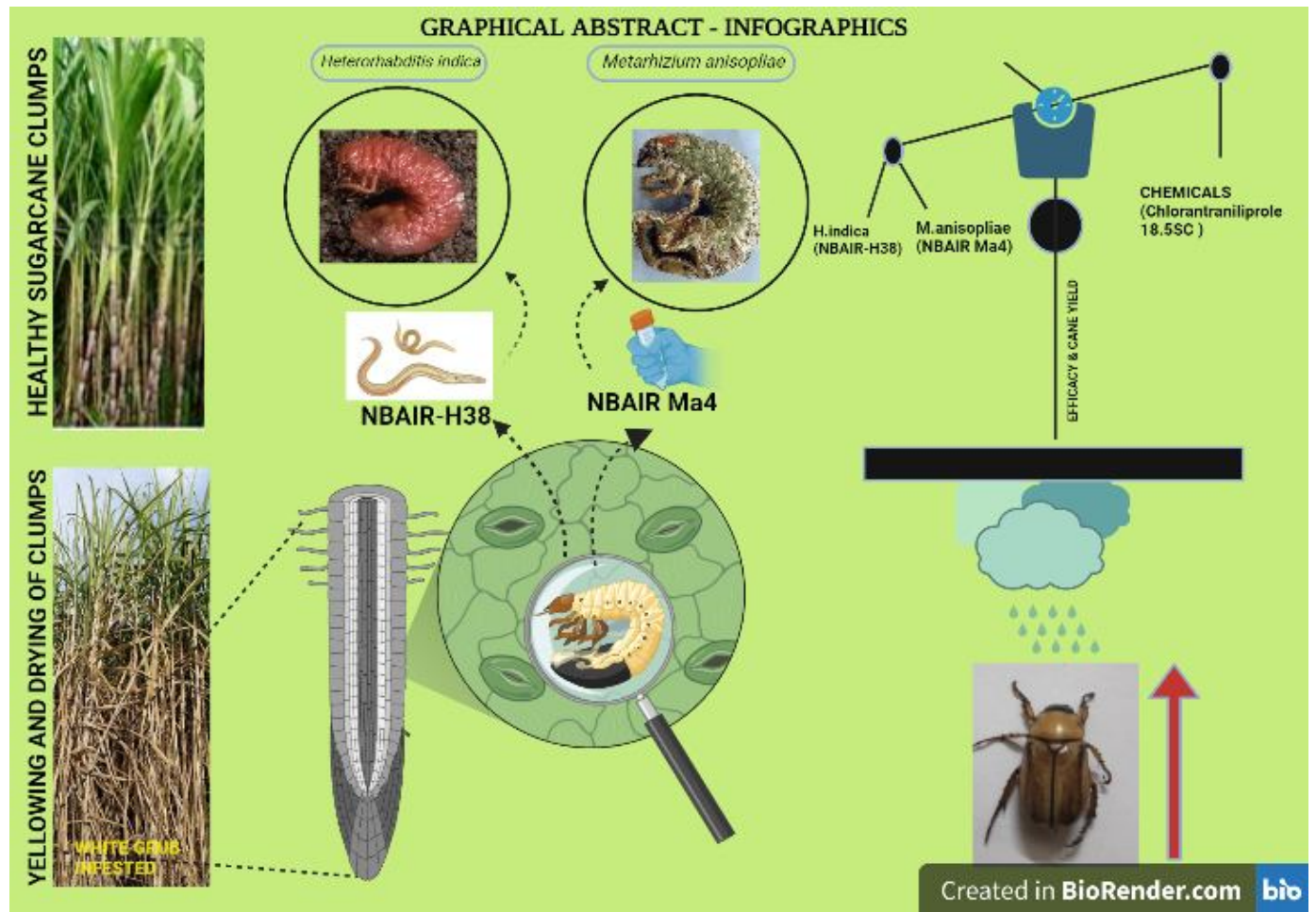


## Seasonal incidence and eco friendly management of white grub in sugarcane using entomopathogenic nematode and entomopathogenic fungus in Andhra Pradesh

### ABSTRACT

High rainfall with increase in humidity ( 68 % to 75 %) along with a decrease in temperature ( 3 to 5 °C less than normal) during June, July and August months favour the emergence of white grub beetles, its egg laying which in turn resulted in severe sugarcane clump damage by white grubs in July, August and September months. Seasonal incidence of white grub in sugarcane growing areas in Andhra Pradesh state showed that damage of sugarcane clumps caused by white grubs infestation was significantly high in march ratoon compared to February ratoon crop; January plant crop and low in January seedling plant crop. Grub damage recorded high in 4 months age sugarcane ratoon crop and low in 6 months and 7 months age sugarcane plant crop. Field efficacy of entomopathogenic nematodes and entomopathogenic fungus in the management of white grubs, *Holotrichia consanguinea* in sugarcane was investigated and promoted biocontrol in white grub endemic areas during 2017-18 to 2019-20. Entomopathogenic nematode (*Heterorhabditis indica* NBAII-H38), entomopathogenic fungi (*Metarhizium anisopliae* (NBAIR Ma4) along with a chemical Chlorantraniliprole were evaluated through soil application. The results indicated that *Heterorhabditis indica* NBAII-H38 (12 kg a.i./ha) soil application two times at monthly interval resulted in higher reduction of white grub damage. *Metarhizium anisopliae* NBAIR Ma4 (2.5 kg a.i./ha) treated plots caused higher percentage reduction of white grub than chlorantraniliprole treatment. Entomopathogenic nematode, *Heterorhabditis indica* and entomopathogenic fungus, *Metarhizium anisopliae* were found effective than the insecticidal application in the management of sugarcane white grubs. Cost benefit of biocontrol agents, *M. anisopliae* and *H. indica* was proved superior to insecticidal application.

**Keywords:**Entomopathogenic nematode,*Heterorhabditis indica*, Entomopathogenic fungus,*Metarhiziumanisopliae*, White grubs, Sugarcane



## INTRODUCTION

Sugarcane is one of India's major commercial crops. Sugarcane is primarily cultivated in several districts of Andhra Pradesh viz. Visakhapatnam, West Godavari, East Godavari, Chittoor, Krishna, Vizianagaram, Srikakulam, and Nellore districts, covering 2.40 lakh hectares and producing 136 lakh tonnes of sugarcane [1]. White grubs are the most obliterating soil pests, causing damage to a wide range of crops.

Paramount levels of root damage to India's sugarcane crop is caused by the white grub *Holotrichia consanguinea*, Blanch (coleoptera: scarabidae). Factors like continuous cultivation of sugarcane also aid in escalating white grub damage. Under severe infestation, which results in drying and dying of

sugarcane clumps as wellmature canes result in complete yield loss [2]. Due its subterranean dwelling nature, predicting the occurrence of white grubs is difficult aswell challenging. The emergence, mobility, and distribution of white grub adults are influenced by weather variables like as rainfall, temperature, humidity, and wind velocity [3]. The emergence of the adult of the Indian Holotrichia species coincides with the onset of the monsoon and is delayed until late in the season.

Apart from feeding on the neem tree foliage, the white grub adults also lay eggs in sugarcane field. The adults feed on foliage of host tree like neem. Third instar grubs feed voraciously on sugarcane roots for three to four months casing yellowing and drying. Sampling techniques for monitoring white grub populations include counting the grubs and formulating indices of population intensity based on plant damage.

Several management tactics were used to manage white grubs, including Argo Ecosystem Analysis approach along with Integrated Pest Management [4-5]. The treatment of white grub is mostly based on insecticide application, which is laborious and expensive as well as polluting the environment. Hence sorting to techniques which naturally infect white grubs includes usage of entomopathogens, such as fungi (*Beauveria and Metarhizium*), bacteria, and nematodes, which are in vogue from ages old.

Entomopathogenic nematodes are opted as an alternative management strategy to curb the White grub menace as they are eco-friendly and cost-effective biological agents[6]. Out of which *Heterorhabditis indica* was found to be encroaching inroads against white grub by Karunakar et al., [7].

keeping the above points in view a study was formulated to investigate the potency of entomopathogenic nematodes and entomopathogenicfungus against the white grub infesting endemic areas of sugarcane in Andhra Pradesh.

## MATERIALS AND METHODS

Preliminary survey was conducted in the sugarcane ecosystems of coastal AndhraPradesh with the help of sugar factory field staff during the month of July, 2017-18 to assess the damage caused by white grub. Observations were undertaken to study the extent of damage cause by white grub in

sugarcane plant crop and ratoon crop in four villages viz., Chebrolu, Rothulpudi, P.Champavaram, Boorampalem of East Godavari district, Andhra Pradesh. Observations on number of sugarcane clumps damaged by white grubs and number of grubs per 10 meter row were recorded in sugarcane fields planted or ratooned during the months of January to **march** month. The presence of grubs per ten-meter row at eight different places at random in the field of sugarcane were used for the estimation of the white grub population. The correlation between white grub population and damaged sugarcane clumps was calculated.

During 2017-18 to 2019-20, field experiments were carried out in white grub endemic areas of Navabharath ventures (Sugar division) operational area, Samalkota, East Godavari **dist.**, Andhra Pradesh, to assess the efficacy of entomopathogenic nematode and entomopathogenic fungus in sugarcane. The field trials were set up in a 5-hectare area comprising four treatments, as listed in table **3,4& 5** in a Randomized Block Design (RDB). Each treatment was replicated eight times in a 5-hectare region at random. Ratoon Sugarcane crop was planted in 2017 and was reaped in the year 2018. Likewise, in 2018 and 2019, a second year crop and third year crop was planted, and was harvested in 2019 and 2020. Treatments were applied in furrows after observing white grub incidence, i.e., after the onset of the monsoon season in July in 2017-18, 2018-19 and 2019-20. Plant damage caused by the white grub was observed and noted at monthly intervals until harvest for three rows of ten metres in each treatment. At harvest, the yield of the cane was measured.

*M. anisopliae* NBAIR-Ma4 was cultured in Sabouraud's Dextrose Yeast Extract Broth (SDYB) (Dextrose 20 g, Mycological peptone 10 g, yeast extract 5 g in 1L distilled water) and then blended with talcum powder at 2% (20 g of pellet in 1 kg talc). *M. anisopliae* NBAIR-Ma4 talc formulations containing  $1.0 \times 10^8$  were homogenized with FYM @ 2.5 kg Ma4 in 250 kg FYM. The fungus-enriched farmyard manure was employed for the tests after a 15-day incubation period. The experiment used a wettable powder formulation of the entomopathogenic nematode *Heterorhabditis indica* (NBAIL H38) procured from NBAIR, Bangalore.

After the commencement of monsoon rains, *M. anisopliae* enhanced FYM was applied to the soil in sugarcane furrows at a rate of 250 kg/ha. Every year, the first application in **july**, and the second in the month of **august** were administered. *H. indica*, an entomopathogenic nematode, was applied twice in July and September at a rate of 12 kg ha<sup>-1</sup> in 150 kg damp sand ha<sup>-1</sup>. In July and August,

a chemical insecticide, Chlorantraniliprole 18.5SC @ 300 ml a.i ha<sup>-1</sup>, was applied to the soil twice at one-month intervals, with an untreated control plot kept for comparison.

At monthly intervals until harvest, observations on the number of plants injured and the frequency of white grubs per 10 metre rows were made. The recorded cane yield was statistically examined to derive inferences, and a cost-benefit ratio was computed.

Percentage reduction of the grubs =  $\frac{\text{Number of white grubs in control} - \text{Number of white grubs in treatment}}{\text{Number of white grubs in control}} \times 100$  [8].

The effect on soil-dwelling organisms was measured in a cubic metre area by extracting the soil, 30 days before and after the treatments. Natural enemies such as spiders, coccinellids, and chrysalids per plant were observed before and after in each treatment. The cost benefit ratio of the treatments has been calculated based on the formula given below.

BC Ratio = NR/CC; NR- Net Returns; CC- Cost of Cultivation

Data on percent mortality were calculated by Abbott's formula [9.]. Data on number of grubs were subjected to arcsine transformations and subjected to analysis of variance.

## RESULTS AND DISCUSSION

### Survey on sugarcane crop damage due to white grub and correlation with weather parameters

Survey on sugarcane crop damage due to white grub and correlation with weather parameters during 2017 was presented in Table 1 and Table 2.

Surveys on sugarcane crop drying in the East Godavari district of Andhra Pradesh from the onset of the monsoon rains in June and July of 2017-18 revealed that the white grub species *Holotrichia consanguinea* was responsible for sugarcane clump mortality.

Incidence was found in sugarcane fields that were planted or ratooned in the months of January to March 2017. Damage of white grubs was seen, and grubs were sampled by digging soil quadrats. The highest and most severe damage was detected in localized patches along field bunds and in the center of the field (Fig.1). Grubs devour sugarcane roots, reducing the amount of water and nutrients available to the plant. For any layman it's a chaotic task to distinguish and comprehend the basic difference amongst white

grub damage symptom with the symptom of drought as visually both appear identical with initial yellowing and wilting of leaves resulting in drying and deterioration of mature stalks.

Amongst four locations, observations recorded during second fortnight of July month, 2017 showed that sugarcane damage by white grubs was highest at Chebrolu village (Table 1). Sugarcane clumps due to white grubs recorded significantly higher damage in **march** ratoon crop ( 39.46%) as compared to February ratoon crop (13.61%) ; January plant crop (10.88% ) and lowest in January seedlings (0.83%) in Chebrolu. Sugarcane clumps mutilation was significantly high in **march** ratoon crop (29.97%) in Rothulpudi village compared to February (14.1%) and January ratoon crops (4.25%).Whereas in P.Chamavaram and Boorampalem, damage was significantly high in **march**ratoon crop and on par with and February ratoon crop. Data on clump damage and age of the crop corroborated that grub damage was highest in **march** ratoon crop (4 months age) ;on the other hand, it was noticed lowest in January ratoon/plant crop ( 6 months age) and January seedling plant crop (7 month age ).

Studies revealed that sugarcane clump damage and grubs count in chebrolu village, East Godavari district, Andhra Pradesh during 2017 indicates that increase in humidity (68% to75%) along with a decrease in temperature(3 to 5°C) during June,Julyand **august** months favour the emergence of beetles , its egg laying which in turn resulted in severe clump damage by white grubs in July, **Augustand** September months i.e., 12.15 %, 14.33% and 19.2 % respectively (Table 2). Rainfall (12.36mm) and low relative humidity (<70 %) triggers adult emergence in Mayand increase in relative humidity( 71% &-72 %) with high amounts of rain received during June(169.76 mm), July( 227.3 mm) and August ( 112.25 mm) also instigated the emergence of beetles resulted in severe clump vandalizationin the months **ofJulyto** September months (12.15% to 19.2 %).

The advent of beetle populationcommencesprimarily afterthe receipt of summer showers with a minimum level rainfall of 11mm sufficient for the adult emergence during the last week of May.As the name June beetles itself suggests the peak period of the beetle emergence in the second fortnight of June which is synonymous to the name of white grub and which continues till the fortnight of August [10].

The pre monsoon increase in atmospheric moisture is a characteristic of the monsoon arrival in India and is useful for forecasting and managing adult beetles [11,12,13]. Another instance of significant upsurge in grub population was correlated with increased relative humidity in case of teak[14].

### **Field efficacy studies**

Field efficacy of entomopathogenic nematode and entomofungus against white grub are presented in Table- 3(2017-18) , Table-4 (2018-19) and Table-5 (2019-20)

During the first-year field trial (2017-18), the per cent sugarcane clumps damaged by white grubs was lowest (7.44 %) in *H. indica* (NBAlI H38) WP @ 12kg ha<sup>-1</sup> (twice application) and superior to chlorantraniliprole 18.5 SC treatment @ 300 ml ha<sup>-1</sup> ( 10.01 %) and *M. anisopliae* (NBAlR Ma4) 2.0% W.P. Formulation @ 2.5kg ha<sup>-1</sup> (twice application) treated plots (11.92 %) (Table 3). White grub population was significantly low ( 1.75 grubs/ 10 m row) in chlorantraniliprole 18.5 SC treatment compared to other treatments and untreated control recorded significantly high grub population of grubs/10m row ( 12.0 grubs/ 10 m row).

The second and third year field trials showed the lowest per cent plant damage by white grubs was observed by the usage of *H. indica* (NBAlI H38) WP @ 12 kg ha<sup>-1</sup> (1.13% and 1.11 %) which was statistically at par with *M. anisopliae* (NBAlR Ma4) @ 2.5kg ha<sup>-1</sup> (1.27% and 1.31%) and untreated control recorded highest plant damage (6.0 % and 3.01%) during 2018-19 and 2019-20 (Table 4 and 5).

Mean number of grubs are high in untreated control and low in *H. indica* ( 3.22 and 3.01 grubs/10m row) and was on par with *M. anisopliae* ( 3.4 and 3.61 grubs/10m row) and chlorantraniliprole 18.5 SC treatment ( 4.18 and 4.33 grubs/10m row) in second and third year trials.

Studies on field efficacy of *M. anisopliae* against white grub, *Leucopholis lepidophora* in sugarcane showed that *M. anisopliae* followed by entomopathogenic nematode application was studied in Maharashtra with minimal clump mortality [15].

Manisegaran *et al.* [16] reported that application of *M. anisopliae* at the rate of 4 x 10<sup>9</sup> conidia ha<sup>-1</sup> was effective against sugarcane white grub *Holotrichia serrata* (Blanch) with 92% reduction of grub population. Samson *et al.* [147] studied that soil application of *M. anisopliae* @ 3.3 x 10<sup>13</sup> conidia ha<sup>-1</sup> against gray black cane grub, *Dermolepida albobirtu* resulted in 50-60 per cent reduction in grub infesting sugarcane in Australia. *M. anisopliae* and *B. bassiana* @ 5x 10<sup>8</sup> conidia ha<sup>-1</sup> in combination with chlorpyrifos were applied @ 2lit. ha<sup>-1</sup> which was found effective in reducing grub population [18].

In the first-year trial (2017-18), cane yield was significantly high ( 52.75 t/ha) with the usage of *H. indica* (NBAlI H38) and was statistically at par with Chlorantraniliprole 18.5SC treatment (49.67 t/ha) as well *M. anisopliae* (NBAlR-Ma4) 2.0% W.P. formulation @ 2.5kg ha<sup>-1</sup> treatment (48.89 t/ha). Untreated control recorded significantly very low cane yield of 13.65t/ha .

In the second and third year trials, the cane yield was significantly higher in *H. indica* (NBAlI H38) treatment (65.44t/ha and 67.31 t/ha) which was statistically at par with Chlorantraniliprole soil application (64.26t/ha and 60.01 t/ha) and *M. anisopliae* (NBAlR-Ma4) (62.4t/ha and 63.21 t/ha) during 2018-19 and 2019-20. Untreated control recorded significantly low cane yields of 22.98t/ha and 59.10t /ha (2018-19 and 2019-20).

The soil application of *M. anisopliae* @  $2 \times 10^{12}$  conidia ha<sup>-1</sup> was effective in the reduction of white grubs and higher yields [19].

The cost benefit ratio was found highest in *H. indica* (NBAlI H38) in three years study (1.05, 1.46 and 1.49) which was followed by *M. anisopliae* (NBAlR Ma4) 2.0% W.P. formulation treatment (1.03, 1.41 and 1.39) and Chlorantraniliprole treatment showed C:B ratio of 1.01 (2017-18), 1.34 (2018-19) and 1.31 (2019-20) (Table 3,4 & 5).

Percentage reduction in plant damage and grub population over control recorded high in *H. indica* (79.2% and 82.29%), *M. anisopliae* (67.74% and 76.04%) and Chlorantraniliprole 18.5SC (72.91% and 85.42%) during 2017-18. Similarly, Percentage reduction in plant damage and grub population over untreated control recorded high in *H. indica* (81.17% and 79.2%), *M. anisopliae* (78.83% and 78.04%) and Chlorantraniliprole 18.5SC (54.17% and 72.99%) during 2018-19.

Likewise, similar trend was observed in 2019-2020 with Percentage reduction in plant damage and grub population over control recorded high in *H. indica* (79.18%), *M. anisopliae* (77.91%) and Chlorantraniliprole 18.5SC (52.01%) during 2019-20. Entomopathogenic nematode, *H. indica* and entomofungus, *M. anisopliae* proved effective in reducing white grub damage compared to insecticide, chlorantraniliprole 18.5SC treatment in all the consecutive years.

## CONCLUSION

An estimation of damage is particularly useful in the early vegetative stage of crop growth, for adopting management practices in current season and also in subsequent growing seasons. It can be epilogued that as an alternative to insecticide chlorantraniliprole sorting to management practices using biocontrol agents such as Entomopathogenic nematode, *Heterorhabditis indica* as well entomofungus, *Metarhizium anisopliae* are not only environmentally friendly but also yields significant results in curbing the pest menace but also for the control of white grub, *Holotrichia consanguinea* in higher cane yield compared to insecticide treatment viz., Chlorantraniliprole 18.5SC soil application. Based on cost-benefit ratio, the treatment with *M. anisopliae*, (ICAR-NBAIR Ma-4) and *Holotrichia consanguinea* (NBAIL H38) were found superior to Chlorantraniliprole 18.5SC insecticidal application in the management of sugarcane white grubs in coastal Andhra Pradesh. Utilization of entomopathogenic nematodes and entomofungus for the management of white grubs is useful for the benefit of farming community.

The higher fecundity rate of insects has compelled the farmers to sort for usage of chemical insecticides from ages old which over a period of time have led to devastating effects not only on the soil inhabiting fauna but also creating a considerable negative impact on non-target organisms as well creating further repercussions viz., environmental pollution and development of resistance in the insects (with) resulting in biotypes. Further, excessive dumping of pesticides at the nick of the moment in haste might end up in residue problems not only on the foliage but also on the soil inhabiting micro fauna. Hence this study involves in usage of native isolates of entomopathogenic nematodes (*Heterorhabditis indica* NBAIL-H38), as well entomopathogenic fungus (*Metarhizium anisopliae* NBAIR Ma4 strain) extracted and tested for the efficient control of White grub menace. These are proved to be effective and a par with insecticidal application (Chlorantraniliprole) preventing the triggering of above mentioned consequences as a resource efficient and economical alternative.

## REFERENCES

1. Kumar IN and Suneetha K. 2016. Profitability analysis and problems of sugarcane in Andhra Pradesh. *International Journal of Applied Research* 2(8): 77-80.

2. Selvi TC, Rhichard TW and Kandasamy R. 2010. Laboratory culture & virulence of *Beauveria brangniartii* isolates on sugarcane white grub, *Holotrichia serrata* F. *Journal of Biopesticides* **3**(1): 177–179
3. Mishra, P.N. and Singh, M.P., 1999. Determination of predominant species of white grub in Garhwal region of Uttar Pradesh hills (India). *Journal of Entomological Research*, **23**(1), pp.65-69.
4. Sahayaray K and Borgio JF. 2009. Distribution of *Metarhizium anisopliae* (Metsch.) Sorokin (Deuteromycotina: Hyphomycetes) in Tamil Nadu, India, Its biocontrol potential on *Dysdercus cingulatus* (Fab.)(Hemiptera :Pyrrhocoridae). *Archives of Phytopathology and Plant Protection*. **42**(5): 424–435.
5. Srikanth J and Singaravelu B. 2011. White grub (*Holotrichia serrata*) as pest of sugarcane and its management. Technical Bulletin No 197 pp.1-8. Sugarcane Breeding Institute, Coimbatore.
6. Ali, J.G., Alborn, H.T. & Stelinski, L.L. Subterranean Herbivore-induced Volatiles Released by Citrus Roots upon Feeding by *Diaprepes abbreviatus* Recruit Entomopathogenic Nematodes. *J Chem Ecol* **36**, 361–368 (2010). <https://doi.org/10.1007/s10886-010-9773-7>
7. Karunakar, G., Easwaramoorthy, S. & David, H. Host — parasite interaction between two species of white grubs infesting sugarcane and two species of entomopathogenic nematodes. *Sugar Tech* **2**, 12–16 (2000). <https://doi.org/10.1007/BF02995579>
8. W. Guo, X. Yan, G. Zhao, R. Han, Efficacy of Entomopathogenic *Steinernema* and *Heterorhabditis* Nematodes Against White Grubs (Coleoptera: Scarabaeidae) in Peanut Fields, *Journal of Economic Entomology*, Volume 106, Issue 3, 1 June 2013, Pages 1112–1117, <https://doi.org/10.1603/EC12477>
9. Abbott, 1925. A method of computing the effectiveness of an insecticide Author(s): Abbott, WS Source: *Journal of Economic Entomology* Volume: 18 Pages: 265-267 .
10. Mittal, I.C., 2000. Survey of scarabaeid (Coleoptera) fauna of Himachal Pradesh (India). *Journal of Entomological Research*, **24**(3), pp.259-269.
11. Yadava, C.P.S., Sharma, G.K., 1995. Indian white grubs and their management. All India Coordinated Research Project on White grubs, Technical Bulletin No. 2. Indian Council of Agricultural Research.
12. Raju, P.V.S., Mohanty, U.C. and Bhatla, R., 2005. Onset characteristics of the southwest monsoon over India. *International Journal of Climatology: A Journal of the Royal Meteorological Society*, **25**(2), pp.167-182.

- 13.V. Anitha, John Wightman & D. John Rogers (2005) Management of white grubs (Coleoptera: Scarabaeidae) on groundnut in southern India, *International Journal of Pest Management*, 51:4, 313-320, DOI: [10.1080/09670870500399924](https://doi.org/10.1080/09670870500399924)
- 14.Garg, V.K., Kulkarni, N. and Meshram, P.B., 2005. Influence of weather parameters on the incidence of white grub, *Holotrichia serrata* Fabr. on teak seedlings in Chhindwara Forest Divisions. *Indian Journal of Tropical Biodiversity*, 13, pp.48-51
15. Kumbhar, R.A., Mohite, P.B. and Baral, S.B., 2019. Bioefficacy of various formulations of biopesticides against white grub, *Leucopholis lepidophora* infesting sugarcane under field condition. *J Entomol Zoo Stud*, 7, pp.1041-1044.
- 16.Manisegaran S, Lakshmi SM and Srimohanapriya V. 2011. Field evaluation of *Metarhizium anisopliae* (Metschnikoff) Sorokin against *Holotrichia serrata* (Blanch) in sugarcane. *Journal of Biopesticides* 4 (2): 190–193.
- 17.Manisegaran S, Lakshmi SM and Srimohanapriya V. 2011. Field evaluation of *Metarhizium anisopliae* (Metschnikoff) Sorokin against *Holotrichia serrata* (Blanch) in sugarcane. *Journal of Biopesticides* 4 (2): 190–193.
18. Bhagat, R.M., Gupta, R.B.L. and Yadava, C.P.S., 2003. Field efficacy of two entomopathogenic fungal formulations against whitegrubs in Himachal Pradesh. *Indian Journal of Entomology (India)*.
- 19.Kulye MS and Pokharkar DS. 2009. Evaluation of two species of entomopathogenic fungi against white grub, *Holotrichia consanguinea* (Blanchard) infesting potato in Maharashtra, India. *Journal of Biological Control* 23 (1): 1–4.

Table 1. Survey on sugarcane crop damage due to white grub in East Godavari district, Andhra Pradesh during 2017-18

Plant Crop / Ratoon crop	Sugarcane clumps damage due to white grubs (%)				Number of white grubs / 10m row			
	Chebrolu*	Rothuloudi	P.Chamavaram	Boorampalem*	Chebrolu*	Rothuloudi	P.Chamavaram	Boorampalem*
January plant crop	10.88 <sup>bc</sup> ( 19.14)	4.95 <sup>c</sup> (0.594)	1.296 <sup>d</sup> ( 0.086)	2.634 <sup>b</sup> ( 0.556)	10.78 <sup>bc</sup> ( 19.08)	4.75 <sup>c</sup>	2.875 <sup>c</sup>	4.375 <sup>bc</sup> ( 12.0)
January seedling plant crop	0.83 <sup>d</sup> ( 3.16)	6.109 <sup>c</sup> ( 0.751)	6.354 <sup>b</sup> (0.758)	3.596 <sup>b</sup> ( 0.546)	1.38 <sup>d</sup> ( 4.07)	7.125 <sup>c</sup>	7.5 <sup>c</sup>	4.625 <sup>c</sup> ( 11.15)
January ratoon crop	5.84 <sup>c</sup> ( 13.83)	4.25 <sup>c</sup> (0.615)	3.706 <sup>c</sup> ( 0.554)	4.58 <sup>b</sup> ( 0.729)	7.25 <sup>c</sup> ( 15.51)	5.875 <sup>c</sup>	6.0 <sup>c</sup>	7.5 <sup>b</sup> ( 15.72)
February ratoon crop	13.61 <sup>b</sup> ( 21.19)	14.1 <sup>b</sup> ( 1.103)	17.759 <sup>a</sup> ( 1.234)	20.28 <sup>a</sup> ( 1.291)	12.88 <sup>b</sup> ( 20.77)	15.875 <sup>b</sup>	18.125 <sup>b</sup>	19.375 <sup>a</sup> ( 25.88)
March ratoon crop	39.46 <sup>a</sup> ( 19.14)	29.97 <sup>a</sup> ( 1.469)	26.41 <sup>a</sup> ( 1.386)	26.124 <sup>a</sup> ( 1.399)	24.5 <sup>a</sup> ( 29.36)	30.0 <sup>a</sup>	24.5 <sup>a</sup>	22.5 <sup>a</sup> (28.03)
CD (0.05)	6.60	0.172	0.155	0.214	4.51	5.29	5.47	4.67
CV%	33.65	18.57	18.82	23.1	24.79	40.56	45.27	39.05

Values in parenthesis are logarithmic transformed values

\*Values in parenthesis are arc sign transformed values

Plant Crop / Ratoon crop	Sugarcane clumps damage due to white grubs (%)				Number of white grubs / 10m row			
	Chebrolu*	Rothuloudi	P.Chamavaram	Boorampalem*	Chebrolu*	Rothuloudi	P.Chamavaram	Boorampalem*
January plant crop	10.88 <sup>bc</sup> ( 19.14)	4.95 <sup>c</sup> (0.594)	1.296 <sup>d</sup> ( 0.086)	2.634 <sup>b</sup> ( 0.556)	10.78 <sup>bc</sup> ( 19.08)	4.75 <sup>c</sup>	2.875 <sup>c</sup>	4.375 <sup>bc</sup> ( 12.0)
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January ratoon crop	5.84 <sup>c</sup> ( 13.83)	4.25 <sup>c</sup> (0.615)	3.706 <sup>c</sup> ( 0.554)	4.58 <sup>b</sup> ( 0.729)	7.25 <sup>c</sup> ( 15.51)	5.875 <sup>c</sup>	6.0 <sup>c</sup>	7.5 <sup>b</sup> ( 15.72)
February ratoon crop	13.61 <sup>b</sup> ( 21.19)	14.1 <sup>b</sup> ( 1.103)	17.759 <sup>a</sup> ( 1.234)	20.28 <sup>a</sup> ( 1.291)	12.88 <sup>b</sup> ( 20.77)	15.875 <sup>b</sup>	18.125 <sup>b</sup>	19.375 <sup>a</sup> ( 25.88)

March ratoon crop	39.46 <sup>a</sup> ( 19.14)	29.97 <sup>a</sup> ( 1.469)	26.41 <sup>a</sup> ( 1.386)	26.124 <sup>a</sup> ( 1.399)	24.5 <sup>a</sup> ( 29.36)	30.0 <sup>a</sup>	24.5 <sup>a</sup>	22.5 <sup>a</sup> (28.03)
CD (0.05)	6.60	0.172	0.155	0.214	4.51	5.29	5.47	4.67
CV%	33.65	18.57	18.82	23.1	24.79	40.56	45.27	39.05

Table 2: Sugarcane white grub incidence and weather in Chebrolu, East Godavari district, Andhra Pradesh during 2017-18

Observation period Monthly	Sugarcane clumps damage due to white grubs (%)	Number of white grubs / 10m row	Rainfall (mm)	Rainy days	Temp <sup>o</sup> C Max	Temp <sup>o</sup> C Min	RH %	Sunshine hours	Sunny days
April	0.0	0.0	7.92	5	36	27	72	361.5	17
May	0.0	0.0	12.36	6	37	29	68	381.5	17
June	0.0	0.0	169.76	26	34	28	71	282.5	2
July	12.15	9.96	227.3	24	33	28	72	253.0	6
August	14.33	12.47	112.25	24	32	27	75	301.5	5
September	19.2	15.18	149.4	24	32	27	78	313.0	4
October	26.14	20.65	106.39	7	31	28	75	287.0	13
November	29.06	23.0	34.28	13	29	26	71	208.5	15
December	36.95	26.22	1.94	1	28	24	67	228.5	27

\* Temp: Temperature; RH : Relative humidity; FN: Forenoon; AN: Afternoon; stdw: standard week

Table 3. Efficacy of entomopathogenic nematodes and entomofungus for the management of white grub in sugarcane during 2017-18

Treatment	Sugarcane clumps damage due to white grubs (%)*	Percentage reduction in white grub damage over control	Number of white grubs / 10m row	Reduction in grub population over control (%)	Cane Yield t/ha	Yield increase over control (%)	Cost Benefit ratio
T1: <i>Heterorhabditis indica</i> WP NBAII H38 @12 kg/ha in 150 kg sand per ha	7.44	79.86	2.125	82.29	52.75	74.12	1.05
T2: <i>Metarhizium anisopliae</i> NBAIR Ma 4 @ 5 kg/ ha in 250 kg FYM per ha	11.92	67.74	2.875	76.04	48.89	72.08	1.03
T3: Chlorantraniliprole 18.5SC @ 0.3 ml / lit	10.01	72.91	1.75	85.42	49.67	72.52	1.01
T4 : Untreated control	36.95		12.0		13.65		
CD (0.05)	1.05		0.255		5.20		
CV%	26.05		18.05		12.05		

DAT : days after treatment ; MAT : months after treatment

	2017-18				2018-19				2019-20			
	Reduction in white grub damage over control (%)	Reduction in grub population over control (%)	Yield increase over control (%)	Cost Benefit ratio	Reduction in white grub damage over control (%)	Reduction in grub population over control (%)	Yield increase over control (%)	Cost Benefit ratio	Reduction in white grub damage over control (%)	Reduction in grub population over control (%)	Yield increase over control (%)	Cost Benefit ratio
NBAII H38	79.86	82.29	74.12	1.05	81.17	79.20	65.44	1.46	79.18	76.34	67.31	1.49
NBAIR Ma 4	67.74	76.04	72.08	1.03	78.83	78.04	64.26	1.41	77.91	73.45	63.21	1.39
Chlorantraniliprole	72.91	85.42	72.52	1.01	54.17	72.99	62.40	1.34	52.01	71.87	60.01	1.31

	NBAII H38	NBAIR Ma 4	Chlorantraniliprole
Reduction in Sugarcane clump damage over control (%)	80.07	74.83	59.7
Reduction in grub population over control (%)	79.28	75.84	76.76
Cane yield increase over control(%)	68.96	66.52	64.98
Cost Benefit ratio	1.33	1.28	1.22

	Reduction in Sugarcane clump damage over control (%)	Reduction in grub population over control (%)	Cane yield increase over control(%)	Net Returns Rs./ha	Incremental Benefit cost ratio
NBAII H38	80.07	79.28	68.96	154676	16.11
NBAIR Ma 4	74.83	75.84	66.52	158075	210.7
Chlorantraniliprole	59.7	76.76	64.98	140338	12.09

NBAII H38	NBAIR Ma 4	Chlorantraniliprole
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Table 4. Efficacy of entomopathogenic nematodes and entomofungus for the management of white grub in sugarcane during 2018-19

Treatment	Sugarcane clumps damage due to white grubs (%)	Percentage reduction in white grub damage over control	Number of white grubs / 10m row	Reduction in grub population over control (%)	Cane Yield t/ha	Yield increase over control (%)	Cost Benefit ratio
T1: <i>Heterorhabditis indica</i> WP NBAII H38 @12 kg/ha in 150 kg sand per ha	1.13	81.17	3.22	79.20	66.50	65.44	1.46
T2: <i>Metarhizium anisopliae</i> NBAIR Ma 4 @ 5 kg/ ha in 250 kg FYM per ha	1.27	78.83	3.40	78.04	64.29	64.26	1.41
T3: Chlorantraniliprole 18.5SC @ 0.3 ml / lit	2.75	54.17	4.18	72.99	61.11	62.40	1.34
T4 : Untreated control	36.0		15.47		22.98		
CD (0.05)	0.43		1.41		5.12		
CV%	34.01		31.22				

DAT : days after treatment ; MAT : months after treatment

	Reduction in Sugarcane clump damage over control (%)	Reduction in grub population over control (%)	Cane yield increase over control(%)	Net Returns Rs Thousand /ha	Incremental Benefit cost ratio
NBAII H38	80.07	79.28	68.96	159.47	33.22
NBAIR Ma 4	74.83	75.84	66.52	158.05	210.7
Chlorantraniliprole	59.7	76.76	64.98	140.33	12.09

Table 5. Efficacy of entomopathogenic nematodes and entomofungus for the management of white grub in sugarcane during 2019-2020

Treatment	Sugarcane clumps damage due to white grubs (%)	Percentage reduction in white grub damage over control	Number of white grubs / 10m row	Reduction in grub population over control (%)	Cane Yield t/ha	Yield increase over control (%)	Cost Benefit ratio
T1: <i>Heterorhabditis indica</i> WP NBAII H38 @12 kg/ha in 150 kg sand per ha	1.11	79.18	3.01	76.34	68.32	67.31	1.49
T2: <i>Metarhizium anisopliae</i> NBAIR Ma 4 @ 5 kg/ha in 250 kg FYM per ha	1.31	77.91	3.61	73.45	67.99	63.21	1.39

T3: Chlorantraniliprole 18.5SC @ 0.3 ml / lit	3.01	52.01	4.33	71.87	59.10	60.01	1.31
T4 : Untreated control	35.85		14.38		21.74		
CD (0.05)	0.41		1.38		4.68		
CV%	33.02		29.69				

DAT : days after treatment ; MAT : months after treatment

	NBAII H38	NBAIR Ma 4	Chlorantraniliprole
Reduction in Sugarcane clump damage over control (%)	80.07	74.83	59.7
Reduction in grub population over control (%)	79.28	75.84	76.76
Cane yield increase over control(%)	68.96	66.52	64.98
Cost Benefit ratio	1.33	1.28	1.22