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Field Evaluation of Native *Bacillus thuringiensis* Strains (solid and Liquid Formulation) Against *Spodoptera litura* (Fabricius) in Groundnut

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ABSTRACT

Twenty eight effective *B.t.* strains (4, 12, 15, 21, 25, 32, 44, 49, 58, 61, 67, 77, 83, 91,106,111,136,139,153,179, 206, 281, 317, 341, 375, 405, 416 and 422) based on preliminary bioassay tested against *S. litura* were prepared as solid and liquid formulations and sprayed in groundnut against *S. litura,* in all the *B.t* strains larval population of *S. litura* per meter row and per cent leaf damage per five randomly selected plants in Groundnut was less in solid formulation compared to liquid formulation. Groundnut pod yield (kg/ha) was more in solid formulation compared to liquid formulation. Among 28 *B.t.* strains, 375 shown minimum larval population of *S. litura* and leaf damage. Maximum pod yield of Groundnut was also highest in plots treated with *B.t.* strain 375.

Key words : *Bacillus thuringiensis, Spodoptera litura,* groundnut, solid and liquid formulation

The tobacco caterpillar, *Spodoptera litura* is a polyphagous pest on groundnut, castor, tomato etc. throughout the India, which appears usually from August and often becomes serious in October and November.

So far, as many as 90 species of insects are listed as groundnut pests. But at present, severe threat to groundnut crop is from leaf eating caterpillar, *Spodoptera litura* which developed resistance to most of the chemical insecticides. The microbial alternatives to chemical insecticides include a variety of biological agents such as Bacteria, Viruses and Fungi. Among bacteria *Bacillus thuringiensis* produces proteinaceous parasporal crystals called Insecticidal Crystal Proteins (ICPS) toxic to lepidopteran pests.

MATERIAL AND METHODS

Field trial was conducted at research farm of Regional Agricultural Reseaech Station (RARS), Tirupati in a Randomized block design with 30 plots for solid formulation in one replication and other 30 plots for liquid formulation in one replication. Two replications were maintained for each formulation. The soil type was red sandy loam. Plot size of 2 x 2.5m^2 was employed for each treatment in a replication. All agronomic practices were followed as per the recommendations. Solid and liquid formulations were prepared prior to field experiments.

Preparation of solid formulations:

Twenty eight effective native *B.t.* strains, based on preliminary bioassay, HD1 (positive reference) and control (negative reference) were selected for field evaluation against *S. litura*. Barley based media was used as solid formulation for growth and multiplication of *B.t.* isolates (Vimaladevi *et al*., 2005)

Five grams of powdered barley was taken in a 250ml conical flask. The remaining ingredients (Yeast extract 63mg, $CaCl_2$ 24mg, $MgSO_4$ 60mg, K_2HPO_4 and KH_2PO_4 50mg were dissolved separately in 50ml distilled water and this was added to already prepared barley. p^H of the medium was adjusted to 7.2. Flasks containing media were sterilized at 15 psi for 20 minutes, cooled and inoculated with 2% (v/v) of *B.t* isolates multiplied on Luria broth and incubated for 48h at 30^{0}C on a shaker at 200rpm. The medium from flasks was centrifuged the pellet was dried in a laminar air flow and used for field application.

Preparation of liquid formulations:

40ml Modified Growth Medium broth was taken in a 250ml conical flask. Flasks containing media were sterilized at 15psi pressure for 20minutes, cooled and inoculated with native *B.t* isolates, along with reference strain (HD1) and incubated for 72h in shaker at 200rpm. This medium was taken at the rate of 2ml/lit for field application. Solid (barley medium) and liquid formulations (MGM broth) were prepared with spore suspension of 3.4 $x10^5$ C.F.U/1ml for field application.

Suspension containing *B.t* was mixed with ujala at the rate of 1ml/lit as UV protectant, jaggery at the rate of 2 g/lit as feeding additive and triton-X at the rate of 2ml/lit as emulsifying agent. Solid formulation of *B.t* was sprayed at the rate of 1g/lit when *S. litura* larva appeared and foliage damage exceeds 25% *i.e* at 60 days after sowing. Treatment details were T_1-4, T_2-12, T_3-15, T_4-21, T_5-25, T_6-32, T_7- 44, T_8-49, T_9-58, T_{10}-61, T_{11}-67, T_{12}-77, T_{13}-83, T_{14}-91, T_{15}-106, T_{16}-111, T_{17}-136, T_{18}-139, T_{19}-153, T_{20}-179, T_{21}-206, T_{22}-281, T_{23}-317, T_{24}-341, T_{25}-375, T_{26}-405, T_{27}-416, T_{28}-422, T_{29}-HD1 and T_{30}-Control.

In each plot pretreatment data of *S. litura* larva in a meter row of each plot and total number leaves and damaged leaves were recorded for five plants selected at random. Each treatment was imposed with *B.t.* formulation at the rate of 1gm/lit. Post treatment counts of larval population per meter row at 3, 5 and 7 days after spraying (DAS) were recorded. Mean per cent reduction of larvae over pre treatment was determined with the following formula.

Mean per cent reduction = (Pre treatment – Post treatment count)/(Pre treatment count)x100

Number of damaged leaves and total number of leaves for 5 randomly selected plants were recorded at 7 days after spraying and pod yield was also recorded after harvest in kg per hectare. The data were subjected to statistical analysis (ANOVA). The results of the field experiment conducted with formulation of 28 *B.t.* isolates were presented here under tables. 1to 4.

RESULTS AND DISCUSSION

Data on leaf damage and larval population per meter row were recorded at 3, 5 and 7 days after spraying (DAS) and pod yield was recorded after harvest in kg per hectare.

Although sporulated cultures may be used directly in pest control, *B.t* preparations are processed further to make their physical properties suitable for field application. Such formulations are being sold as either wettable powders or granules or suspension of spores (Bernhard and Utz, 1995).

Larval population of *S. litura* per meter row was recorded at 3, 5 and 7 Days after spraying. Mean per cent reduction of larvae over pre treatment was determined with the following formula.

Mean per cent reduction = (Pre treatment – Post treatment)/(Pre treatment)x100

Solid formulation:

Larval population of *S. litura* per meter row at 3DAS was lowest (9.0) in plot treated with *B.t.* strain 341. Mean per cent reduction of larval population over pre treatment was maximum (56.83%) in HD1 reference strain, and it was followed by the *B.t.* strain 375 (51.45%). Minimum larval population of *S. litura* (7.0 larvae per meter row) per meter was observed at 5 DAS in HD1 and 375 *B.t.* strains. Mean per cent reduction of larvae over pre treatment was maximum (68.32%) in HD1 reference strain followed by *B.t.* strain 21 (57.27%). Minimum larval population (5.0) of *S. litura* per meter row was recorded at 7 DAS in plot treated with *B.t.* strains HD1, 375 and 416. Mean per cent reduction of larvae over pre treatment was highest (77.02%) in HD1 reference strain followed by *B.t.* strain 375 (74.47%). More than 50 per cent mean reduction of *S. litura* larval population was recorded in plots treated with *B.t.* strains 4, 12, 15, 21, 32, 44, 77, 83, 111, 139, 206, 281, 341, 375, 405, 416, HD1 (Table 1).

Per cent leaf damage due to *S. litura* was minimum (12.83%) in plots treated with HD1 reference strain followed by *B.t.* strain 375 (14.06%) (Table 3).

Maximum pod yield (3900kg/ha) was recorded in the plots treated with HD1 reference strain followed by *B.t.* strain 375 (3870.0kg/ha). Minimum yield (2480 kg/hectare) was recorded in control (Table 4).

Inorder to increase the persistence of *B.t*, jaggery, phenols and flavonoids have been used in tank mix (Jacobs and Sundin, 2001). Srivastava *et al*. (2009) added certain amendments like (natural oils, clay and flour), surfactant (Tween 80), dispersants (cellulose), light blockers (lignin), stickers (pregelatinized) added to enhance bioefficacy of *B.t*. against lepidopterans, coleopterans and dipterans.

Barley, *Hordium vulgare* contains on an average 63-65% starch, 8-13% protein, 2-3% fat, 1-1.5% soluble gums, 8-10% cellulose and 2-2.5% ash. Based on nutritional value of barley as well as its easy availability, the present study was undertaken to exploit the potential of barley in the multiplication of *B.t*. The study showed that barley could be successfully used as a carbon source.

Table 1. Field evaluation of native *B.t.* isolates (Solid formulation) against *Spodoptera litura* larvae in Groundnut.

Treat-ments	Iso-lates	Pre-treatment (No. of larvae/ mt row)	Post treatment					
			No. of larva/mt row			Mean % reduction		
			3 DAS	5 DAS	7 DAS	3 DAS	5 DAS	7 DAS
T_1	4	20	10.5	9	6	47.22 (43.41)	55.05 (47.90)	69.70 (56.63)
T_2	12	22	13	12.5	9.5	40.58 (39.51)	42.96 (40.93)	56.83 (48.93)
T_3	15	21	11	9.5	7	46.68 (43.06)	54.58 (47.63)	66.82 (54.83)
T_4	21	20	10	8.5	5.5	49.62 (44.78)	57.27 (49.20)	72.31 (58.30)
T_5	25	15.5	10	9	7	34.24 (35.44)	41.39 (40.01)	53.15 (46.93)
T_6	32	19.5	13	12	9.5	32.54 (34.51)	37.70 (37.72)	50.40 (45.23)
T_7	44	19.5	13	12	9.5	33.33 (35.26)	38.49 (38.35)	51.59 (45.91)
T_8	49	15	12	11.5	10	20.54 (26.51)	24.11 (28.70)	33.48 (35.34)
T_9	58	21.5	14.5	13.5	10.5	31.36 (33.76)	36.07 (36.74)	49.67 (44.80)
T_{10}	61	18.5	14.5	14	12	21.32 (27.42)	24.26 (29.51)	35.15 (36.36)
T_{11}	67	18.5	13.5	12.5	10	26.90 (31.16)	32.16 (34.29)	45.61 (42.40)
T_{12}	77	18.5	13.5	13	10.5	26.76 (31.11)	29.71 (33.03)	43.53 (41.27)
T_{13}	83	18.5	11.5	11	8.5	37.87 (37.98)	40.64 (39.59)	54.09 (47.35)
T_{14}	91	19.5	13	12	9.5	32.54 (34.51)	37.70 (37.72)	50.40 (45.23)
T_{15}	106	17	13	12.5	10.5	23.26 (28.73)	26.04 (30.46)	38.19 (38.17)
T_{16}	111	22.5	12	11	8	46.54 (43.00)	51.19 (45.68)	64.53 (53.47)
T_{17}	136	18	12.5	11.5	9	30.00 (33.14)	35.63 (36.61)	48.75 (44.26)
T_{18}	139	17.5	9.5	9	6.5	45.07 (42.13)	48.19 (43.96)	62.34 (52.20)
T_{19}	153	16	12	11.5	9.5	24.71 (29.70)	28.04 (31.97)	41.37 (39.88)
T_{20}	179	16	11.5	10.5	8.5	28.04 (31.97)	34.31 (35.86)	46.86 (43.20)
T_{21}	206	18.5	9.5	8	5.5	48.09 (43.89)	56.91 (48.98)	70.29 (56.97)
T_{22}	281	17.5	12.5	11.5	7.5	28.29 (32.10)	33.55 (35.23)	57.07 (49.07)
T_{23}	317	18	14	13.5	11.5	21.88 (27.83)	24.38 (29.43)	36.25 (37.02)
T_{24}	341	16	9.5	8.5	6.5	43.53 (41.27)	46.86 (43.20)	59.80 (50.71)
T_{25}	375	19.5	9.5	7	5	51.45 (45.84)	64.08 (53.18)	74.47 (59.74)
T_{26}	405	20	11.5	11	9	42.68 (40.79)	44.95 (42.10)	55.05 (47.90)
T_{27}	416	19	9.5	7.5	5	50.00 (45.00)	60.56 (51.09)	73.33 (59.09)
T_{28}	422	18.5	13.5	13	10.5	26.76 (31.11)	29.71 (33.03)	43.53 (41.27)
T_{29}	HD1	22	9	7	5	56.83 (48.93)	68.32 (55.77)	77.02 (61.52)
T_{30}	Control	17.5	19.5	21	22.5	-	-	-
	S.Em±	1.44	0.85	0.9	1.22	3.83	3.4	4.2
	CD (P=0.05%)	4.17	2.47	2.6	3.54	11.1	9.86	12.17

Values in parenthesis are angular transformed values.

Table 2. Field evaluation of native *B.t.* isolates (Liquid formulation) against *Spodoptera litura* larvae in Groundnut.

Treat-ments	Iso-lates	Pre-treatment (No. of larvae/ mt row)	Post treatment					
			No. of larva/mt row			Mean % reduction		
			3 DAS	5 DAS	7 DAS	3 DAS	5 DAS	7 DAS
T_1	4	18.50	10.50	9.00	7.50	43.09 (41.02)	51.03 (45.59)	59.41 (50.43)
T_2	12	16.50	10.50	9.50	8.50	36.11 (36.92)	41.67 (40.13)	48.33 (44.04)
T_3	15	19.00	11.00	9.50	8.00	41.67 (40.13)	49.72 (44.84)	58.06 (49.64)
T_4	21	16.50	8.50	7.50	6.00	48.16 (43.92)	54.41 (47.54)	63.42 (52.87)
T_5	25	16.50	11.50	10.50	9.50	30.33 (33.41)	36.21 (36.95)	42.46 (40.66)
T_6	32	20.50	14.50	14.00	12.00	29.07 (32.60)	31.34 (33.97)	41.15 (39.88)
T_7	44	16.50	11.50	11.00	9.50	30.00 (33.18)	33.33 (35.26)	41.67 (40.13)
T_8	49	17.00	15.50	15.00	13.00	9.03 (17.17)	11.81 (20.09)	22.92 (27.98)
T_9	58	17.50	13.00	12.50	11.00	24.67 (29.04)	27.80 (31.52)	37.66 (37.80)
T_{10}	61	19.00	17.00	16.50	14.00	10.64 (19.02)	13.03 (21.13)	24.93 (29.09)
T_{11}	67	16.50	13.50	13.00	11.00	18.20 (25.25)	21.14 (27.34)	33.27 (35.22)
T_{12}	77	17.50	14.50	14.00	12.00	16.28 (22.67)	18.91 (24.33)	30.43 (33.06)
T_{13}	83	15.00	10.00	9.50	8.00	33.48 (35.34)	36.61 (37.23)	45.98 (42.64)
T_{14}	91	20.00	14.50	14.00	12.00	27.19 (31.29)	29.57 (32.71)	40.10 (39.29)
T_{15}	106	15.00	13.00	12.50	11.00	12.95 (20.58)	16.52 (23.93)	26.34 (30.78)
T_{16}	111	17.50	10.50	9.00	7.50	40.00 (39.23)	48.33 (44.04)	55.83 (48.41)
T_{17}	136	14.50	11.00	10.50	8.50	23.32 (28.54)	26.44 (30.43)	40.38 (39.35)
T_{18}	139	19.00	11.50	10.00	8.50	39.44 (38.91)	47.50 (43.57)	55.28 (48.03)
T_{19}	153	15.50	13.50	13.00	11.00	13.03 (21.13)	15.97 (23.52)	28.99 (32.58)
T_{20}	179	16.50	13.00	12.50	11.00	20.56 (26.61)	23.89 (29.19)	33.33 (35.26)
T_{21}	206	19.50	10.50	9.00	7.50	45.92 (42.62)	53.82 (47.19)	61.45 (51.64)
T_{22}	281	15.00	9.50	8.50	7.50	36.16 (36.86)	42.41 (40.45)	50.00 (45.00)
T_{23}	317	21.00	18.50	18.00	15.50	11.90 (19.24)	14.29 (21.93)	26.19 (30.57)
T_{24}	341	16.00	10.00	9.00	7.50	37.65 (37.84)	44.31 (41.68)	53.14 (46.80)
T_{25}	375	18.00	9.00	8.00	6.00	49.54 (44.73)	55.42 (48.11)	66.87 (54.89)
T_{26}	405	16.00	10.50	9.50	8.50	33.92 (35.50)	39.80 (38.89)	46.86 (43.20)
T_{27}	416	20.00	10.00	9.00	7.00	48.99 (44.41)	54.55 (47.62)	64.14 (53.35)
T_{28}	422	17.00	14.00	13.50	11.50	17.71 (24.88)	20.49 (26.89)	32.64 (34.78)
T_{29}	HD1	20.00	9.00	8.00	5.50	54.89 (47.81)	60.15 (50.87)	72.31 (58.30)
T_{30}	Cont.	16.00	18.50	21.00	23.00	-	-	-
	S.Em±	1.27	0.96	0.82	0.83	4.04	3.78	3.92
	CD (P=0.05%)	3.69	2.78	2.39	2.42	11.70	10.96	11.34

Values in parenthesis are angular transformed values.

Table 3. Effect of native *B.t.* isolates against leaf damage caused by *Spodoptera litura* at 7 DAS in Groundnut

Treat-ments	Isolate	Solid formulation		Liquid formulation	
		% leaf Damage		% leaf Damage	
		(Pre treatment)	(Post treatment)	(Pre treatment)	(Post treatment)
T_1	4	42.88 (40.90)	15.45 (23.15)	49.81 (44.89)	21.88 (27.86)
T_2	12	45.63 (42.49)	21.07 (27.32)	48.92 (44.38)	25.45 (30.29)
T_3	15	40.48 (39.51)	15.57 (23.23)	49.15 (44.51)	23.03 (28.66)
T_4	21	47.35 (43.48)	15.26 (22.99)	54.13 (47.39)	21.15 (27.38)
T_5	25	49.27 (44.58)	24.22 (29.48)	39.81 (39.12)	21.91 (27.90)
T_6	32	38.32 (38.24)	19.98 (26.54)	49.32 (44.61)	28.43 (32.22)
T_7	44	37.87 (37.98)	19.21 (25.95)	45.63 (42.49)	26.18 (30.77)
T_8	49	38.55 (38.34)	25.76 (30.40)	40.61 (39.59)	28.32 (32.14)
T_9	58	39.22 (38.77)	21.30 (27.48)	49.27 (44.58)	29.97 (33.19)
T_{10}	61	40.61 (39.59)	26.92 (31.25)	40.01 (39.23)	27.71 (31.76)
T_{11}	67	36.81 (37.35)	21.99 (27.94)	37.42 (37.71)	23.36 (28.89)
T_{12}	77	36.24 (37.01)	22.54 (28.34)	57.31 (49.20)	37.13 (37.54)
T_{13}	83	39.26 (38.80)	19.19 (25.95)	41.65 (40.14)	22.70 (28.42)
T_{14}	91	42.37 (40.59)	22.64 (28.41)	39.26 (38.80)	22.84 (28.55)
T_{15}	106	41.85 (40.31)	26.67 (31.10)	36.81 (37.35)	24.09 (29.39)
T_{16}	111	48.92 (44.38)	19.54 (26.22)	47.35 (43.48)	22.74 (28.47)
T_{17}	136	57.31 (49.20)	32.57 (34.80)	37.87 (37.98)	23.05 (28.68)
T_{18}	139	45.22 (42.23)	18.77 (25.67)	49.15 (44.51)	23.91 (29.24)
T_{19}	153	36.51 (37.16)	23.15 (28.76)	41.88 (40.33)	27.28 (31.48)
T_{20}	179	41.88 (40.33)	25.60 (30.38)	38.32 (38.24)	23.49 (28.98)
T_{21}	206	49.15 (44.51)	16.95 (24.31)	50.77 (45.44)	20.82 (27.14)
T_{22}	281	39.81 (39.12)	18.07 (25.14)	37.15 (37.55)	18.88 (25.75)
T_{23}	317	40.01 (39.23)	26.10 (30.69)	40.24 (39.37)	27.50 (31.62)
T_{24}	341	41.65 (40.14)	18.63 (25.57)	37.57 (37.80)	18.98 (25.82)
T_{25}	375	49.81 (44.89)	14.06 (22.01)	46.61 (43.04)	16.78 (24.18)
T_{26}	405	49.32 (44.61)	23.59 (29.06)	45.22 (42.23)	24.37 (29.52)
T_{27}	416	49.15 (44.51)	15.02 (22.80)	44.42 (41.78)	17.62 (24.82)
T_{28}	422	36.27 (37.03)	22.42 (28.26)	37.87 (37.98)	24.18 (29.43)
T_{29}	HD1	55.22 (47.99)	12.83 (20.99)	49.39 (44.65)	16.11 (23.66)
T_{30}	Control	35.62 (36.55)	66.38 (54.58)	33.72 (35.50)	59.76 (50.63
	S.Em±	1.89	1.04	2.16	1.00
	CD (P=0.05%)	5.48	3.02	6.25	2.91

Values in parenthesis are angular transformed values.

Table 4. Effectiveness of native *B.t.* isolates on the pod yield of Groundnut.

Treatments	Isolates	Solid formulation (Kg/ha)	Liquid formulation (Kg/ha)
T_1	4	3680.0	3520.0
T_2	12	3400.0	3240.0
T_3	15	3640.0	3480.0
T_4	21	3780.0	3680.0
T_5	25	3260.0	3060.0
T_6	32	3140.0	2860.0
T_7	44	3200.0	2980.0
T_8	49	2600.0	2280.0
T_9	58	3020.0	2800.0
T_{10}	61	2660.0	2300.0
T_{11}	67	2940.0	2700.0
T_{12}	77	2840.0	2540.0
T_{13}	83	3300.0	3160.0
T_{14}	91	3080.0	2840.0
T_{15}	106	2800.0	2440.0
T_{16}	111	3600.0	3600.0
T_{17}	136	2980.0	2760.0
T_{18}	139	3500.0	3480.0
T_{19}	153	2820.0	2500.0
T_{20}	179	2960.0	2740.0
T_{21}	206	3740.0	3620.0
T_{22}	281	3440.0	3260.0
T_{23}	317	2740.0	2360.0
T_{24}	341	3440.0	3380.0
T_{25}	375	3870.0	3760.0
T_{26}	405	3320.0	3180.0
T_{27}	416	3820.0	3720.0
T_{28}	422	2880.0	2620.0
T_{29}	HD1	3900	3800.0
T_{30}	Control	2480.0	2100.0
	S.Em±	258.9	270.0
	CD (P=0.05%)	794.6	780.9
	C.V.	8.51	8.92

Since barley is low in protein content, an external nitrogen source was provided. The nitrogen source played a major role in toxin production (Vimaladevi *et al*., 2005).

According to Vimaladevi *et al*., (2005) yield of Castor was higher (1539 gm) when *B.t.* multiplied on barley medium compared to nutrient broth medium (89.10 gm) and molasses medium (216.68 gm). The cost of production was also less in barley medium compared to others.

Liquid formulation:

Minimum larval population of *S. litura* (8.50 per meter row) was recorded at 3DAS by *B.t.* strain 21. Mean per cent reduction of *S. litura* larvae over pre treatment was highest (54.89) in HD1 reference strain and it was followed by *B.t.* strain 375 (49.54%). Minimum larval population of *S. litura* (7.50) per meter row was recorded at 5 DAS in plot treated with *B.t.* strain 21 followed by *B.t.* strains HD1 and 375 (8.0). Highest mean per cent reduction

of larval population (60.15%) over pre treatment was recorded in HD1 followed by *B.t.* strain 375 (55.4%). Minimum larval population of *S. litura* (5.50) per meter row was recorded at 7DAS in HD1 followed by *B.t.* strains 21 and 375(6.0). Highest mean per cent reduction of larval population (72.31%) was recorded in HD1 reference strain followed by *B.t.* strain 375 (66.87%) (Table 2).

Per cent leaf damage due to *S. litura* in post treatment at 7 days after spray was less in plot treated with *B.t.* strain HD1 (16.11%), which was on par with the *B.t,* strains 416 (17.62%), 281(18.88%) and 341 (18.98%) (Table 3).

Maximum yield (3800kg/ha) in groundnut was recorded with HD1 reference strain followed by *B.t,* strain 375 (3760.0kg/ha) (Table 4).

Two formulations of native *B.t.* strains when sprayed in groundnut against *S. litura*, larval population per meter row was reduced more in solid formulation treated plots compared to liquid formulation. For example when the *B.t.* strain 375 was sprayed larval population per meter row in solid formulation (5.0) was less than that of liquid formulation (6.0) at 7DAS. Mean per cent reduction of larvae over pre treatment was also more in solid formulation compared to liquid formulation. For example when the *B.t.* strain 375 was sprayed mean per cent reduction over pre treatment in solid formulation (74.47%) was more than that of liquid formulation (66.87%) at 7 DAS (Table 1 and 2).

Two formulations of native *B.t.* strains when sprayed in Groundnut, per cent leaf damage due to *S. litura* was less in solid formulation compared to liquid formulation. For example when the *B.t.* strain 375 was sprayed percent leaf damage in solid formulation (14.06%) was less than that of liquid formulation (16.78%) (Table 3).

Plots treated with solid formulation of native *B.t.* strains recorded more yield in compared to liquid formulation. When the *B.t* strain 375 was sprayed yield in solid formulation (3870 kg/hectare) was more than that of liquid formulation (3760 kg/hectare) (Table 4)

Overall in all the *B.t.* strains larval population of *S. litura* per meter row and per cent leaf damage per five randomly selected plants was less in solid formulation compared to liquid formulation and hence the pod yield (kg/ha) was more in plots sprayed with solid formulation compared to liquid formulation (Table 1, 2, 3 and 4)

B.t. was highly effective against lepidopteran larvae of groundnut tested but not against homopteran insects. (Jayanthi *et al*., 1996). Dipel (0.05%) + Chlorpyriphos (0.025%) and Dimilin (0.025%) + Chlorpyriphos (0.025%) were superior and significantly reduced the larval population of *S. litura* by 71.86% and 69.25% respectively on groundnut (Obulpathi *et al*., 2000). According to Loganathan *et al*., (2002) the *B.t.* based Spicturin @ 2.0, 1.5, and 1.0 lit/ha effectively decreased the *S. litura* larvae on groundnut and it was next best to Chlorpyriphos.

B.t ($1x10^7$/ml) along with fenvalerate (0.005%) resulted in highest larval population reduction of *S. litura*, lowest leaf damage (20.15%) and highest pod yield (15.03g/plant) in groundnut (Jayanthi and Padmavathamma, 2001). Average yield was 5.52 ± 0.33 tons/fedon following the application of *B.t.* spray (750 gm/fedon) against *S. exigua* (Salama *et al*., 1999).

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