* was ranged from 34.50 to 45.62 per cent in treatments and there was difference among treatments and untreated control in different plots in terms of foliar damage before spray. Seven days after spray, the foliar damage due to *S. litura* was ranged from 16.37 to 43.48 per cent in different plots treated with liquid formulations of *B. thuringiensis* strains. F493 (17.47%) and F504 (17.82%) recorded lowest per cent defoliation which were on par with standard check HD-1 (16.37%) followed by the other treatments, C79 (17.57%), C33 (18.42%), N30 (19.47%), C105 (19.48%), C44 (20.82%), C97 (21.00%), C134 (21.12%), C212 (19.74%), K18 (18.64%), K83 (21.18%), N48 (19.82%), F287 (19.78%), F468 (20.48%) and F487 (20.05%). In untreated control, the damage was 43.48 per cent.

14 DAS: Fourteen days after spray, foliar damage caused by *S. litura* was ranged from 14.31 to 50.83 per cent in various plots. Treatment with F493 (14.31%) was superior over the other treatments and on par with HD-1 (15.47%).The treatments in their order of efficacy were K18 (16.71%), F287 (16.85%), C79 (17.00%), C212 (17.50%), C105 (17.90%) and K83 (17.42%) were also statistically on par with each other and standard check HD-1. The foliar damage was reduced in other *Bt* treated plots also at a considerable level, but there was not much variation in their efficacy levels at 14 days after treatment compared to 7 days after treatment, whereas, the foliar damage in untreated control was 50.83 per cent.

Pod and Haulm yield: The pod yield in different liquid formulations treated plots was ranged from 995 to 1806 kg/ ha and highest pod yield of 1806 kg/ ha was recorded in HD-1, followed by F493 (1802.5 kg/ ha), F504 (1720 kg/ ha) which were superior over the other treatments. These treatments were statistically on par with C79 (1702 kg/ ha), C105 (1689.5 kg/ ha), N141 (1595.5 kg/ ha), N30 (1585.5 kg/ ha), K83 (1567.5 kg/ ha), N115 (1517.5 kg/ ha), K18 (1504.5 kg/ ha), N3 (1480 kg/ ha), K10 (1455.5 kg/ ha), C33 (1455 kg/

ha) and K6 (1452.5 kg/ ha). Haulm yield was highest in HD-1 (3975 kg/ ha), followed by N58 (3926 kg/ ha), F504 (3900 kg/ ha), F493 (3875.5 kg/ ha), C97 (3650 kg/ ha) and K10 (3650 kg/ ha), whereas, there is no statistical difference among the treatments for haulm yield sprayed with liquid formulations of *B. thuringiensis*. In untreated control, the haulm yield was 2957.5 kg/ ha (Table 4).

From the present studies it is proved that, among the two different formulations of *B. thuringiensis* tested for the field efficacy, barley based solid formulations were comparatively effective than MGM diet based liquid formulations. It can be substantiated with the findings of Guire and Shash [7] who reported prolonged persistence of 14 days and slow decrease in efficacy of *B. thuringiensis* encapsulated starch formulations against *Ostrinia nubilalis* compared to formulations without encapsulating agents. Further, Tamez-Guerra *et al*. [8] reported that, spray-dried *Btk* formulations composed of citric or lactic acid, pre-gelatinized corn flour, corn starch, isopropyl alcohol sugar and corn oil were not inferior to *Btk* technical grade against *H.zea*, *Trichoplusia ni*, *H.virescence* and *S. exigua* and resistant to solar radiation after 8h of artificial exposure.

Teera *et al*. [9] reported that, among the various adjuvants they tested, gelatinized tapioca starch and milk powder improved suspensibility but adversely affected wettability of the dried formulated product. Vegetable oil and Tween 20 enhanced wettability but resulted in poor suspensibility. Silica fume was used to enhance flowability because it reduced clumping and caking of the powder resulting from the addition of vegetable oil. Formulation containing 10 per cent *B. thuringiensis*, 10 per cent gelatinized tapioca starch, 10 per cent sucrose, 38 per cent tapioca starch, 20 per cent milk powder, 10 per cent silica fume, 2 per cent polyvinyl alcohol, 5 per cent Tween 20, 1 per cent refined rice bran oil, and 1 per cent antifoam solution was found to be optimum in terms of the physical and biological properties of the dried product. This formulation had 55 per cent suspensibility, 24 s for wetting time, and 5.69x 10^4 CFU mL^{-1} of LC_{50} value against *S. exigua* larvae. In another study, Vimaladevi *et al*. [5] reported that barley based *B. thuringiensis* formulations were cost effective. They also reported higher yield of Castor (1539 g) when *B. thuringiensis* multiplied on Barley medium compared to nutrient broth medium (89.10 g) and molasses medium (216.68 g). The cost of production was also less in Barley medium compared to others.

Jayanthi and Padmavathamma [10] also reported a higher efficacy of *B.thuringiensis* formulation (Dipel WP) @1×10^7 sporesmL^{-1}+ fenvalerate 0.05 (20.10%) against *S. litura* which also recorded higher pod yield of groundnut under glass house conditions. Further, the present findings were comparable with Patil and Hegde [11] who reported that, *Btk* and *Sl NPV* were most effective in reducing larval population of *S. litura*. Likewise, several other researchers (Malathi *et al.*; Sharma; Chatterjee 2008, Al-Otaibi) [12-15] reported that *Btk* was effective against *S. litura* larval population. Besides a good efficacy of *B. thuringiensis* and other biorational insecticides like neem against *H. armigera* in cotton the population of predatory insects *i.e.*, lady beetles, lacewings, spiders and predatory bugs were insensitive to neem seed extract and *B. thuringiensis* applications (Ma *et al*.) [16]. Ramaprasad *et al*, [17] advocated the use of Biosap (*B. thuringiensis* var. *kurstaki asporogenic*) and Biolep (*Bt* var. *kurstaki sporogenic*) against *S. litura* in tobacco nurseries. On the other hand, a moderate efficacy of *B.thuringiensis* formulation at 5×10^7 spore's mg^{-1} @ 0.2 per cent against *S. litura* was reported by Rabari *et al.* [18] In which treatments with neem oil @ 0.5 per cent (53.87%) and *B.thuringiensis* (50.50%) found to be as effective as thiodicarb in larval mortality in topical application at 72h after treatment.

Contrary to the current findings, Prabagaran *et al*. [19] reported that, chlorpyriphos was the most effective in controlling *S. litura* throughout the study period compared to *B.thuringiensis* collections from their study. However, among *Bt* strains, P*BT*-372 was superior and this strain harbouring multiple *cry* genes. Jat *et al*. [20] reported a lower efficacy of *Bt* formulation (Dipel 8L) against *S. liturai.e.* 56.09 per cent reduction in larval population.

Table 3: Efficacy of solid formulations of *B. thuringiensis* against *S. litura* in groundnut

Treatment	Strain	Larval count (No./m. row)			Per cent Defoliation			Pod yield (kg/ha)	Haulm yield (kg/ha)
		Pre-treatment	3 DAS	7 DAS	Pre-Treatment	7 DAS	14 DAS		
T1	C33	24.5	7.5 (2.79)	6.0 (2.48)	40.86	18.90 (25.76)	16.78 (24.18)	1548.0	3250.0
T2	C44	23.5	8.5(3.00)	7.5 (2.79)	33.70	17.74 (24.90)	17.64 (24.82)	1429.0	3687.5
T3	C59	22.0	9.5 (3.15)	8.0 (2.87)	39.93	23.49 (28.99)	19.98 (26.53)	1723.5	3812.5
T4	C63	19.5	11.5 (3.45)	6.5 (2.56)	41.43	22.62 (28.39)	19.42 (26.13)	1375.0	2687.5
T5	C79	18.5	12.5 (3.59)	8.5 (3.00)	35.68	18.77 (25.67)	17.77 (24.91)	1747.5	3675.0
T6	C92	20.5	11.0 (3.38)	9.5 (3.11)	39.80	24.22 (29.47)	24.40 (29.59)	1412.5	2917.5
T7	C97	22.5	8.5 (3.00)	7.5 (2.83)	46.27	19.00 (25.74)	17.46 (24.68)	1520.0	3860.0
T8	C105	17.5	11.5 (3.46)	10.0 (3.24)	41.49	23.07 (28.68)	26.69 (31.09)	1768.5	3175.0
T9	C134	18.0	11.0 (3.39)	10.5 (3.32)	42.29	24.88 (29.91)	24.05 (29.35)	1337.5	3105.5
T10	C212	19.5	13.0 (3.67)	11.5 (3.46)	37.08	18.63 (25.56)	19.60 (26.27)	1447.5	3270.0
T11	K18	20.5	12.0 (3.52)	10.0 (3.24)	36.00	19.90 (26.48)	19.74 (26.37)	1517.5	3085.0
T12	K83	19.0	13.0 (3.67)	10.5 (3.31)	40.89	19.62 (26.28)	21.70 (27.76)	1650.0	3695.0
T13	N3	16.5	13.0 (3.65)	10.0 (3.24)	38.70	22.77 (28.48)	20.77 (26.97)	1300.0	3350.0
T14	N30	17.5	10.0 (3.23)	8.5 (3.00)	46.95	25.18 (30.10)	24.78 (29.84)	1633.5	3250.0
T15	N44	18.5	12.0 (3.53)	10.5 (3.32)	35.47	20.87 (27.09)	19.58 (26.25)	1432.5	3882.5
T16	N48	23.5	10.5 (3.32)	8.5 (3.00)	38.84	22.84 (28.53)	23.08 (28.70)	1267.5	2875.0
T17	N58	22.5	10.5 (3.31)	9.0 (3.08)	45.33	26.67 (31.06)	22.75 (28.48)	1350.0	3297.5
T18	N93	20.5	12.5 (3.60)	7.0 (2.74)	40.55	23.86 (29.22)	21.29 (27.45)	1500.0	3450.0
T19	N115	19.0	12.5 (3.61)	10.5 (3.32)	34.88	20.52 (26.87)	18.13 (25.18)	1377.5	3250.0
T20	N141	18.5	13.0 (3.65)	8.5 (2.99)	37.97	22.34 (28.11)	19.82 (26.38)	1667.5	2987.5
T21	F287	19.5	13.0(3.67)	6.5 (2.64)	43.47	17.64 (24.81)	24.78 (29.82)	1562.0	3725.0

T22	F297	17.0	11.5 (3.46)	8.5 (2.99)	35.82	21.07 (27.31)	20.53 (26.92)	1400.0	2775.0
T23	F468	19.5	9.0 (3.08)	7.5 (2.83)	47.91	23.18 (28.74)	23.98 (29.32)	1711.5	3922.5
T24	F487	17.5	10.0 (3.24)	7.0 (2.74)	38.95	17.78 (24.89)	17.90 (25.03)	1562.5	3200.0
T25	F493	18.5	7.0 (2.73)	5.5 (2.45)	44.13	14.93 (22.70)	14.10(22.05)	1857.5	3925.0
T26	F504	22.5	7.5 (2.82)	5.0 (2.35)	41.51	17.84 (24.97)	15.43 (23.11)	1825.0	3975.0
T27	K10	19.5	12.0 (3.53)	8.0 (2.89)	44.85	26.38 (30.86)	25.20 (30.10)	1350.0	3161.5
T28	K6	22.5	11.0 (3.38)	9.5 (3.16)	37.15	18.95 (25.80)	20.10 (26.64)	1401.0	2910.0
T29	HD-1	19.5	7.5 (2.76)	4.5 (2.23)	42.68	16.87 (24.25)	15.65 (23.30)	1862.5	4270.0
T30	Control	18.0	22.5 (4.79)	24.0 (4.93)	39.70	40.15 (39.32)	48.63 (44.21)	1024.0	1525.0
	CD		0.6	0.45		4.2	3.7	364.2	
	CV%		8.7	4.83		7.4	6.5	11.7	
	F pr.		<0.01	<0.01		0.003	<0.001	0.01	N.S

Figures in parentheses are arcsine transformed values

Table 4: Efficacy of liquid formulations of *B. thuringiensis* against *S. litura* in groundnut

Treatment	Strain	Larval count (No./ m. row)			Pre-Treatment	Per cent Defoliation		Pod Yield (kg/ha)	Haulm yield (kg/ha)
		Pre treatment	Post treatment			7 DAS	14 DAS		
			3 DAS	7 DAS					
T1	C33	24.0	9.5 (3.16)	8.0 (2.89)	38.65	18.42 (25.39)	18.90 (25.67)	1455.0	3275.0
T2	C44	22.0	12.5 (3.57)	10.5 (3.31)	37.90	20.82 (27.10)	19.50 (26.14)	1337.5	3387.5
T3	C59	19.0	10.0 (3.23)	8.5 (2.99)	35.50	22.56 (28.27)	22.00 (27.96)	1322.5	3562.5
T4	C63	16.0	15.5 (3.91)	14.0 (3.79)	38.85	24.88 (29.90)	23.00 (28.63)	1294.5	3275.0
T5	C79	22.5	12.0 (3.52)	11.5 (3.46)	39.40	17.57 (24.75)	17.00 (24.32)	1702.0	3475.0
T6	C92	21.5	11.5 (3.37)	11.0 (3.36)	37.50	24.45 (29.61)	23.00 (28.65)	1397.0	3220.5
T7	C97	19.5	13.5 (3.71)	12.5 (3.60)	42.25	21.00 (27.01)	20.87 (27.13)	1312.5	3650.0
T8	C105	19.0	12.0 (3.52)	9.0 (3.08)	44.53	19.48 (26.09)	17.90 (25.03)	1689.5	3475.0
T9	C134	22.5	11.0 (3.21)	10.5 (3.31)	40.68	21.12 (27.29)	20.85 (27.13)	1314.8	3434.0
T10	C212	23.5	12.0 (3.49)	11.0 (3.39)	41.44	19.74 (26.29)	17.50 (24.72)	1409.8	3160.0
T11	K18	24.5	12.5 (3.44)	11.0 (3.38)	37.50	18.64 (25.46)	16.71 (24.13)	1504.5	2962.5
T12	K83	22.5	15.0 (3.93)	13.0 (3.67)	39.58	21.18 (27.40)	17.42 (24.66)	1567.5	3050.0
T13	N3	19.5	11.5 (3.40)	11.0 (3.38)	37.50	22.95 (28.59)	21.87 (27.88)	1480.0	3150.0
T14	N30	20.5	11.5 (3.45)	10.0 (3.23)	38.40	19.47 (25.99)	22.40 (28.22)	1585.5	2962.5
T15	N44	17.0	11.5 (3.46)	9.0 (3.08)	36.05	23.30 (28.86)	23.00 (28.59)	1412.5	3471.0
T16	N48	22.5	9.5 (3.16)	8.0 (2.91)	39.50	19.82 (26.43)	19.35 (26.07)	1244.0	3522.5
T17	N58	18.5	11.0 (3.38)	10.5 (3.24)	38.40	24.40 (29.56)	22.53 (28.31)	1322.5	3926.0
T18	N93	19.5	11.5 (3.46)	10.5 (3.20)	37.95	25.50 (30.33)	24.10 (29.37)	1372.5	3275.0
T19	N115	18.5	12.0 (3.52)	11.0 (3.05)	38.20	26.40 (30.90)	25.65 (30.41)	1517.5	3062.5
T20	N141	17.5	13.0 (3.67)	12.0 (3.49)	39.50	25.45 (30.29)	25.35 (30.23)	1595.5	3164.0
T21	F287	18.5	12.0 (3.43)	10.0 (3.23)	39.80	19.78 (26.39)	16.85 (24.23)	1392.0	3050.5
T22	F297	17.5	12.5 (3.57)	10.5 (3.24)	34.50	22.75 (28.48)	20.43 (26.86)	1373.5	3220.0
T23	F468	18.5	9.5 (3.16)	8.0 (2.89)	44.90	20.48 (26.89)	22.68 (28.43)	1296.0	2987.5
T24	F487	18.0	11.0 (3.39)	10.0 (3.09)	39.36	20.05 (26.60)	17.98 (25.08)	1025.2	3106.5
T25	F493	24.5	9.0 (3.08)	7.5 (2.63)	44.72	17.47 (24.70)	14.31 (22.20)	1802.5	3875.5
T26	F504	27.0	10.0 (3.24)	8.0 (2.89)	43.20	17.82 (24.97)	19.85 (26.44)	1720.0	3900.0
T27	K10	24.0	13.0 (3.67)	10.0 (3.24)	39.38	22.55 (28.35)	18.40 (25.40)	1455.5	3650.0
T28	K6	19.5	12.0 (3.53)	8.5 (2.99)	40.43	20.81 (27.07)	20.05 (26.60)	1452.5	3512.5
T29	HD-1	26.5	8.5 (3.00)	6.0 (2.54)	45.62	16.37 (23.83)	15.47 (23.14)	1806.0	3975.0
T30	Control	17.5	21.5 (4.55)	23.5 (4.87)	35.80	43.48 (41.24)	50.83 (45.47)	995.0	2957.5
l.s.d.			0.9	0.63		5.4	3.6	390.6	
CV			12.3	24.91		9.5	6.5	13.3	
F. Test			Sig	Sig.		Sig.	Sig.	Sig.	NS

Figures in parentheses are arcsine transformed values

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