INTRODUCTION
I. INTRODUCTION

Sugar is an important component of the daily diet of human beings. Over 187 countries are producing sugar in the world and 166.74 million tonnes of raw sugar is produced annually, out of which 130.02 million tonnes is contributed from sugar cane and 36.72 million tonnes from sugar beet (Anonymous, 2008a). In the world, about 72% sugar is produced from sugar cane and 28% from sugar beet (Table 1). The countries viz. Brazil, India, Australia, Mexico, Thailand, Indonesia grow sugar cane and Germany, France, Russia and other European countries are producing sugar from sugar beet. Few countries viz. U.S.A., China, Egypt and Pakistan cultivate both sugar cane and sugar beet for the production of sugar and its by-products.

Indian sugar industry, second largest after the textile industry, is a unique agro based industry located in rural areas and is playing a vital role in the socio-economic transformation of the country. About 48 million sugar cane farmers, their dependants and large numbers of laboures have been involved in sugar cane cultivation. More than 0.5 million skilled and unskilled workers are engaged in the sugar industry with the additional employment generation by the subsidiary industries, too. Sugar cane (Saccharum officinarum Linn.) is one of the major economically important cash crops grown in India, which is the largest sugar producer in the world (30.77 mt), second after Brazil (32.50 mt) in 2006-07 (Anonymous, 2008b). Sugar cane is cultivated extensively in about 5.15 million ha area in India. Maharashtra, Uttar Pradesh, Karnataka, Tamil Nadu and Gujarat are the leading sugar cane producing States in the country. In India, 501 working sugar factories (251 co-operative) crushed 278.87 million tonnes of sugar cane and produced 28.30 million tonnes of sugar during 2006-07. The sugar cane area of India is broadly classified into sub-tropical and tropical regions, the latter harvests better cane yield and sugar recovery. Maharashtra is known as the sugar bowl of the country having the largest area of 1.05 million ha under sugar cane second after UP (2.25 million ha).
Maharashtra State is producing 9.07 mt of sugar annually out of the total production of the country (29.50 mt in 2007-08), accounting for 32% of sugar production of the country. Average cane yield of Maharashtra State is 74.9 t/ha with a sugar recovery of 11.39 % as compared to 69.0 t/ha with 10.16 % sugar recovery in India (Anonymous, 2008c).

Table 1. Sugar production in the world

<table>
<thead>
<tr>
<th>Country</th>
<th>Raw Sugar Production (Million Tonnes Raw Value)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(a) Cane Sugar Production</td>
</tr>
<tr>
<td>Brazil</td>
<td>26.36</td>
</tr>
<tr>
<td>India</td>
<td>14.74</td>
</tr>
<tr>
<td>China</td>
<td>10.26</td>
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<tr>
<td>Thailand</td>
<td>7.28</td>
</tr>
<tr>
<td>Australia</td>
<td>5.31</td>
</tr>
<tr>
<td>Mexico</td>
<td>5.36</td>
</tr>
<tr>
<td>Other countries</td>
<td>38.95</td>
</tr>
<tr>
<td>Total (82 countries)</td>
<td>108.24</td>
</tr>
<tr>
<td>(b) Beet sugar production</td>
<td></td>
</tr>
<tr>
<td>World Total</td>
<td>19.86</td>
</tr>
<tr>
<td>Other countries</td>
<td>14.99</td>
</tr>
<tr>
<td>Total (31 countries)</td>
<td>34.59</td>
</tr>
<tr>
<td>World Total</td>
<td>142.83</td>
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</tbody>
</table>

* % of total sugar produced in world. Source F. O. Licht, January 25, 2008; mt – million tonnes

The sugar cane crop is cultivated under a number of biotic and abiotic stresses resulting into a low yield and low sugar recovery. At present, sugar cane is the major source for production of sugar in India. The productivity of sugar cane is affected mostly by vagaries of monsoon, improper and untimely cultivation practices, monoculture, infestation of pests, poor ratoon management, etc. In addition, the limiting factors viz. low and high temperature, problematic soils, flowering have to taken into consideration. During recent years, the sugar cane cultivation has been
facing the problems like inadequate irrigation water availability due to poor rainfall and flood conditions due to excess rains in some pockets. The sugar factories are facing the cyclic lean periods during the drought years and suffer shortage of cane supply (Patil et al., 2007). In the last 50 years, monoculture of sugar cane crop in irrigated areas has created the problems of soil salinity and drainage, which result in a great decline of average sugar cane productivity making this crop non-profitable at the farmers level. Insect and non-insect pests are also responsible for low yields. A few pests *viz.* Aleurolobus barodensis Mask (whitefly), Leucopholis lepidophora Brum (white grub) and Emmalocera depressella Swinhoe (root borer), which hitherto were considered to be of a minor in importance, have assumed a serious dimension causing huge losses in sugar cane. Recently, introduction of a new pest, sugar cane woolly aphid, intensified the problem of sugar cane growers and the epidemic of the pest from 2002-03 to 2006-07 lowered the cane area and cane yield considerably in India. Increased cost of key inputs *viz.* seed material, fertilizers, irrigation water, plant protection measures, labour wages has increased the cost of production of sugar cane thus narrowing the net profit of the farmers. Production of excess or low sugar cane is always harmful to the industry and farmers, also. Due to the limitations of the available cultivated land, the industry has no longer depends on the extensive cultivation of sugar cane.

This situation has resulted in inadequate cane supply to the sugar factories and hence, the factories could not run for a stipulated period during the crushing season. Running of the sugar factories below the capacity installed ultimately results in increased overhead costs and leads to heavy economic losses, even during the normal crushing season i.e. 160 days. Therefore, the crushing period has to be extended by 2-3 months to reduce the cost of sugar production and to utilize the manpower and machinery sufficiently.

Export of sugar in the country is very less as compared to Brazil, Thailand, Mauritius and Australia and mainly due to the low keeping quality and increased cost of production of sugar, less Govt. subsidies etc.
Our efforts in future have to be concentrate mainly to reduce the cost of sugar production by extending the crushing season of sugar factories and to produce good quality sugar at a lower cost for increasing the export of sugar.

With due consideration of the above points, the sugar industry has a need to turn to cultivate supplementary crop and to meet the nation's requirement of sugar, jaggery, ethanol, co-generation etc. The recent globalization process has posed new challenges for the sugar cane agriculture and sugar industry in India. Under these circumstances, the sugar cane growers and sugar mills in India should plan and act immediately to compete with the other sugar producing countries, where the cost of production of sugar cane and sugar is less than that in India. The possibility of removal of subsidies on beet sugar as per the demand of Global Alliance for Sugar Trade Reforms (GASTR), it is expected that in the near future, this policy may reduce the production of sugar from sugar beet mainly in Europe. European countries are the third largest world group in the production of white sugar (16.74 million tonnes). Sugar beet is the major source of raw material for the production of white sugar in the European countries.

This situation calls for an immediate exploitation of supplementary sources of raw material for the production of white sugar, ethanol and sugar beet is the best option. Sugar beet crop (Plate 1) can offer a valuable alternative or supplementary to sugar cane in tropical areas. Agribusiness has recognized the need to increase the sugar production in the face of new demand driven by the food versus fuel debate, growing population and changing human habits. Tropical sugar beet can be grown in relatively dry areas, as it requires substantially much less water than sugar cane. The beet crop is also a faster growing crop, allowing the farmers to cultivate two crops on their land in the same period as sugar cane crop takes more than 12 months to mature. Tropical sugar beet delivers equal output of sugar yield as in sugar cane and can be used both for processing of sugar and ethanol. An alternative to cane, sugar beet supports the
biodiversity, when used in the areas of extensive sugar cane monocultures. This will definitely increase the productivity and income at farmers' level and bring significant benefits to the agricultural sector.

Although sugar beet is a temperate region crop, efforts were made to exploit the sugar beet as a source of raw material for the production of white sugar in India during the early seventies with a strong research support through the All India Co-ordinated Research Project on sugar beet by ICAR. The research efforts have resulted in generating the primary technology on various aspects of sugar beet cultivation and its post harvest utilization. Sugar beet cultivation was tried at IISR, Lucknow, (UP) and at CSRS, Padegaon (M.S.) in 1970's. The sugar beet cultivation was taken up in Sriganganagar area of Rajasthan for sugar production and in Sundarban area of West Bengal for alcohol production during 1970's and it was proved that sugar beet cultivation is possible in sub-tropical India, too. However, earlier the genotypes available had low yield potential, low sugar content and were suitable only for the Sub-tropical regions. Hence, the crop could not get momentum in India except Sriganganagar area of Rajasthan. Beet processing in this area has also stopped in the nineties for want of adequate supply of raw material and economic inviability of the crop for sugar production. However, sugar beet is a relatively a new crop to the Indian farmers and its success largely depends on the proper varieties, sowing time, fertilizer scheduling, water management, plant protection, proper harvesting etc. Selection of a variety has an active role as the genotypic differences cause yield and quality variations in sugar beet.

Recently, the multinational seed companies Syngenta, SesVanderhave, Strub etc. have developed Tropicalized Sugar Beet (TSB) hybrids, which have high yield potential and sugar content. It is claimed that these genotypes can be grown successfully round the year and it is possible to grow the crop in the tropical belt, also. The Agricultural Universities in Maharashtra State and Vasantdada Sugar Institute (VSI), Pune have conducted preliminary research on sugar beet cultivation. During 2005-2007, the research was intensified with an object to test sugar
beet genotypes in various parts of the State in different planting seasons. The experience gained through these efforts is quite encouraging. Considering the thermo-insensitiveness, higher production potential (50-60 t/ha) and more sugar content (17 to 19%) of these genotypes, serious thought was given by the researchers, policy makers, sugar industry and the Government of India and the Government of Maharashtra State to exploit the crop to supplement the sugar cane crop as a source of raw material for the production of white sugar and ethanol. Considering the economic importance of sugar beet, the Vasantdada Sugar Institute (VSI) has initiated the work since 2002-03 on its potentiality in Maharashtra.

Tropical sugar beet varieties are gaining momentum in the country including the States like Maharashtra, Tamil Nadu, Uttar Pradesh, Rajasthan and Gujarat. In primary trials, the Syngenta varieties HI 0064 (Shubhra), Dorotea (Cauvery) and Posada (Indus) and IISR, Lucknow sugar beet varieties, IISR Comp 1 and LS - 6 were screened in 38 sugar factories in Maharashtra State.

The Samarth Cooperative Sugar Factory Ltd., Vadigodri, Dist. Jalna, Maharashtra State with financial support from Govt. of India and technical guidance of Vasantdada Sugar Institute has commissioned a pilot plant for processing of tropical beet for sugar production by mixing a juice of sugar beet in a juice of sugar cane (30:70). One private sugar factory from Maharashtra has also started to process only sugar beet juice for production of sugar from sugar beet and first harvests have delivered the expected high yield and top-quality sugar.

Harneshwar Agro Products Power and Yeast Ltd, Kalas, Tal. Indapur, Dist. Pune in co-operation with Syngenta Pvt. Ltd., has started a commercial cultivation of sugar beet on 12000 acres of farmers field.

Sugar beet, *Beta vulgaris* Linnaeus is a biennial and temperate climate-loving crop. The sugar content in the sugar beet was found to be 14 to 19 % and it contains 3 to 4 per cent more sucrose than sugar cane. Sugar beet can regularly produce 10 tonnes of white sugar /ha. in a 5 to 6 months growth period instead of minimum 12 months of cane crop growth.
period. One-hectare sugar beet crop can yield 9-10 tonnes of sugar or 6000-7000 lit. of ethanol (Baloach et al., 2002; Kakade, 1985; Anonymous, 2007). Research on Tropical sugar beet cultivation is in progress at Vasantdada Sugar Institute (VSI), Pune and maximum of, 108.19 t/ha beet yield has been obtained in a winter season (Patil et al., 2007).

Optimum time for sowing of sugar beet in Maharashtra State is second fortnight of October and sugar beet variety HI 0064 noticed suitable in respect of yield and quality, followed by Dorotea and Posada. Application of 120:60:60 Kg. NPK/ha is an optimum dose for getting the maximum yield and purity. However, it is necessary to chalk out the details and more precise cultivation practices viz. row to row and plant-to-plant distance, method of sowing, inter culturing, pest and diseases management, nutrient management as per soil type and climate zones.

Sugar beet is now emerging as a commercial field crop because of favorable characters like moderate water requirement of 80 – 100 ha cm, capacity to improve soil conditions and ability to withstand and grow in saline-alkali soils. The sugar factories are also eager in growing of sugar beet in their operational area’s as it is beneficial for them to prolong the crushing season and to reduce the cost of sugar production through maximum utilization of man power and infrastructure facilities.

Being a new crop, several constraints are noticed in the cultivation of sugar beet and the severe incidence of insect, noninsect pests and diseases is major, particularly in a rainy and summer season (Agnihotri, 1990; Cooke, 1993a; Cooke, 1993b; Patil et al., 2007). The various sugar beet diseases, fungal, bacterial, viral etc. are encountered sporadically in the field as per climatic conditions. The fungal, viral, bacterial pathogens that cause various diseases viz. *Erysiphe betae*, *Alternaria spp.*, *Cercospora beticola*, *Rhizoctonia solani*, *R. bataticola*, *Pythium betae*, *Fusarium spp.*, *Sclerotium rolfsii* are reported in India on sugar beet crop (Mukhopadhyay and Sharma, 1968; Singh et al., 1971; Sen et al., 1974; and Patil et al., 2007). The diseases reduced the root yield by 20-25% and have been found to be the main cause for low production of
sugar in Maharashtra. Control of diseases in sugar beet is also a crucial factor to maintain a strong and profitable sugar beet industry.

More than 500 insect and non-insect pests are recorded to infest the sugar beet crop at world level. Beet crop is a host of many devastating pests during its growth, although relative importance of each species varies from field to field, area to area and season to season. The pests infesting the sugar beet crop can be broadly divided in to three categories namely leaf and crown feeders (defoliators), root feeders and sucking pests. Among the leaf and crown feeders, sugar beet crown borer (*Hulstia undulatella* Clemens), web worms (*Loxostege sticticalis* L. *Loxostege similalis* L., *Spoladea recurvalis* Fab.), cut worms viz. black cut worm (*Agrotis ipsilon* Hufnagel), army cut worm (*Euxoa auxiliaries* Grote), army worms i.e. *Spodoptera litura* Fab., *Spodoptera exigua* Hub. (Plate 2' and grass hoppers (*Melonoplus differentialis* Thomos) are important to infest the sugar beet. Beet leaf hopper (*Circulifer tenellus* Baker), aphids, thrips, red spider mites and hoppers are the major sucking pests causing notable losses. Sugar beet root maggot (*Tatanops myopaeformis*), wire worms (*Limonius californicus* Mannerheim), white grubs (*Lachnosterna* spp., *Phyllophaga* spp.), root aphids (*Pemphigus populivenae* Fitch), nematodes, root knot nematodes (*Melidogyne* spp.) are the important subterranean pests infesting the beet (Whitney and Duffus, 1993). Rook, wood-pigeon, rabbit, hare, coypu, field mice are the important non insect vertebrate pests infesting the beet crop (Jones and Dunning, 1972).

Defoliating pests of sugar beet caused appreciable damage at different growth stages (Avasthy and Shrivastava, 1972; Khan and Sharma, 1971). In Europe, out of total sugar beet area, 40% area is severely attacked by defoliator pests and needs to be treated (Anonymous, 2001). In India, defoliating insects viz. *Spodoptera litura* Fabricius, *Diacrisia obliqua* Walker, *Plusia orichalcea* Fabricius, *Agrotis ipsilon* Rott. have caused the appreciable damage to the crop at different growth stages (Khan and Sharma, 1971; Avasthy and Shrivastava, 1972; Singh et al., 1980; Tewari et al., 1986; Patil et al., 2007).
*Spodoptera litura* is the most destructive pest of sub-tropical and tropical agriculture, and has the potential to be a serious pest of crops in Asia (Nathan and Kalaivani, 2005). The beet armyworm, *S. litura* (Lepidoptera: Noctuidae) is the most important pest causing severe damage to the beet crop in India. *Spodoptera litura* (Sugar Beet Armyworm) is the most important pest that occurs in epidemic form in Maharashtra State during winter and summer season. The beet webworm *Spoladea recurvalis* causes major damage, second after *S. litura*. If, sugar beet field is left unprotected, young larvae of *Spodoptera spp.* defoliate the beet crop completely and older larvae eat the entire leaf within a short period (Cooke, 1993b). Young larvae of *Spodoptera* spp. skeletonised the leaves however, the older ones eat the entire lamina and able to defoliate the crop completely in a very short period (Cooke, 1993b and Patil et al., 2007). Cent per cent defoliation by this pest has resulted in 42% beet root yield loss (Muro and Irigoyen, 1998). The full grown larvae of *S. litura* also feeds on beet roots, as they live in the soil during the day time.

As the sugar beet crop is relatively new to Indian conditions in general and Maharashtra in particular, it is highly essential to have a information on pests infesting sugar beet. Knowledge about the species abundance is important for the development of an integrated pest management strategy. Hence, studies regarding the biology of this pest infesting sugar beet are necessary.

Increasing area under some economically important crops (mainly soybean, Bt cotton, tobacco, sugar beet) and protected cultivation has provided suitable sites for feeding and overwintering of *S. litura*. The pest tends to occur earlier than before, which is helpful in building a large population by increasing their original numbers and generations in the field. Several workers studied the life cycle and biology of *S. litura* earlier in many crops. However, studies in sugar beet are merger. However, changing climatic conditions, changing cropping pattern and introduction of new crops to the new locality with reference to global warming conditions, it
makes highly necessary to study the biology and life cycle of the pest in the context of sugar beet crop introduction in India for its management.

Protection and maintenance of existing natural enemy population in integrated pest management (IPM) context represents an efficacious strategy to reduce the pest incidence. Hence, it is essential to record the natural enemies found on these pests. Combating such devastating pest, it is highly necessary to have all the options open to formulate the integrated approach. Resistant genotypes are one of the important options in this line. The resistance to *S. litura* attack can be identified by screening the various genotypes against this pest in the field. The identification of sugar beet resistance or susceptibility to *S. litura* helps in selecting the varietal pattern for commercial cultivation of the crop with minimum cost of plant protection. This will also prove helpful in developing resistant varieties to *Spodoptera*, in a near future.

The control measures recommended to the farmers should be economically beneficial. Therefore, during finalizing the strategies for the management of pests, it is needed to estimate the losses caused by *S. litura* in sugar beet. Excess defoliation due to insect pests is one of the reasons for notable yield reduction in sugar beet. Accurate estimates of yield losses are seldom possible in field trials using pesticides to control the damage, because the pest attack is rarely sufficiently uniform or severe to permit the collection of data and the pesticides may also give incomplete control, especially if applied too late. Therefore, it is necessary to make attempts to simulate the pest damage in artificial defoliation studies for estimating the losses in sugar and beet root yield which are important to the growers, who need to take the decisions on control measures to prevent such damage.

It is well known that most of the chemical pesticides are responsible for a variety of known and unknown adverse effects in animal and human health. These chemicals also have adverse effects on our environment. Despite the large consumption of chemical pesticides, it is estimated that crop losses vary between 20 and 30% due to pests alone. Keeping this point in view and fueled by lavish venture capital money and
unrestrained enthusiasm for biotechnology, a flush of biopesticide products arose in the 1980’s to exploit the extraordinary potential of biopesticides as environmentally benign alternatives to chemicals. In India, only 12 biopesticides (Bacillus thuringiensis var. israelensis, B. thuringiensis var. kurstaki, B. thuringiensis var. galleriae, B. sphaericus, Trichoderma viride, T. harzianum, Pseudomonas fluorescens, Beauveria bassiana, NPV of Helicoverpa armigera, NPV of S. litura, neem based pesticides, Cymbopogan) have been registered against 194 chemicals, which are used as chemical pesticides.

Releases of indigenous natural enemies particularly Trichogramma spp., application of microbial pathogens and use of selective and safer pesticides (botanicals, biopesticides, insect pathogens) in Spodoptera management programmes, without affecting the local natural enemies, are necessary. The role of biological control agents of armyworms is mainly carried out by generalist predators and parasitoids, especially during spring-summer. Study on the integration of different biological control agents (parasitoid and pathogen), botanicals and safe insecticides and their incorporation, as a component in integrated Spodoptera management is highly essential.

Although biological control has been found the effective against these pests, the disastrous pests like Spodoptera can be controlled through integrated approach including mechanical, cultural, biological and chemical control. Considering the limitations of bio-control viz. timely and sufficient availability at farmers level, time required for control, adverse climatic factors, it is necessary to have an option of need based chemical control in hand for quick and timely control of the pest. The various tools of management are advocated to manage the economic losses caused by pests and use of insecticides is the last step of defence during the severe incidence. However, there is a need for judicious use of insecticides when pest crosses the ETL.

Although chemical pesticides are generally cost-effective in controlling pests and diseases and, as a consequence, have become an
integral part of modern agriculture and many of these are also implicated in ecological, environmental and human health problems. New molecules with the improved properties are available. However, these are beyond the means of many farmers in developing countries due to their cost. It seems that indiscriminate use of insecticides for the control of pests in many commercial crops has led to the development of resistance inadvertently in insects to all the groups of insecticides world wide. *Spodoptera litura* has developed resistance against wide range of insecticides and a multifaceted approach is required for its effective management (Kumar and Regupathy, 2000). *Spodoptera litura* acquired resistance to endosulfan, cypermethrin, fenvalerate and monocrotophos (Radhika and Subbaratnam, 2006). The need for resistance management with the use of integrated management has a positive influence on the *Spodoptera* management for ensuring sustainability. New chemicals along with the conventional insecticides, if used judiciously and in rotation, can help in preventing the insecticide resistance in the pests. Bio-control methods viz. neem products, egg parasitoids are environmentally safe and therefore, seems most benefitting in integrated pest management. Considering *Spodoptera* as a major pest, the several control measures need to be evaluated to find out the effective and safe method and its proper inclusion in the IPM programme.

Integrated pest management (IPM) is becoming popular and also gaining momentum in recent years. Economic benefit accrued due to IPM practices like risk minimization and reduction in yield variations ensure constant returns. Further, the partial budget analysis of various IPM practices shows the higher additional returns and is obtained entailing low or very negligible costs. Benefit Cost Ratio (BCR) also indicates significant improvement in returns by producing IPM over other prevailing methods. In addition, there are various indirect economic benefits like protection of natural enemies, maintenance of human and animal health, reducing insecticidal resistance, reducing losses of crops, trees, water and wildlife. Some research evidence indicated that these indirect economic benefits even surpass the direct benefits (Sivaramane *et al.*, 1997). IPM strategies
involving all the tools such as mechanical, cultural, behavioral, host plant resistance, biological and chemical control are being advocated with the main intention of minimizing the ill effects of insecticides by restricting their use. It is essential to evaluate all these IPM tools to reduce *S. litura* incidence in commercial cultivation of sugar beet and other crops.

Development of ecofriendly management practices to obtain sustained crop yields over a long period is highly essential. Considering the pollution problems of chemical insecticides related to soil, water, natural enemies of pests, resistance, residue etc., the present work will help to minimize the pest problem in a cheaper and safe way at farmers level.

Considering the increase of sugar beet potential in India and *S. litura* as one of the most important barriers in commercial cultivation of sugar beet, the environmental hazards of chemical insecticides and their resistance in the pests, it is time to search for effective and cheaper integrated pest management strategies of *Spodoptera litura* in sugar beet. Therefore, considering the a menace of pests in sugar beet, the present investigations are undertaken with the following objectives,

1. To survey and identify the various pests of sugar beet.
2. To study the biology, life cycle and behavior of *S. litura* in the laboratory.
3. To record the natural enemies of *S. litura* in sugar beet fields.
4. To study the seasonal incidence of *S. litura* in various varieties.
5. To find out the nature and extent of damage caused by major pests.
6. To evaluate bio-control agents, botanicals and chemical insecticides against *S. litura* in sugar beet field.
7. To standardize IPM module for the control of *S. litura* in sugar beet.