ISBN: 978-81-973427-0-7

14. Sustainable Management Practices of Major Crop Pests of Sugarcane in India

Shamik Dey, Ishanu Mandal,
Sagnik Saha, Sohum Roy,
Sagnik Ghosh, Rahul Nandi

Faculty of Agriculture,
JIS University,
Kolkata, India

Abstract:

Sugarcane (Saccharum officinarum) grows in more than a hundred countries all over the world yielding a huge product of sugar (170 million), led by Brazil and India. Sugarcane has one of the most economic importance for production of sugars and many byproducts in India. Genetic engineering and plant breeding keeps on producing new opportunities against crop losses due to biotic and some abiotic factors.

Application of species-specific chemical pesticides with proper doses show efficacy but in general, chemical control has questionable benefits in terms of effect on significant growth stages of the crop as well as the natural balance woven between the non-target constituents of the corresponding environments due to application as well as residual hazards. On the other hand, Sterile Insect Technique (SIT), Integrated Pest Management (IPM) and Biointensive Integrated Pest Management (BIPM) practices have been proven helpful in mitigating the same threats without risking further repercussions on the environment. In 2022 alone, India's sugarcane yield was calculated to be around 84 metric tons per hectare due to implementation of such ecologically sustainable Management strategies.

Keywords:

BIPM, Chemical-Control, Sugarcane, IPM, Sustainable-Management, SIT

14.1 Introduction:

Sugarcane, referring mainly typically to the 37 species under the Genus *Saccharum* of the Family Poaceae along with all the varieties included within, is an important cash crop of many tropical and subtropical countries including India as its second largest producer. At present, almost all of the commercially cultivated varieties are complex hybrids, which can be crossed.

Sugarcane typically is a tall perennial plant which can grow erect up to 5-6 m and is typically comprised of two types of root systems (sett and shoot roots), stalk, leaves and inflorescence. Unfortunately, at present, almost all the plant parts of this crop are prone to pest infestation across different growth stages of the entire period of cultivation.

As many as 288 insect pests (David *et al*., 1986; David, 2004) accompanied by 76 non insect pests (Geetha *et al.*, 2018) tend to infest the crop across different agroclimatic zones of India. Among these, 24 insect pests wreak havoc on the quantity as well as the quality of the produce, causing as much as 20-30% yield loss on an average. (Singh, 2019).

Over the past decade, results of a staggering majority of the research work dedicated towards observation and management practices of such noxious entities have indicated lesser efficiency of the chemical control methods in terms of efficacy as well as collateral damages of the non-target environmental factors. Such tendencies have encouraged the research establishments to incline towards eco-friendly alternatives, like Biointensive Integrated Pest Management (BIPM), which promise long-term sustenance upon implementation. (Jasmine *et al*., 2012).

In light of these findings, the upcoming units will attempt to analytically unfold the current challenges of Sugarcane cultivation, in terms of crop pests and their management strategies and indicate feasible eco-friendly solutions with respect to Indian agriculture, which can potentially substitute lesser efficient means which involves administration of hazardous ingredients.

14.2 Sustainable Management Options Against the Insect Pest of Sugarcane:

Different eco-friendly pest management methods are considered for achieving the sustainable environment and ecological conditions. These pest management methods include the following practices:

14.2.1 Cultural Control:

It includes different methods like Methods of planting, spacing, seed rate, sowing time to control the insect pest in the field condition. Different cultural methods are discussed against all the insect pest profile of Sugarcane.

A. Sugarcane Early Shoot Borer:

a. Early planting in December and January avoids the early shoot borer.
b. Sugarcane intercropped with Dhaincha, Onion, Garlic had the lowest incidence of early shoot borers.
c. 3 days after planting, apply trash mulch to the ridges to a depth of 10-15 cm (about 5.91 in)
d. Grow resistant sugarcane varieties like CO 312, CO 421, CO 661, CO 853.

B. Sugarcane Internode Borer:

a. Planting non-infested seed cane.
b. Postharvest stubble ploughing is used to reduce overwintering larvae.
c. Leaving crop wastes, garbage, and broken stalks in fields over winter to kill remaining larvae (Gravois *et al.*, 2014).
d. Application of excessive doses of nitrogenous fertilizer should be avoided.

C. Sugarcane Top Shoot Borer:

a. Trash mulching followed by minor earthing up operations.
b. Avoiding plantation of sorghum or maize as intercrops.
c. Using paired row technique while planting.
d. Taking out and destroying the dead heart plants.
e. Only apply recommended nitrogen dosages in the field
f. Avoiding irrigation during the peak moth emergence time.
g. Opting for tolerant cultivars CO 859, CO 1158, and CO 7224

D. Plassey Borer:

a. It is necessary to control the application of nutrients particularly nitrogenous fertilizer
b. Higher levels of nitrogen, phosphorus, and potassium, as well as late maturity and sugar accumulation in plant cane, appear to favour borer proliferation (Gupta and Rabha, 2003).
c. Mandatory removal of infested plant parts.
d. Destroying infested plants at weekly intervals.

E. Sugarcane Pyrilla:

a. After harvesting, cane waste should be entirely removed from the field so that it can be burned or composted.
b. In addition to preserving hygienic conditions and facilitating plant protection activities, the removal of leaves starting in August lowers *Pyrilla* populations.
c. Prevention of *Pyrilla* infection in both crops can be done by not cultivating sugarcane, sorghum, or ratoon in nearby fields (Jagtap *et al.*, 1985).
d. The persistent practice of ratooning significantly increases the number of pests.

F. Sugarcane White Fly:

a. It is beneficial to regulate nutrients by avoiding overdosing and applying nitrogen later than necessary (Srikanth *et al.*,2012).
b. As the pest multiplies in environments with minimal water stress, crops should be properly watered to prevent excessive dryness or flooding
c. Nitrogen control should be combined, particularly in ratoon crops, to reduce pest infestation.
d. Severely contaminated leaves should be routinely detrashed and burned.

G. Sugarcane Scale:

a. Since infected setts impact germination, it is crucial to select healthy seed from pest-free areas and uninfected fields.
b. Avoiding waterlogging minimizes humidity and aids in reducing the scale population.
c. Wide row spacing, wrapping, propping, and detrashing all contribute to crop cleanliness and make pesticide application easier in endemic regions (Srikanth *et al.*,2012).

d. Scale-infected dry and green leaves should be removed from affected crops every two weeks and burned (Kalra, 1979).

H. Sugarcane Mealy Bug:

a. Removing the leaf sheaths from infected setts and planting them limits the spread of mealy bugs to fresh plants and new locations.
b. Detrashing is necessary to expose the mealybug colonies to stressors that are both biotic and abiotic.
c. It is important to prevent excessive nitrogen application and rat infestation in places where the pest infestation is common.
d. d.Reducing the frequency of mealybugs requires managing water stress and Crop heal th in general (Srikanth *et al.*, 2012)
e. It is best to refrain from multi ratooning.

I. Sugarcane Wolly Aphid:

a. Reducing the risk of introduction into a new location can be achieved by avoiding the transportation of seed material or green tops as fodder from affected areas.
b. In the early stages of infestation, the affected leaves ought to be eliminated.
c. Common methods for controlling sucking pests include using nitrogenous fertilisers sparingly, preventing overwatering, ensuring adequate drainage, and growing the least susceptible varieties.
d. Due to the decreased concentration of sap, irrigated fields saw less infestation (Joshi and Viraktamath 2004).

J. Sugarcane Termite:

a. Regular cross-cultural interactions and observation assist in determining the issue as soon as possible.
b. It is best to remove dead wood, stubbles, and undecomposed plant waste since they serve as a haven for termites and their attacks.
c. Partial decomposed FYM shouldn't be put in areas where termites are a problem.
d. Mulching encourages termite infestation; thus, it should be regularly checked for symptoms.

K. Sugarcane White Grub:

a. In endemic locations, crop rotation employing lowland paddy sugarcane as a control measure will temporarily mitigate the issue.
b. In locations where grub populations are endemic, converting to sunflower farming also prevents their growth.
c. White grub infestation on sugarcane is decreased by sowing trap crops including sorghum, maize, and onions.
d. In August, flooding up to two inches above the soil's surface for seventy-two hours can kill grubs and pupae (Theurkar *et al.*, 2012).

14.2.2 Mechanical Control:

It is the pest management strategy which include the application of different physical approaches such as formation of fence or development of barriers or electronic barriers.

The following mechanical controls are described in different insect pest of sugarcane.

A. Sugarcane Early shoot borer:

a. Dead hearts are extracted between April and June from 3-5 cm below the surface and then destroyed by burning or burial.
b. Reducing the infestation of shoot borer can be achieved via spike-infested shoots.
c. Removal of dried leaves every month (Field Sanitation) following cane production in locations where shoot borer also acts as stem borer.

B. Sugarcane Internode borer:

a. Planting healthy seed cane and monitoring and surveying to detect the first moth appearing in the crop.
b. In order to let parasitoids, if any, to escape to the field but prevent pests, manually remove plants affected with top shoot borer throughout the summer months (February to June) using plastic mesh begs.

C. Sugarcane Top Shoot BORER:

a. From April to September, during the first week of every month, plants affected with shoot borders (dead hearts) were rouged.

D. Plassey Borer:

a. Collection of borers under light traps to destroy the population.
b. Collect and destroy the egg mass from the primary infestation.
c. Also collect and destroy infected sugarcane top shoot parts.

E. Sugarcane Pyrilla:

a. Population growth is reduced by regularly removing and destroying the puffy, white *Pyrilla* egg masses. As an alternative, the egg masses could be stored in discarded fabric bags and hung in various locations throughout the field to enable
b. Selective appearance of adult egg parasitoids during the nymphae's entrapment.
c. Male *P. Perpusilla* were more numerous than female *P. Perpusilla,* being attracted to a 40-watt fluorescent tube (Srikanth *et al.*, 2012). It was suggested that light traps be used to contain the *P. Perpusilla* outbreak (Dhiman, 2001). The insect problem can be reduced by hand-picking and eliminating the egg masses (Agarwal and Butani, 1976).

F. Sugarcane White Fly:

a. De-trashing the old leaves carefully when the pest is observed at the initial stage.
b. Yellow sticky trap can be used for management of White fly.
c. Clipping and deposing off the affected leaves to prevent the spread of white fly infestation at its severe stages. (Ananthanarayana *et al.*, 1984)

G. Sugarcane Wolly Aphid:

a. Clipping and destruction of lower leaves and must stake and band the leaves 5 to 6 months old leaves to check the Aphid population. (Chakravarthy 2005).
b. Installation of yellow sticky trap.

H. Sugarcane Termite:

a. Destruct the termite colonies in those species that build termitarium by breaking open the nest and must remove the queen termite which is able to reproduce with male one (Srikanth *et al.*, 2012).
b. Termite bait systems can help to eliminate an entire colony from sugarcane field.

I. Sugarcane White Grub:

a. Farmers in the village may use the light trap, petromax, or lantern on the fields next to trees or shrubs, on irrigation channels, or near tubewell huts.
b. The light trap may highlight the harm caused by white grubs in a farmer's land. By immersing the gathered insects in kerosine water, they can be killed.
c. Alternatively, the adult beetle can be killed by drowning it in kerosine water after being shaken ferociously or by shaking the twigs of trees and plants such as Ber, Kheri, Neem.

14.3 Genetic Control:

14.3.1 Genetic Control for Lepidopteran Pests:

The primary cause of sterility in the SIT is dominant fatal mutations (DLMs) in germ cells caused by ionising radiation. The majority of chromosomal aberrations that result in DLMs are those that, after fertilisation, cause the chromosome bridges to form during anaphase, indicating the presence of dicentric chromosomes; other abnormalities in the dividing nuclei that cause the zygote or embryo to die also occur. While the majority of DLMs are produced early in the process of embryogenesis in insects, they are expressed relatively late in the development of the embryo in Lepidoptera, and the cleavage nuclei do not exhibit any obvious chromosomal bridges. (LaChance, 1967). Additionally, chromosomal fragments can survive several mitotic cell divisions and can even be inherited by progenitor cells. Due to the large amount of cytoplasm present in mature oocytes, radiation exposure in females may disrupt the normal progression of meiosis, including chromosomal segregation, and result in various secondary damages. As a result, doses of 100–200 Gy are sufficient to induce almost total sterility in female irradiated insects, as shown in several investigated lepidopteran pests.

The remarkable resistance of Lepidoptera to ionising radiation is the consequence of a complex interplay between several intracellular processes and genetic characteristics. Lepidopteran cells produced in culture are 50–100 times more resistant to radiation-induced death than mammalian cells, as was previously found, but only 3–9 times more resistant than dipteran cells. (Koval, 1996; Marec *et al.*, 2001)

14.3.2 Genetic Control for Hemipteran Pests:

Given that crops might be harmed by them at any point during development and eventual release, Hemiptera are an uncommon target insect group for the SIT. Despite this, attempts have been undertaken to determine whether populations of specific hemipteran pest species may be targeted by the SIT; some researchers have even suggested that the brown marmorated stink bug, Halyomorpha halys, could be a suitable option. (Suckling *et al.*, 2019).

Hemiptera are a rare target insect category for the SIT because they could affect crops at any point in their growth or potential release. Nevertheless, investigations have been conducted to see if the SIT might target populations of particular hemipteran pest species; some experts have even proposed that the brown marmorated stink bug, Halyomorpha halys, might be a good choice (Suckling, 2019).

It's interesting to note that whilst female *Nezara viridula* green vegetable bugs needed a dose of 28 Gy to become completely sterile, males could be sterilised by >99% with an irradiation dose of 16 Gy or higher. This result is similar to the Halyomorpha halys study that was previously mentioned.

14.3.3 Chemical Control:

A. Sugarcane Early Shoot Borer:

a. Application of Carbofuran 3G 1 kg a.i./ha or Thimet 10G 3 kg a.i./ha ten days before the commencement of 3rd brood in sub-tropical India.
b. Fipronil at 90 g a.i./ha applied at 0 or 45 DAP did not reduce C. infuscatellus between-season population carry-over in stubbles (Mann *et al.*, 2009).
c. c. Drenching with Chlorantraniliprole (Coragen) 18.5 SC @ 150 ml/acre dissolved in 400 lit of water in the 1st week of May followed by irrigation for the control of 2nd and 3rd brood of top borer.

B. Sugarcane Internode Borer:

a. Spraying Monocrotophos fortnightly during the growing seasons.
b. Application of Carbofuran 3G on the soil at 30 kg/ha in case of severe damage.
c. Lowest intensity (1.48%) and incidence (1.21%) of INB were recorded in Chlorantraniliprole 18.5 SC at 0.36 ml/l of water Among the seven insecticides tested at Rudrur, Telangana, exhibiting significantly superior yield than the control (Padmasri *et al.*, 2014).

C. Sugarcane Top Shoot Borer:

a. Drenching of Chlorantraniliprole (Coragen) 18.5 SC @ 150 ml/acre dissolved in 400 lit of water in the 1st week of May followed by irrigation for the control of 2nd and 3rd brood top borer.

D. Plassey Borer:

a. Use of Carbofuran 3 G @ 33 Kg/ha at the time of earthing-up has been found effective against borers in general and top borers in particular.
b. An IPM module i.e. Mechanical + Carbofuran + Trichocard has been found to be superior for the control of plassey borer.
c. The percentage of Plassey Borer after treatment with 2 kg a.i./ha malathion was 16.25% compared with 66.42% in controls (Deka *et al.*, 1999).

E. Sugarcane Pyrilla:

a. Apply Chlorophyriphos 20 % EC2.5 ml/lit of water.
b. Lambda Cyhalothrin 5 % EC in 2 ml/lit of water can be used.
c. Use Dimethoate 30% EC 1.5 ml/lit of water when Sugarcane pyrilla attacks in severe stage.
d. Apply Thiamethoxam 25 % WG 0.5 gm/lit of water.
e. Foliar application of Acetamiprid 20% S.P 0.5gm/lit water.
f. Acephate 75 SP (0.05%), deltamethrin 2.8 EC (0.0028%), malathion 50 EC (0.10%), Imidacloprid 17.8 SL (0.01%), Achook 300(1.0%), NSKE (5.0%) and Nimbicidin 300 (1.0%) were significantly superior in reducing the pest population (Rajak, 2006).

F. Sugarcane White Fly:

a. Spraying fenitrothion 50 EC @ 2 lit / ha (1000 lit spray fluid)
b. Spraying acephate 2g per litre of water.
c. Spraying Imidacloprid @17.8 SL 0.03ml/L of water.
d. Efficacy of thiamethoxam Against the pest increased with increasing rates of the insecticide (Vijayaraghavan and Regupathy, 2006).
e. Effective with highest yield.

G. Sugarcane Scale:

a. Pre-soaking the setts in 0.1% solution malathion.
b. Spraying Dimethoate @ 2ml/ lit along with sticker after detrashing.
c. Apply contact insecticides like dichlorvos or any @ 2ml/lit of water by using hand sprayer.
d. Sett treat-Ment with acephate 75 SP at 1 g/l for 15 min before planting + spraying acephate 75 SP at 1 g/l twice at 30-day interval after detrashing the lowest four or five leaves just Before the initial appearance of the pest was highly effective in reducing the incidence of scale insect (Bhavani, 2013).

H. Sugarcane Mealy Bug:

a. Application of any one of the following insecticides per ha and when the incidence is noticed spray on the stem only, methyl parathion 50 EC 1000 ml, malathion 50 EC 1000 ml.
b. If severe infestation is noticed detrash and spray with dimethoate 30 EC @ 1 ml/ lit mixed with fish oil resin soap @ 2.5 ml/lit.
c. Acephate and acetamiprid cause the highest mortality of mealybug (95.00 And 96.66%) (Tewari and Yadav, 2005).

I. Sugarcane Wooly Aphid:

a. Flonicamid (Mainman) is a good choice because it is selective, has low toxicity to natural enemies and is partially systemic.
b. Spray Malathion 50 EC 2 ml / lit. Dimethoate 30 EC 1.7 ml / lit, Oxydemeton methyl 25 EC 1.3 ml / lit, or Dusting with Malathion 5% dust @ 10 kg / ac.

J. Sugarcane Termite:

a. Dipping the setts in Imidacloprid 70WS 0.1% or Chlopyriphos 20 EC 0.04% for 5min.
b. Soil Treatment with Lindane 1.6 D @ 50 kg / ha.

K. White Grub:

a. Effective chemical control of white grubs depends on moving the insecticide down to the root zone where the grubs are feeding. This is best accomplished by applying ½ to ¾ inches of water immediately after application. Repeat irrigation every four or five days to continue moving the insecticide into the soil.
b. Incorporation of Carbofuran 3CG @ 33.0 kg/ha or Phorate 10CG @ 25.0 kg/ha in soil before sowing.
c. Soil drenching of Imidacloprid 40% + fipronil 40% – 80 WG at 300 g ha^{-1} was found to be the most effective treatment followed by Clo-Thianidin 50 WDG at 250 g ha^{-1}(Mane and Mohite, 2014; Mane and Mohite, 2015a)

14.2.4 Biological Control:

It includes the application of living organisms (predator, parasitoid and pathogens) to manage the insect pest in field condition.

A. Sugarcane Top Shoot Borer:

a. Administering Teepol twice on 35 and 50 DAP together with 1.5 x 13 5 IBS / ha (750 sick larvae / ha) of granulosis virus.
b. Hourly release of 125 gravid female *Sturmiopsis inferens, a* tachinid parasite.
c. Enhancement of egg parasitoids from the genus *Trichogramma* (Trichogrammatidae; Hymenoptera) and larval parasitoids from the species *Microplitis* (Braconidae;

Hymenoptera) and *Sturmiopsis* (Tachinidae; Diptera) is the usual biological method used to manage sugarcane borer populations.

B. Sugarcane Internode Borer:

a. Promote the use of biocontrol agents such as egg parasitoids like *Trichogramma chilonis* and larval parasitoids like *Stenobracon deesae* and *Apanteles flavipes.*
b. Internode borers are controlled by releasing pupal parasitoids as well.
c. Anand Dr. Bacto’s Brave is an eco-friendly bio insecticide containing *Beauveria bassiana* which acts on the cuticle of susceptible insects and kills them by producing toxins. The recommended dosage is 2.5 ml per litre of water.

C. Sugarcane Top Shoot Borer:

a. Release of lab raised *Trichogramma japonicum* (egg parasitoids) at 50,000 per hectare three times in a fortnight at the height of egg laying/emergence of moths for the third and fourth broods
b. Preservation of naturally occurring parasitoids with distinct stages.
c. The wasp *Cotesia flavipes* is the most important parasitoid of the sugarcane borer used in biological control in Brazil (Geetha *et al*., 2018). The wasps are bred in laboratories and are released on plantations infested with borers.

D. Plassey Borer:

The larvae are parasitized by natural enemies such as *Cotesia flavipes* Cameron and *Stenobracon deesae* (Cameron) (Hymenoptera: Braconidae) while migrating from infested internodes to healthy ones. The extent of natural parasitism by *Cotesia flavipes, Stensobracon deesae* and an unidentified parasitoid was found to be 9.8, 3.6 and 2.1%, respectively. Several workers reported that 40-65% larvae were parasitized by C. flavipes and parasitism increased with increase in incidence (Singh *et al.* 1999).

E. Sugarcane Pyrilla:

a. Parasitoid lepidopteran *Epiricania melanoleuca* is the most dangerous natural enemy of *Pyrilla perpusilla* and are used to biocontrol the population of P. perpusilla.
b. Both males and females were used in the investigation to ascertain the effects of parasitism in adult *Pyrilla perpusilla*. There were two hundred people freed on sugarcane leaves in cages. The individuals were manually parasitized, and after five repetitions (n = 100) of each gender exhibiting evidence of parasitism, they were removed and placed in distinct plastic vials measuring 3.5 cm in diameter by 10.0 cm in height, in order to document the observations about adult mortality and longevity.

F. Sugarcane Whitefly:

a. Application of predator *Chrysoperlla carnea*, the maximum reduction of whitefly population Is observed (57.3%) in August followed by September (57.14%). conducted studied on to evaluate performance of Chrysoperlla carnea (Stephens) on 6 insect pests of sugarcane and found very good predation on final instars of whitefly nymphs.

b. The parasitoids *Eretmocerus* and *Encarsia* are the most often used biological control agents for whiteflies. These small wasps lay their eggs under or inside the nymphs of whiteflies. After feeding, the wasp larvae grow into nymphs and pupae before emerging as adults to devour additional whiteflies.

G. Sugarcane Scale:

a. Promoting the presence of predators such as *Pharascymnus horni* and *Chilocorus nigritus* to manage the sugarcane scale insect population**.**
b. Releasing predatory mites like *Tyrophagus putrescentiae* and *Sancassania nuda*, as well as parasitoids like *Anagyrus mayurensis*, to feast on scale insects.

H. Sugarcane Mealy Bug:

a. Coccinellid beetles, including *Nephus regularis, Scymnus coccivora, Rodolia fumida,* and *Cheilomenes sexmaculata*, are significant predators of mealybug nymphs.
b. *Leptomastix dactylopii, Anagyrus pseudococci, Verticillium lecanii, Beauveria bassiana,* and *Hypoaspis* sp. Are some of the biological control agents that have been introduced, and they are effective in Controlling the infestation.

I. Sugarcane Wooly Aphid:

a. Apply only the recommended dose of chemical fertilizers. Excessive application of nitrogen fertilizers will result in outbreak of the aphids.
b. Monitor the sugarcane crop for the early detection of the pest. The aphid outbreak occurs in patches, particularly in shady areas where the humidity is higher.
c. If the predators are present, they should be conserved by avoiding spraying of chemical pesticides.

J. Sugarcane Termites:

a. Termites can be successfully managed by goods that include termite-attacking nematodes.
b. Termite mounds can be treated with a solution containing fungi, such as *Beauveria bassiana* or *Metarhizium* sp., to suppress termite infestation.
c. It has been reported that using neem seed kernel extracts to control termites on trees and agricultural crops works well.
d. Adding crushed neem leaves or seeds or wood ash to termite tunnels will deter them.

K. White Grubs:

a. It was discovered that *B. cereus* was more effective than nematodes and entomopathogenic fungi.

b. In June and July, when beetles are emerging and actively ovipositing, the white muscardine fungus *Beauveria brongniartii*, mixed with carrier materials such press mud, lignite, or talc, can be administered at 2.5 × 102 spores/ha to target immature grubs. (Theurkar *et al*., 2012)

14.4 Conclusion:

In conclusion, the preceding sections considerably attempt to comprehensively delineates the prevailing challenges associated with major crop pests in Indian sugarcane cultivation and elucidates diverse management strategies employed to mitigate their impact. It is evident from the gathered evidence that conventional chemical control methods have historically been extensively used for pest management in sugarcane. However, their recurrent application poses notable environmental and health hazards. The exploration of sustainable alternatives, such as Integrated Pest Management (IPM), Biological Integrated Pest Management (BIPM), and Sterile Insect Technique (SIT), demonstrates their efficacy in pest suppression while minimizing adverse impacts. These eco-friendly strategies, embracing diverse control measures and biological control agents, present promising avenues for sustainable pest management in sugarcane cultivation. Their integration ensures a harmonized approach, leveraging ecological principles to maintain pest populations below the economic injury level. The overarching consensus from the literature reviewed emphasizes the imperative shift towards these sustainable pest management practices. IPM, BIPM, and SIT offer viable solutions, reducing reliance on chemical pesticides, conserving natural resources, and safeguarding ecological balance. The documented proceedings underscore the importance of a holistic approach, combining scientific insights and innovative practices, to address the intricate challenges posed by major crop pests in sugarcane cultivation on multiple levels in a simultaneous fashion.

In essence, the pursuit of sustainable management practices aligns with the imperative need for environmentally conscious and economically viable solutions. Embracing IPM, BIPM, and SIT heralds a paradigm shifts towards a more ecologically sustainable and resilient future for the sugarcane industry in India.

14.5 Acknowledgement:

Heartfelt gratitude goes out to all the present and past constituents of the faculty of the School of Agricultural Sciences, JIS University, for their precious time, patience, perseverance and guidance which equipped us with a progressive mindset to continue our pursuit of knowledge, progression and excellence throughout the rest of our respective academic and professional careers as well as life in general. A special note of thanks goes out to our parents and equivalent guardians whose unwavering support prevented our resolves from shattering in front of any and all difficulties, helping us to forge a new path ahead.

14.6 Reference:

1. Agarwal RA. 1980. Eradication of a major pest of sugar cane. *International Sugar Journal*, 82(978): 177-179.

2. Agarwal RA and Butani DK. 1976. Sugarcane leafhopper, *Pyrilla perpusilla* and its control. *Cane Grower's Bull*, 3(1): 1-3.
3. Ananthanarayana K, Shanmugasundaram S and David H. 1984. Studies on the insecticidal control of sugarcane whitefly, Aleurolobus barodensis mask. *Pestology*, *8:* 9-21.
4. Assefa Y and Conlong DE. 2009. A checklist of phytophagous insects of sugarcane in Ethiopian estates. In *Proceedings of the Annual Congress-South African Sugar Technologists' Association* (No. 82, pp. 495-499). South African Sugar Technologists' Association.
5. Bains SS, Dev and Roy TC. 1981. Integrated management of sugarcane pests in the Punjab. In: *Proceedings of the National Symposium on Sugarcane Stalk Borer, Karnal, India:* 147–155.
6. Barrion AT, Libetario EM and Litsinger JA. 1987. An earwig predator of Asian pink stem borer (PSB) in upland rice. *International rice research newsletter*, *12*(1): 21.
7. Bhavani B. 2013. Studies on the biology of sugarcane early shoot borer, Chilo infuscatellus Snellen on artificial diet in North coastal region of Andhra Pradesh, India. *International Journal of Social Science & Interdisciplinary Research*, *2*(9): 70-89.
8. Chakravarthy AK. 2005. Studies on sugarcane woolly aphid *Ceratovacuna lanigera* Zehnter (Homoptera: Aphididae) in Karnataka, South India. *Advances in Indian entomology: productivity and health (a silver jubilee supplement No. 3, Volume I):* 213-228.
9. Chand H, Kumar A, Paswan S and Dwivedi GP. 2015. Efficacy and economics of insecticides against Chilo infuscatellus Snell. and *Emmalocera depressella* Swinhoe in Sugarcane. *Annals of Plant Protection Sciences*, *23*(2): 298-301.
10. Chand NASIB and Deshmukh SN. 1973. Some observations on the behaviour of the dispersing larvae of Bissetia steniella (Hampson) and their susceptibility to some common insecticides. *Indian sugar*.
11. David H, Easwaramoorthy S and Jayanthi R. 1986. Sugarcane entomology in India.
12. David BV. 2004. *General and applied entomology*. Tata McGraw-Hill Education.
13. Deka MK, Gupta MK and Singh SN. 1999. Effect of different dust formulation of insecticides on the incidence of sugarcane insect pests. *Indian Sugar*, *49*(5): 357-361.
14. Deole S. 2016. Studies on pink stem borer, *Sesamia inferens* Walker of maize, Zea mays L. with particular reference to neonate larval behavior and its management. *Indira Gandhi Krishi Vishwavidyalaya*, *Raipur*, *India*.
15. Dhiman SC. 2001. Incidence of mass attraction of *Pyrilla perpusilla* Walker on fluorescent light at Saharanpur, Uttar Pradesh. *Journal of Applied Zoological Researches*, *12*(2/3): 142-143.
16. Gao Y, Hu Y, Fu Q, Zhang J, Oppert B, Lai F and Zhang Z. 2010. Screen of *Bacillus thuringiensis* toxins for transgenic rice to control *Sesamia inferens* and *Chilo suppressalis*. *Journal of invertebrate pathology*, *105*(1): 11-15.
17. Geetha MV, Kalyanasundaram M, Jayaraj J, Shanthi M, Vijayashanthi VA, Hemalatha D and Karthickraja K. 2018. Pests of sugarcane. *Pests and Their Management:* 241-310.
18. Godse DB and Nayak P. 1983. Nuclear polyhedrosis of Sesamia inferens (Noctuidae: Lepidoptera) the pink stem borer of rice. *Current science (Bangalore)*, *52*(14): 682-683.
19. Gravois K, Viator S, Reagan TE, Beuzelin JM, Griffin JL, Tubana BS and Hoy JW. 2014. Sugarcane production handbook. *Louisiana State University Agricultural Center Pub*, *2859*.

20. Gupta MK and Rabha DC. 2003. Growth and development of plassey borer, *Chilo tumidicostalis* Hampson. on plant and second ratoon sugarcane. *Journal of Applied Zoological Research*, *14*(1): 38-41.
21. Hill DS. 1987. *Agricultural insect pests of the tropics and their control*. Cambridge University Press.
22. Huang F, Parker R, Leonard R, Yong Y and Liu J. 2009. Frequency of resistance alleles to *Bacillus thuringiensis*-corn in Texas populations of the sugarcane borer, *Diatraea saccharalis* (F.) (Lepidoptera: Crambidae). *Crop Protection*, *28*(2): 174-180.
23. Irshad M and Shah MM.1982. Mechanical control of *Acigona* stenieltus Hampson. in sugarcane. *Entomological News l (12):* 8-11.
24. Isaac PV and Misra CS. 1933. The chief insect pests of sugarcane and methods for their control. *Agric Livestock India*, *3*(4): 315-324.
25. Jagtap AB, Ghule BD and Deokar AB. 1985. Incidence of Pyrilla perpusilla on ratoon sorghum and sugarcane. *Journal of Maharashtra Agricultural Universities*.
26. Jasmine RS, Rajendran B and Rani RK. 2012. BIPM components for the management of borer complex in sugarcane. *Journal of Biopesticides*, *5*, 209.
27. Joshi S and Viraktamath CA. 2004. The sugarcane woolly aphid, *Ceratovacuna lanigera* Zehntner (Hemiptera: Aphididae): its biology, pest status and control. *Current Science:* 307-316.
28. Kalra AN. 1979. Sugarcane pests and their control. *Sugarcane pests and their control.*
29. Kapoor MS. 1957. Studies on the bionomics and control of *Bissetia steniellus* Hampson in the Punjab. *Indian Journal of Entomology*, *19*(2): 132-43.
30. Koval TM. 1996. Moths: myths and mysteries of stress resistance. *BioEssays*, 18(2): 149-156.
31. LaChance LE. 1967. The induction of dominant lethal mutations in insects by ionizing radiation and chemicals-as related to the sterile male technique of insect control. *Genetics of insect vectors of disease, 21:* 617-650.
32. Mann RS, Uppal SK, Sharma S and Mann KK. 2009. Soil efficacy of fipronil to early-stage pests of sugarcane, and its effect on development on Chilo infuscatellus Snellen (Crambidae: Lepidoptera). *International Journal of Pest Management*, *55*(4): 307-315.
33. Mane PB and Mohite PB. 2014. Efficacy of newer molecules of insecticides against white grub in sugarcane. *Asian Journal of Bio Science*, *9*(2): 173-177.
34. Mane PB and Mohite PB. 2015a. Efficacy of insecticides against white grub, *Leucopholis lepidophora* infesting sugarcane in western Maharashtra. *Annals of Plant Protection Sciences*, *23*(1): 49-51.
35. Marec F, Tothová A, Sahara K and Traut W. 2001. Meiotic pairing of sex chromosome fragments and its relation to atypical transmission of a sex-linked marker in *Ephestia kuehniella* (Insecta: Lepidoptera). *Heredity, 87*(6): 659-671.
36. Padmasri A, Vidyasagar GE and Bharathi V. 2014. Evaluation of new molecules for management of stem borer on sugarcane. *Journal of Agriculture and Veterinary Science*, *7*(6): 40-42.
37. Rajak DC. 2006. Evaluation of insecticides, botanicals and bioagents for the control of *Pyrilla perpusilla* and effect on related parasitoid, *Epiricania melanoleuca* in sugarcane. *Indian Journal of wPlant Protection*, *34*(2): 245.
38. Ramanujam B, Poornesha B and Yatish KR. 2016. Screening of Beauveria bassiana and Metarhizium anisopliae Isolates against Sesamia inferens (Walker). *Indian journal of entomology*, *78*(4): 388-391.

39. Sardana HR. 2001. Influence of summer inter-cropping on the incidence of root borer, *Emmalocera depressella* of sugarcane. Indian Journal of Entomology, 63(1): 49-51.
40. Sardana HR and Misra A. 2003. Influence of row spacing and companion cropping on the incidence of major sugarcane borers. *Indian Journal of Ecology*, 30(2): 199-208.
41. Singh MR. 2019. *All India Coordinated Research Project on Sugarcane*. Technical Report https://doi. org/10.37580/JSR. 2019.2. 9.176-183.
42. Singh S, Singh M and Jain JL. 1999. Plassey Borer (*Chilo Tumidicostalis* Hampson) A Serious Pest of Sugarcane Crop in Harinagar Area. *BHARATIYA SUGAR*, 41-43.
43. Suckling DM, Levy MC, Roselli G, Mazzoni V, Ioriatti C, Deromedi M and Anfora G. 2019. Live traps for adult brown marmorated stink bugs. *Insects*, 10(11): 376.
44. Srikanth J, Salin KP and Jayanthi R. 2012. Sugarcane pests and their management. *Sugarcane Breeding Institute, Coimbatore,* 88.
45. Tewari RK and Yadav RA. 2005. Bio-efficacy of newer insecticides against black bug (*Cavelerius sweeti*) and mealy bug (Saccharicoccus sacchari) of sugarcane. *Indian Journal of Entomology*, *67*(2): 175.
46. Theurkar SV, Patil SB, Ghadage MK, Zaware YB and Madan SS. 2012. Distribution and Abundance of White grubs (Coleoptera: Scarabaeidae) in Khed Taluka, part of Northern Western Ghats, MS, India. *International Research Journal of Biological Sciences*, *1*(7): 1-6.
47. Vijayaraghavan C and Regupathy A. 2006. Bioefficacy of thiamethoxam (Actara 25WG) against sugarcane whitefly *Aleurolobus barodensis* Maskell. *International Journal of Agricultural Sciences*, *2:* 299-304.