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Evaluation of Nano Based Biopesticides against *S. litura* on Groundnut

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A B S T R A C T

Field evaluation of nano based biopesticides *Bacillus thuringiensis*, *Nomura earileyi* and *Beauveria bassiana* against *S. litura* larvae resulted the highest mean per cent reduction was 77.00 per cent in *Bt* treated with CaO barley based solid formulation in three days after treatment, followed by 73.72 in CaO based *B. bassiana* talc formulations (T_{21}), 68.44 per cent in CaO based *N. rileyi* broken rice formulations (T_{15}) in seven days after treatment. Ten days after spraying the mean per cent reduction was ranged from 0.00 to 16.67 per cent. The results indicated that *Bt* grown on barley flour and with CaO nanoparticles was found as effective treatment with highest pod and haulm yield of 1993 kg ha^{-1}, 3899 kg ha^{-1} respectively, followed by 1919 kg ha^{-1}, 3828 kg ha^{-1} with *Bt* grown on barley flour with MgO nanoparticles during *rabi*, 2016. The similar trend was observed during *rabi*, 2017.

Introduction

Groundnut (*Arachis hypogea*) is one of the principal oilseed crops grown in tropical and subtropical region of the world. The tobacco caterpillar, *Spodoptera litura* (F.), has been reported as one of the major insect pest of groundnut and feed on 112 cultivated food plants all over the world (Mousa *et al.*, 1980) of which 40 are grown in India (Basu, 1981; Muthukrishnan *et al*., 2005). It passes through 5-6 overlapping generations annually (Sasidharan and Varma, 2005; Kumar and Chapman, 2006) and if not controlled timely, it may causes in huge crop losses ranging from 25.8-100 percent in various parts of India (Ahmad *et al*., 2005). The management of *S. litura* using insecticides has become difficult because of the development of resistance and effect to non-target organisms *viz*., natural enemy population as well as frequent use of these insecticides increasing problems of human health and environmental pollution. Biological control of insect pests is one of the most important component of Integrated Pest Management (IPM), wherein entomopathogens such as bacteria, viruses and fungi are exploited against insect pests.

The insecticidal bacterium *Bacillus thuringiensis (Bt*) has been employed globally for insect pest management on several crops. It has proven itself to be a valuable tool for the control of lepidopteran insects on vegetables, cotton, soybean, hardwood and coniferous forests. Entomopathogenic fungi are potential agents for pest control due to their specificity, mode of action and ease of application.

Vimaladevi *et al.*, (2005) reported that *Nomuraearileyi* (Farlow) Samsonand is one of the cosmopolitan occurrence primarily infecting Lepidoptera and particularly the economically important, polyphagous noctuid pests. *Beauveriabassiana*is the causative agent of the white muscardine disease of many insect species and has been extensively used for the control of many important pests of various crops around the world (Varma and Morales 1996). The bioefficacy of entomopathogens in relation to colony forming units (cfu) in *Bt*, number of conidia in *N. rileyi* and *B. bassiana* were chance to increase the bioefficacy with respect to the mortality of lepidopteran larvae by adding minerals. These minerals are namely calcium, magnesium, iron and zinc will enhance the cfu in *Bt*, conidial count in *N. rileyi* as well as *B.bassiana*. As a result the efficacy of entomopathogns will increase and also there is a chance to decrease the dose of biopesticides. Nanoparticles are atomic or molecular aggregates characterized by size less than 100 nm. These are actually modified form of basic elements derived by altering their atomic as well as molecular properties of elements (Suchea, *et al.*, 2006). To enhance the biopesticides efficacy in terms of increasing the number of spores in *Bt*, as well as conidial number in *N. rileyi* and *B. bassiana* the mineral salts *viz*., Calcium, magnesium, iron and zinc were added to the media before inoculation **(**Valicente *et al.*, 2010). By considering all these issues the present studies were carried out.

Materials and Methods

Preparation of nanoparticulate solutions

Oxide nanoparticles of Zn, Ca, Mg and Fe weighing 250 mg was added to 500 ml of distilled water (500 ppm) and from this solution different concentrations (100, 50, 20 and 10 ppm) of nanoparticulate solutions were prepared by adding the respective volumes of distilled water.

From the prepared nanoparticulate solutions Zn**,** Fe, Ca and Mg at 10 ppm, 20 ppm, 50 ppm, 100 ppm and 500 ppm in 1:9 ratio (1ml of nanoparticulate solution to 9ml of LBA media) was added to the Luria Bertani Agar media before sterilisation to study the catalytic activity of nanomaterials on the *Bacillus thuringiensis.* Similarly the nanoparticles of Zn, Fe, Ca & Mg at the same concentrations were added to Sabouraud Maltose Agar media (SMAY) and Sabouraud Dextrose Agar medeia (SDAY) media before sterilisation to study their activity on growth and multiplication of *N. rileyi* and *B. bassiana*.

These nano enriched biopesticides were tested against *S. litura* larvae under laboratory conditions. The concentrations of nanomaterial enriched biopesticides which were proved effective were evaluated under field conditions against *S. litura* on groundnut.

Assessment of viability of *Bt, Nomuraea* and *Beauveria* with Carriers

Preparation of solid formulations of *B. thuringiensis* with the composition of Barley flour solid media grown under nanomaterial based media

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

Media preparation

Five grams of barley flour was taken in a 250 ml conical flask. Simultaneously yeast extract, $CaCl_2$, $MgSO_4$, K_2HPO_4 and KH_2PO_4 ingredients were dissolved separately in 50ml distilled water and this was added to already prepared barley in conical flask. The p^H of the medium was adjusted to 7.2 and the flasks containing media were sterilized at 15 psi for 20 minutes, cooled and inoculated with 2% (v/v) of *Bt* multiplied on Luria broth and incubated for 48 h at 30°C on a shaker at 200 rpm. The medium from flasks was centrifuged, the pellet was dried in a laminar air flow and used for field application (Vimaladevi *et al*., 2005) (Plate 9).

Preparation of solid formulations of *N. rileyi and B. bassiana* with the composition of Broken rice and Talcused as solid media grown under nanomaterial based media

Media preparation with broken rice

One hundred grams of broken rice was washed, drained and soaked in water for 3h before starting the experiment. The excess of water was drained by decanting and shade dried for half an hour to remove the excess moisture. The substrates were packed separately in individual autoclaved at 15 psi for 50 min. After autoclaving, the substrates were cooled at room temperature and preserved in the refrigerator till further use. These substrates were inoculated individually with *Nomuraea* and *B. bassiana* (Lingappa and Patil, 2002) (Plate 10).

Media preparation with talc

SMAY broth was used for the production of *N. rileyi* spores in 100ml conical flasks. The sterilized broth was inoculated with spores of *N. rileyi* and incubated at 20± 5 °C temperature and 85% RH in constant temperature and humidity controlled chamber for 20 days. The conidial strength per ml of broth was assessed and the wettable powder was prepared mixing talc powder as a carrier material to obtain strength of 2 x 10^8 conidia per ml of spray solution (Mallikarjuna *et al*., 2010).

Field experiment

The experiment was conducted during the period of 2016-17 and 2017-18 *rabi* season to evaluate the efficacy of these nanomaterial based biopesticides under field conditions at Dry land farm, S. V. Agricultural College, Tirupati after standardization of bio-pesticides against *S. litura* through bioassay method under laboratory conditions during the year 2016 and 2017 at Department of Entomology, IFT, RARS, Tirupati.

Field preparation

The land was thoroughly ploughed thrice and levelled uniformly. Recommended doses of fertilizers i.e. nitrogen (10 kg ha^{-1}), phosphorus (40 kg ha^{-1}), potassium (16 kg ha^{-1}) were applied as basal application and gypsum (500 kg^{-1}) applied at the time of peg formation. Manual weeding was taken up at 20 and 40 days after sowing.

Seed treatment and layout

Groundnut seed was treated with mancozeb @3 g/kg seed to protect the crop from soil and seed borne diseases. The experiment was laid out in randomized block design. Individual plot size was 3 × 5 m with the spacing of 30 cm between rows and 10 cm plant to plant (Plate 12).

Spraying

The standardised nanomaterial based biopesticides against *S.litura* under laboratory conditions were prepared with different formulations and sprayed on groundnut for the management of *S.litura* at 45 to 50 days after sowing to know the efficacy under field conditions.

Data recorded on

Pre count of the *S.litura* larvae was taken before spraying.

Post count of the *S.litura* larvae was taken at 3, 7 and 10 days after spraying.

Per cent damage was recorded at 7 days and 14 days after spraying.

Harvest of the crop

The groundnut crop was harvested at 110 days after sowing by manual pulling, simultaneously stripping of the pods and dried under shade conditions.

Fresh weight, dry weight of the pod and also dry weight of the haulm was recorded as kg/plot and converted into per hectare.

Results and Discussion

Field trials were conducted during *rabi*, 2016-17 and 2017-18 for testing the efficacy of solid formulations of effective nanomaterial based *B. thuringiensis*, *N. rileyi* and *B. bassiana* against *S. litura*in groundnut. A total of twenty six treatments along with untreated control were sown in randomized block design with two replications by including all the three biopesticides. Groundnut crop was sown during *rabi* season in both years as per the agronomic practices recommended by ANGRAU.

B. thuringiensis grown in nanoparticles based media were inoculated to barley based solid formulations containing spores, cells and crystal suspensions. Similarly *N.rileyi*, *B.bassiana* grown under nanoparticles based media were also inoculated to rice and talc based solid formulations and allowed to grow. These formulations were sprayed @ 2g per litre when the defoliation was observed above economic threshold level (25%) in groundnut. The composition of spray fluid containing mixture of robin blue @ 1 ml L^{-1} as UV protectant, jaggery @ 2g/liter as feeding additive, *Bt*@ 1 g L^{-1} in solid formulation was sprayed when *S. litura* larvae was observed and foliage damage exceeded 25 per cent at 50 days after sowing. Triton-X @ 2 ml L^{-1} was added as emulsifying agent.

The observations were recorded on *S. litura* population at one day before treatment and 3 and 7 days after spraying (DAS) on 10 plants randomly selected in both the replications. The per cent foliar damage was recorded one day before spray as pre-treatment count and at 7 and 14 days after spraying as post treatment. The pod yield (kg ha^{-1}) and haulm yield (kg ha^{-1}) were recorded after harvesting of the crop.

Field efficacy of nanomaterial based biopesticides against *S. litura*on groundnut larval population

Observations were recorded on *S.litura* larvae before and after treatment of the nanomaterial based biopesticides with regular intervals during 2016. The pre-count of *S.litura* larvae was recorded one day before treatment and it was ranged from 19.50 to 25.50 no./10 plants in different plots laid for evaluating the nanomaterial based biopesticides. The results revealed that population was reduced after application of these biopesticides. The third day after treatment, the mean per cent reduction was ranged from 0.00 to 77.00 per cent. The highest per cent mean population reduction was recorded (77.00) in treatment CaO at 20ppm based *Bt* formulations (T_3) followed by 66.7 per cent with MgO at 50ppm (T_4) based *Bt* formulations, 57.9 per cent with

FeO at 50ppm (T_2) based *Bt* formulations and 47.8 per cent ZnO at 20ppm (T_1)based *Bt* formulations. Similarly in *Bt* without nanomaterial treatment (T_{21}) it was 45.96 per cent where as in control the mean per cent reduction was 0.00. The larval count was reduced in all treatments except untreated control at 3 days after spray. Lowest larval population was recorded in CaO at 20ppm (T_3) based *Bt* (5.5 larva/10 plants) and MgO at 50ppm (T_1) based *Bt*. In untreated control, the larval population was 21.5 larva/10 plants. The mean per cent reduction 7 days after spraying was ranged from 0 to 75 per cent. The highest mean per cent reduction was 75 in CaO based *B. bassiana* talc formulations (T_{19}), followed by 68.44 per cent in CaO based *N.rileyi* broken rice formulations (T_{21}). Ten days after spraying the mean per cent reduction was ranged from -12.5 to 15.8 per cent (Table 1).

Observations were recorded on the larval population of *S.litura* before treatment and after treatments of the nanomaterial based biopesticides at 3rd, 7th and 10th days after spraying during*rabi*2017. The pre-count of *S.litura* larval population was ranged from 20.5 to 26.5/10 plants in different plots laid for evaluating the nanomaterial based biopesticides. Studies revealed that the population was reduced after application of these biopesticides. The third day after treatment, the population was ranged from 0.0 to 74.44 per cent. The mean *S.itura* population was observed to be reduced to the extent of 74.44 per cent in treatments CaO based *Bt* formulations (T_3) followed by 66.60 per cent with MgO based *Bt* formulations(T_4), 58.35 per cent with FeO based *Bt* formulations (T_2) and 54.76 per cent ZnO based *Bt* formulations (T_1). Similarly in *Bt* without nanomaterial treatment (T_{21}) it was 45.96 per cent where as in control the mean per cent reduction was 0.00. The larval count was reduced in all treatments except untreated control at 7 days after spray. The lowest larval population was recorded in CaO and MgO based *Bt* (T_3 and T_4 respectively) (4.5 larva/10 plants), followed by FeO and ZnO based *Bt* (T_2 and T_1 respectively) (5.5 larva/10 plants). In untreated control, the larval population was 19.5 larva/10 plants. The mean per cent reduction of *S. litura* larva at 7 days after spraying was ranged from 0.00 to 73.72 per cent. The highest mean per cent reduction was 73.72 in CaO based *B. bassiana* talc formulations (T_{21}), followed by 68.44 per cent in CaO based *N. rileyi* broken rice formulations (T_{15}). Ten days after spraying the mean per cent reduction was ranged from 0.00 to 16.67 per cent (Table 2).

Foliar damage

The data on foliar damage due to *S.litura* was recorded from different treatments at one day before spray, 7 and 14 days after spray. The results indicated that one day before spray, the foliar damage due to *S.litura* was ranged from 29.69 to 41.36 per cent in different plots during *rabi*, 2016 and34.42 to 43.61 per cent in *rabi*, 2017 (Table 3 and 4).

At 7 DAS

At seven days after spray, the foliar damage due to *S. litura* in groundnut was ranged from 17.01 to 32.10 per cent in different plots treated with nanomaterial based *Bt*, *N.rileyi* and *B.bassiana* solid formulations. *Bt* grown on barley flour and with CaO nanoparticles was found as effective treatment (T_3) with lowest damage of 16.73 per cent defoliation followed by *Bt* grown on barley flour and with MgO nanoparticles(T_4) (17.01 %) which were superior over the other treatments and statistically on par with each other. The other treatments *viz*., *N.rileyi* with CaO nanomaterial based broken rice formulation (T_7) (17.35 %), *B.bassiana* CaO nanomaterial based talc formulation (T_{19}) (20.78 %). In untreated control, the foliar damage was 32.10 per cent in *rabi* 2016.

Similarly, during 2017 *rabi* also the above mentioned treatments were found effective in recording the lowest per cent defoliation 14.76% *Bt* grown on barley flour and with CaO nanoparticles was found as effective treatment with lowest damage of per cent defoliation followed by *Bt* grown on barley flour and with MgO nanoparticles (16.48%) which were superior over the other treatments and statistically on par with each other. The other treatments *viz*., *N.rileyi* with CaO nanopartical broken rice formulation (17.17%), *B.bassiana* with CaO nanoparticle talc formulation (17.85%).

At 14 DAS

Fourteen days after spray, foliar damage was ranged from 5.6 to 33.83 per cent in different treatments. *Bt* grown on barley flour and with CaO nanoparticles was found as effective treatment (T_3) with lowest damage of 5.6 per cent defoliation followed by *Bt* grown on barley flour and with MgO nanoparticles (T_4) (6.2%) which were superior over the other treatments and statistically on par with each other.

The other treatments *viz*., *N.rileyi* with CaO nanoparticle in broken rice formulation (T_5) (7.3%), *B.bassiana* CaO nanoparticle talc formulation (T_{19}) (7.4%) were on par with each other. 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 7 days after treatment and 14 days after treatment, whereas, the foliar damage was 33.83 per cent in untreated control during *rabi*, 2016.

During 2017, fourteen days after spray, the foliar damage due to *S.litura* was ranged from 3.96 to 38.20 per cent in different treatments. *Bt* grown on barley flour with CaO nanoparticles (T_3) was found to be effective treatment with lowest damage of 3.96 per cent defoliation followed by *Bt* grown on barley flour and with MgO nanoparticles (T_4) (4.76%) which were superior over the other treatments and statistically on par with each other. The other treatments *viz*., *N. rileyi* with CaO nanoparticle in broken rice formulation (T_7) (5.98%), *B.bassiana* CaO nanoparticle talc formulation (T_{19}) (6.91%) were on par with each other. 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 7 days after treatment and 14 days after treatment, whereas, the foliar damage was 38.20 per cent in untreated control.

Pod yield

Pod yield was recorded at the time of harvest during the year 2016 and 2017. The data on pod yield in solid formulations of *Bt* strains was in the range of 896 to 1919 kg ha^{-1}. The results indicated that *Bt* grown on barley flour and with CaO nanoparticles was found as effective treatment with highest pod yield of 1993 kg ha^{-1} followed by *Bt* grown on barley flour with MgO nanoparticles 1919 kg ha^{-1} which were superior over the other treatments and statistically on par with each other. In untreated control, pod yield was 896 kg ha^{-1} (Table 3).

During 2017, the pod yield in solid formulations of *Bt* strains was in the range of 911 to 2022 kg ha^{-1}. *Bt* grown on barley flour with CaO nanoparticles was found as effective treatment (T_3)with highest pod yield of (2022 kg ha^{-1}) followed by *Bt* grown on barley flour with MgO nanoparticles (T_4) (1933 kg ha^{-1}) which were superior over the other treatments and statistically on par with each other. In untreated control (T_{26}), pod yield was 911 kg ha^{-1} (Table 4).

Table.1 Field efficacy of different nano based biopesticides against *S. litura* in groundnut during *rabi* 2016

S. No.	Name of the Treatment	Larval count/10 plants				Mean % reduction		
		Pre treatment	**3 DAS**	**7 DAS**	**10 DAS**	**3 DAS**	**7 DAS**	**10 DAS**
1.	T1 (*Bt* grown on barley flour and with Zn nanoparticle	23.00	9.50	7.50	5.50	47.8 (43.75)	8.7 (17.15)	8.7 (17.51)
2.	T2 (*Bt* grown on barley flour and with Fe nanoparticle)	24.00	10.50	6.50	4.50	57.9 (49.54)	16.7 (24.09)	8.3 (16.78)
3.	T3 (*Bt* grown on barley flour and with Ca nanoparticle)	20.00	8.50	5.50	3.50	77.0 (61.34)	15.0 (22.79)	10.0 (18.43)
4.	T4 (*Bt* grown on barley flour and with Mg nanoparticle)	21.00	11.50	6.50	4.50	66.7 (54.74)	23.8 (29.21)	9.5 (17.98)
5.	T5 (*Nomuraea* grown on broken rice and with Zn nanoparticle)	22.00	21.50	13.50	12.50	2.3 (8.67)	36.4 (37.09)	4.5 (12.31)
6.	T6 (*Nomuraea* grown on broken rice and with Fe nanoparticle)	23.50	23.00	12.50	10.50	0.0 (0.00)	47.8 (43.75)	8.7 (17.15)
7.	T7(*Nomuraea* grown on broken rice and with Ca nanoparticle)	22.50	22.00	9.50	7.50	0.0 (0.00)	63.2 (52.65)	9.5 (17.98)
8.	T8 (*Nomuraea* grown on broken rice and with Mg nanoparticle)	25.50	25.00	11.50	8.50	0.0 (0.00)	58.3 (49.80)	12.5 (20.7)
9.	T9 (*Nomuraea* grown on talc and with Zn nanoparticle)	23.00	22.50	11.50	10.50	0.0 (0.00)	47.8 (43.75)	4.3 (12.04)
10.	T10 (*Nomuraea* grown on talc and with Fe nanoparticle)	23.00	21.50	9.50	8.50	0.0 (0.00)	53.33 (46.91)	4.8 (12.6)
11.	T11 (*Nomuraea* grown on talc and with Ca nanoparticle)	22.50	22.00	5.50	4.50	0.0 (0.00)	58.7 (50.01)	5.0 (12.92)
12.	T12 (*Nomuraea* grown on talc and with Mg nanoparticle)	19.50	19.00	8.50	6.50	0.0 (0.00)	57.5 (49.31)	10.5 (18.93)
13.	T13 (*Beauveria* grown on broken rice and with Zn nanoparticle)	22.50	22.00	13.50	10.50	0.0 (0.00)	45.0 (42.13)	15.0 (22.79)
14.	T14 (*Beauveria* grown on broken rice and with Fe nanoparticle)	23.50	21.00	11.50	9.50	0.0 (0.00)	57.1 (49.11)	9.5 (17.98)
15.	T15 (*Beauveria* grown on broken rice and with Ca nanoparticle)	23.50	23.00	8.50	5.50	0.0 (0.00)	61.9 (51.89)	13.6 (21.67)
16.	T16 (*Beauveria* grown on broken rice and with Mg nanoparticle)	20.50	20.00	9.50	7.50	0.0 (0.00)	61.1 (51.42)	11.1 (19.47)
17.	T17 (*Beauveria* grown on talc and with Zn nanoparticle)	22.50	22.00	10.50	8.50	0.0 (0.00)	45.2 (42.27)	10.0 (18.43)
18.	T18 (*Beauveria* grown on talc and with Fe nanoparticle)	20.50	20.00	9.50	6.50	0.0 (0.00)	42.9 (40.89)	15.8 (23.41)
19.	T19 (*Beauveria* grown on talc and with Ca nanoparticle)	23.00	22.00	5.50	4.50	0.0 (0.00)	75.0 (60.00)	4.5 (12.31)
20.	T20 (*Beauveria* grown on talc and with Mg nanoparticle)	21.50	21.00	8.50	6.50	0.0 (0.00)	61.9 (51.89)	9.5 (17.98)
21.	T21 (*Bt* grown on talc)	22.00	9.50	15.50	13.50	45.2 (42.27)	7.3 (15.68)	9.1 (17.55)
22.	T22 (*Nomuraea* grown on talc)	24.00	23.50	18.50	17.50	0.0 (0.00)	26.1 (30.71)	4.3 (12.04)
23.	T23 (*Nomuraea* grown on broken rice)	23.00	22.50	13.50	11.50	0.0 (0.00)	50.0 (45.00)	10.0 (18.43)
24.	T24 (*Beauveria* grown on talc)	22.50	22.00	12.50	10.50	0.0 (0.00)	45.5 (42.39)	9.1 (17.55)
25.	T25 (*Beauveria* grown on broken rice)	23.00	22.50	14.50	12.50	0.0 (0.00)	42.9 (40.89)	9.5 (17.98)
26.	T26 (control (water spray))	20.00	20.00	21.50	22.50	0.0 (0.00)	-7.5 (15.89)	-12.5 (20.00)
	F pr.	<0.05	<0.05	<0.05	<0.05			-

Figures in parentheses are arcsine transformed values

Table.2. Field efficacy of different nano based biopesticides against *S. litura* in groundnut during *rabi* 2017

S. No.	Name of the Treatment	Larval count/10 plants				Mean % reduction		
		Pre treatment	**3 DAS**	**7 DAS**	**10 DAS**	**3 DAS**	**7 DAS**	**10 DAS**
1.	T_1 (*Bt* grown on barley flour and with Zn nanoparticle)	24.50	8.00	5.50	3.50	54.76 (47.23)	31.25 (33.99)	6.66 (14.96)
2.	T_2 (*Bt* grown on barley flour and with Fe nanoparticle)	26.50	9.00	5.50	3.50	58.35 (55.15)	38.89 (38.58)	16.36 (23.86)
3.	T_3 (*Bt* grown on barley flour and with Ca nanoparticle)	21.50	7.00	4.50	2.50	74.44 (66.77)	35.71 (36.70)	14.44 (22.33)
4.	T_4 (*Bt* grown on barley flour and with Mg nanoparticle)	23.50	10.00	4.50	2.50	66.60 (54.33)	55.00 (47.87)	14.44 (22.33)
5.	T_5 (*Nomuraea* grown on broken rice and with Zn nanoparticle)	23.00	19.00	12.50	11.00	17.39 (24.65)	34.21 (35.80)	12.00 (20.27)
6.	T_6 (*Nomuraea* grown on broken rice and with Fe nanoparticle)	25.00	22.50	10.50	9.00	10.00 (18.43)	53.33 (46.91)	7.5 (15.89)
7.	T_7(*Nomuraea* grown on broken rice and with Ca nanoparticle)	24.00	21.00	8.50	6.50	12.50 (20.7)	68.44 (55.80)	13.53 (21.62)
8.	T_8 (*Nomuraea* grown on broken rice and with Mg nanoparticle)	25.00	23.50	10.50	7.00	6.00 (14.18)	55.32 (48.05)	13.33 (21.42)
9.	T_9 (*Nomuraea* grown on talc and with Zn nanoparticle)	26.00	21.00	9.50	8.50	19.23 (26.01)	43.18 (41.08)	10.53 (18.93)
10.	T_{10} (*Nomuraea* grown on talc and with Fe nanoparticle)	22.00	21.50	8.50	7.50	2.27 (8.67)	45.00 (42.13)	11.76 (20.06)
11.	T_{11} (*Nomuraea* grown on talc and with Ca nanoparticle)	22.00	21.50	5.50	3.00	2.27 (8.67)	65.12 (53.80)	14.29 (22.21)
12.	T_{12} (*Nomuraea* grown on talc and with Mg nanoparticle)	21.50	17.50	7.50	5.00	18.60 (25.55)	57.14 (49.11)	13.33 (21.41)
13.	T_{13} (*Beauveria* grown on broken rice and with Zn nanoparticle)	21.50	20.50	12.50	9.00	4.65 (12.45)	39.02 (38.66)	8.00 (16.43)
14.	T_{14} (*Beauveria* grown on broken rice and with Fe nanoparticle)	23.00	22.50	9.50	8.00	2.17 (8.48)	45.00 (42.13)	15.79 (23.41)
15.	T_{15} (*Beauveria* grown on broken rice and with Ca nanoparticle)	23.50	21.50	7.50	4.50	8.51 (16.96)	59.52 (50.49)	10.00 (18.43)
16.	T_{16} (*Beauveria* grown on broken rice and with Mg nanoparticle)	20.50	19.00	7.50	5.50	7.32 (15.69)	60.53 (51.08)	16.67 (24.10)
17.	T_{17} (*Beauveria* grown on talc and with Zn nanoparticle)	22.00	20.50	9.50	7.00	6.82 (15.14)	45.00 (42.13)	6.67 (14.91)
18.	T_{18} (*Beauveria* grown on talc and with Fe nanoparticle)	20.50	19.00	8.50	5.50	7.32 (15.69)	45.96 (42.68)	15.29 (23.02)
19.	T_{19} (*Beauveria* grown on talc and with Ca nanoparticle)	24.00	22.50	5.00	5.00	6.25 (14.48)	73.72 (58.82)	14.29 (22.21)
20.	T_{20} (*Beauveria* grown on talc and with Mg nanoparticle)	22.50	19.00	7.50	5.00	15.56 (23.23)	60.53 (51.08)	13.33 (21.41)
21.	T_{21} (*Bt* grown on talc)	23.50	8.00	13.50	11.50	45.96 (42.68)	0.0 (0.00)	14.81 (22.64)
22.	T_{22} (*Nomuraea* grown on talc)	25.50	24.50	17.50	16.50	9.80 (18.25)	23.91 (29.28)	5.71 (13.83)
23.	T_{23} (*Nomuraea* grown on broken rice)	22.00	21.00	12.50	10.50	0.0 (0.00)	43.18 (41.08)	16.00 (23.58)
24.	T_{24} (*Beauveria* grown on talc)	24.50	21.00	10.50	8.50	14.29 (22.21)	45.00 (42.13)	19.05 (25.88)
25.	T_{25} (*Beauveria* grown on broken rice)	23.00	21.00	13.50	11.00	8.70 (17.15)	35.71 (36.70)	18.52 (25.49)
26.	T_{26} (control (water spray))	21.50	21.50	22.50	22.00	0.0 (0.00)	1.0 (5.74)	0.5 (4.05)
	F	<0.05	<0.05	<0.05	<0.05			

Figures in parentheses are arcsine transformed values

Table.3. Field efficacy of different nano based biopesticides against *S.litura* in groundnut during *rabi*2016

S.No.	Name of the Treatment	% Defoliation in 2016			Pod yield (kg/ha) 2016	Haulm yield (kg/ha) 2016
		Pre treatment	**7 DAS**	**14 DAS**		
1.	T1 (*Bt* grown on barley flour and with Zn nanoparticle	38.28 (38.22)	20.91 (27.21)	8.2 (16.64)	1786	3560
2.	T2 (*Bt* grown on barley flour and with Fe nanoparticle)	39.35 (38.85)	20.18 (26.69)	7.5 (15.89)	1840	3667
3.	T3 (*Bt* grown on barley flour and with Ca nanoparticle)	36.54 (37.19)	17.01 (24.36)	5.6 (13.69)	1993	3899
4.	T4 (*Bt* grown on barley flour and with Mg nanoparticle)	33.55 (35.39)	17.35 (24.62)	6.2 (14.42)	1919	3828
5.	T5 (*Nomuraea* grown on broken rice and with Zn nanoparticle)	33.22 (35.20)	21.79 (27.83)	15.7 (23.34)	1386	2763
6.	T6 (*Nomuraea* grown on broken rice and with Fe nanoparticle)	38.27 (38.21)	26.03 (30.68)	14.6 (22.46)	1473	2935
7.	T7(*Nomuraea* grown on broken rice and with Ca nanoparticle)	33.69 (35.48)	20.78 (27.12)	7.4 (15.79)	1934	3256
8.	T8 (*Nomuraea* grown on broken rice and with Mg nanoparticle)	34.17 (35.77)	24.46 (29.64)	12.8 (20.96)	1574	3136
9.	T9 (*Nomuraea* grown on talc and with Zn nanoparticle)	36.68 (37.27)	27.53 (31.65)	16.1 (23.66)	1482	2951
10.	T10 (*Nomuraea* grown on talc and with Fe nanoparticle)	33.83 (35.56)	26.65 (31.08)	15.0 (22.79)	1580	3150
11.	T11 (*Nomuraea* grown on talc and with Ca nanoparticle)	35.12 (36.35)	21.51 (27.63)	9.1 (17.56)	1640	3670
12.	T12 (*Nomuraea* grown on talc and with Mg nanoparticle)	37.77 (37.92)	21.00 (27.27)	9.6 (18.05)	1631	3253
13.	T13 (*Beauveria* grown on broken rice and with Zn nanoparticle)	32.10 (34.51)	25.68 (30.45)	14.0 (21.97)	1485	2959
14.	T14 (*Beauveria* grown on broken rice and with Fe nanoparticle)	35.02 (36.28)	28.02 (31.96)	16.3 (23.81)	1560	3108
15.	T15 (*Beauveria* grown on broken rice and with Ca nanoparticle)	36.92 (37.52)	20.80 (27.13)	10.1(18.53)	1696	3380
16.	T16 (*Beauveria* grown on broken rice and with Mg nanoparticle)	38.61 (38.41)	20.78 (27.12)	9.1 (17.56)	1597	3181
17.	T17 (*Beauveria* grown on talc and with Zn nanoparticle)	35.63 (36.65)	24.84 (29.89)	13.1 (21.22)	1423	2836
18.	T18 (*Beauveria* grown on talc and with Fe nanoparticle)	36.11 (36.94)	22.12 (28.05)	10.7 (19.09)	1520	3030
19.	T19 (*Beauveria* grown on talc and with Ca nanoparticle)	34.87 (36.19)	16.73 (24.14)	7.3 (15.68)	1904	3373
20.	T20 (*Beauveria* grown on talc and with Mg nanoparticle)	37.39 (37.61)	21.03 (27.29)	9.3 (17.76)	1586	3161
21.	T21 (*Bt* grown on talc)	40.11 (39.29)	27.43 (31.58)	16.0 (23.58)	1303	2594
22.	T22 (*Nomuraea* grown on talc)	33.92 (35.62)	26.38 (30.90)	14.7 (22.54)	1229	2446
23.	T23 (*Nomuraea* grown on broken rice)	41.36 (40.02)	29.05 (32.61)	17.4 (24.65)	1160	2307
24.	T24 (*Beauveria* grown on talc)	37.01 (37.47)	27.14 (31.40)	15.7 (23.34)	1220	2430
25.	T25 (*Beauveria* grown on broken rice)	39.86 (39.15)	27.51 (31.63)	15.8 (23.42)	1129	2248
26.	T26 (control (water spray)	29.69 (33.02)	32.10 (34.51)	33.83 (35.56)	896	1783
	C.D.	-	4.20	7.06	20.76	21.53
	SE(m)	-	1.43	2.41	7.08	7.35
	SE(d)	-	2.03	3.41	10.2	10.39
	C.V.	-	8.28	20.12	0.66	0.67

Figures in parentheses are arcsine transformed values

Table.4. Field efficacy of different nano based biopesticides against *S.litura* in groundnut during *rabi*2017

S. No.	Name of the Treatment	% Defoliatioin			Pod yield (kg/ha)	Haulm yield (kg/ha)
		Pre treatment	**7 DAS**	**14 DAS**		
1.	T1 (*Bt* grown on barley flour and with Zn nanoparticle	38.78 (38.52)	19.31 (26.06)	8.25 (16.69)	1806	3582
2.	T2 (*Bt* grown on barley flour and with Fe nanoparticle)	41.35 (40.02)	19.51 (26.21)	7.25 (15.62)	1857	3690
3.	T3 (*Bt* grown on barley flour and with Ca nanoparticle)	38.04 (38.08)	14.76 (22.59)	3.96 (11.48)	2022	4027
4.	T4 (*Bt* grown on barley flour and with Mg nanoparticle)	40.55 (39.55)	16.65 (24.08)	4.76 (12.60)	1933	3851
5.	T5 (*Nomuraea* grown on broken rice and with Zn nanoparticle)	37.22 (37.60)	26.50 (30.98)	14.30 (22.22)	1401	2786
6.	T6 (*Nomuraea* grown on broken rice and with Fe nanoparticle)	42.27 (40.55)	25.74 (30.49)	12.68 (20.86)	1496	2958
7.	T7(*Nomuraea* grown on broken rice and with Ca nanoparticle)	37.19 (37.58)	17.17 (24.48)	5.98 (14.15)	1948	3279
8.	T8 (*Nomuraea* grown on broken rice and with Mg nanoparticle)	34.67 (36.07)	23.11 (28.73)	11.47 (19.80)	1594	3158
9.	T9 (*Nomuraea* grown on talc and with Zn nanoparticle)	38.68 (38.46)	26.38 (30.90)	14.63 (22.49)	1499	2974
10.	T10 (*Nomuraea* grown on talc and with Fe nanoparticle)	35.33 (36.47)	25.50 (30.33)	13.30 (21.39)	1595	3174
11.	T11 (*Nomuraea* grown on talc and with Ca nanoparticle)	42.12 (40.47)	19.08 (25.90)	7.68 (16.09)	1954	3693
12.	T12 (*Nomuraea* grown on talc and with Mg nanoparticle)	41.77 (40.26)	19.15 (25.95)	8.25 (16.69)	1646	3276
13.	T13 (*Beauveria* grown on broken rice and with Zn nanoparticle)	36.10 (36.93)	25.53 (30.35)	12.04 (20.30)	1508	2982
14.	T14 (*Beauveria* grown on broken rice and with Fe nanoparticle)	38.52 (38.36)	27.62 (31.70)	14.47 (22.36)	1574	3131
15.	T15 (*Beauveria* grown on broken rice and with Ca nanoparticle)	37.42 (37.71)	19.30 (26.06)	8.81 (17.27)	1716	3403
16.	T16 (*Beauveria* grown on broken rice and with Mg nanoparticle)	40.61 (39.59)	19.17 (25.96)	7.58 (15.98)	1614	3203
17.	T17 (*Beauveria* grown on talc and with Zn nanoparticle)	37.13 (37.54)	23.35 (28.90)	11.49 (1981)	1438	2860
18.	T18 (*Beauveria* grown on talc and with Fe nanoparticle)	43.11 (41.04)	21.02 (27.29)	9.32 (17.78)	1534	3053
19.	T19 (*Beauveria* grown on talc and with Ca nanoparticle)	38.87 (38.57)	17.85 (24.99)	6.91 (15.24)	1924	3384
20.	T20 (*Beauveria* grown on talc and with Mg nanoparticle)	41.39 (40.04)	20.51 (26.93)	7.38 (15.76)	1609	3185
21.	T21 (*Bt* grown on talc)	43.61 (41.33)	26.03 (30.68)	14.18 (22.12)	1317	2616
22.	T22 (*Nomuraea* grown on talc)	34.42 (35.92)	25.28 (30.18)	13.38 (21.46)	1249	2469
23.	T23 (*Nomuraea* grown on broken rice)	43.36 (41.18)	27.30 (31.50)	15.85 (23.46)	1177	2329
24.	T24 (*Beauveria* grown on talc)	38.51 (38.36)	25.71 (30.46)	14.09 (22.05)	1235	2453
25.	T25 (*Beauveria* grown on broken rice)	38.87 (38.57)	26.26 (30.83)	14.44 (22.33)	1143	2272
26.	T26 (control (water spray))	35.22 (36.40)	36.68 (37.27)	38.20 (38.17)	911	1805
	C.D.		2.90	9.21	21.53	5.35
	SE(m)		0.99	3.14	7.35	1.82
	SE(d)		1.40	4.44	10.39	2.58
	C.V.		5.96	37.91	0.67	0.08

Figures in parentheses are arcsine transformed values

Haulm yield

Groundnut haulm was shade dried and dry haulm weight was recorded during the year 2016 and 2017. The dry haulm yield was ranged from 1783.0 to 3899.0 kg ha-1 in different plots treated with nanomaterial based solid formulations of *Bt.* The highest haulm yield was recorded in *Bt* grown on barley flour and with CaO nanoparticles was found with highest pod yield of (3899 kg ha^{-1}) followed by *Bt* grown on barley flour and with MgO nanoparticles (3828 kg ha^{-1}) which were superior over the other treatments and statistically on par with each other. In untreated control, haulm yield was 1783 kg ha^{-1} during *rabi* 2016.

Similarly, haulm yield was recorded during*rabi*2017 and it was ranged from 1805 to 4027 kg ha-1 in different plots treated with nanomaterial based solid formulations of *Bt.* The highest haulm yield was recorded in *Bt* grown on barley flour and with CaO nanoparticles was found as effective treatment with highest pod yield of (4027 kg ha^{-1}) followed by *Bt* grown on barley flour and with MgO nanoparticles (3851 kg ha^{-1}) which were superior over the other treatments and statistically on par with each other. In untreated control, haulm yield was 1783 kg ha^{-1}.

Under field conditions the three tested nanomaterial based biopesticides*viz.*, *Bt* (Vimala Devi and Vineela, 2015; Vimala Devi *et al*., 2005; Lalitha and Muralikrishna 2012), *N. rieyi* (Rao *et al*., 2005; Pavone *et al*., 2009) and *B. bassiana* (Varma and Morales 1996; Patel *et al*., 2014) were found effective biopesticides against *S. litura* larvae in groundnut. The significant highest per cent mortality within 3 DAS in *Bt* treated plots in both seasons while in *N. rileyi* and *B.bassiana* treated plots the maximum mortality was observed at 7 DAS. The significant highest pod yield and haulm yield was recorded in both the seasons treated with nanomaterial enriched biopesticides when compared with biopesticides without nanoparticles as well as control. The literature pertaining to this aspect is scarce hence further studies are needed to know the increased efficacy of biopesticides whether it could be from increased number of spores by adding minerals at nano scale or due to nanoparticles directly.

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