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 (T21), 68.44 per cent in CaO based N. rileyi broken rice formulations (T15) 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.

Keywords
Biopesticides, S. litura, Groundnut, Bt, Barley

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 *Nomuraea rileyi* (Farlow) Samson and is one of the cosmopolitan occurrence primarily infecting Lepidoptera and particularly the economically important, polyphagous noctuid pests. *Beauveria bassiana* 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 entomopathogens 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     |
| CaCl₂        | 24 g     |
| MgSO₄        | 60 mg    |
| K₂HPO₄       | 50 mg    |
| KH₂PO₄       | 50 mg    |
| Water        | 50 ml    |
Media preparation

Five grams of barley flour was taken in a 250 ml conical flask. Simultaneously yeast extract, CaCl₂, MgSO₄, K₂HPO₄ and KH₂PO₄ ingredients were dissolved separately in 50ml distilled water and this was added to already prepared barley in conical flask. The pH 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 10⁸ 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 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 (T₃) followed by 66.7 per cent with MgO at 50ppm (T₄) 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 formulations 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$_{15}$). 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 and 34.42 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$_2$) (17.35 %), B. bassiana CaO nanomaterial based talc formulation (T$_{19}$) (20.78 %).
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 nanoparticle in broken rice formulation (T3) (5.98%), B. bassiana CaO nanoparticle talc formulation (T19) (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.

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 (T3) with lowest damage of 5.6 per cent defoliation followed by Bt grown on barley flour and with MgO nanoparticles (T4) (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 (T5) (7.3%), B.bassiana CaO nanoparticle talc formulation (T19) (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 (T3) 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 (T4) (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 (T2) (5.98%), B.bassiana CaO nanoparticle talc formulation (T19) (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 (T3) with highest pod yield of (2022 kg ha⁻¹) followed by Bt grown on barley flour with MgO nanoparticles (T4) (1933 kg ha⁻¹) which were superior over the other treatments and statistically on par with each other. In untreated control (T26), pod yield was 911 kg ha⁻¹ (Table 4).


| 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 (20.70) |
| 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) | 53.3 (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.     | T1 (*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.     | T2 (*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.     | T3 (*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.     | T4 (*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.     | T5 (*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.     | T6 (*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.     | T7 (*Nomuraea* grown on broken rice and with Ca nanoparticle) | 24.00 | 21.00 | 8.50 | 6.50 | 12.50 (20.7) | 68.44 (58.80) | 13.53 (21.62) |
| 8.     | T8 (*Nomuraea* grown on broken rice and with Mg nanoparticle) | 25.00 | 23.50 | 10.50 | 7.00 | 6.00 (14.18) | 55.52 (48.05) | 13.33 (21.42) |
| 9.     | T9 (*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.    | T10 (*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.    | T11 (*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.    | T12 (*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.    | T13 (*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.    | T14 (*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.    | T15 (*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.    | T16 (*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.    | T17 (*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.    | T18 (*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.    | T19 (*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.    | T20 (*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.    | T21 (*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.    | T22 (*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.    | T23 (*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.    | T24 (*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.    | T25 (*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.    | T26 (control (water spray)) | 21.50 | 21.50 | 22.50 | 22.00 | 0.0 (0.00) | 1.0 (5.74) | 0.5 (4.05) |

Figures in parentheses are arcsine transformed values
| 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
| S. No. | Name of the Treatment                                                                 | % Defoliation | 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 (19.81)       | 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. rileyi (Rao et al., 2005; Pavone et al., 2009) and B. bassiana (Varma and Morales 1996; Patet 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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