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Pest Management Trends in Sunflower in Karnataka

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Abstract

Sunflower is the mainstay of edible oil security of our populace. Karnataka is popularly nicknamed as the "Sunflower State" of India, it occupies prime position on the oilseed map of the country, accounting for more than 50 per cent of the total acreage and contributing over 35 per cent of the national sunflower production. However, it is often cultivated on poor and marginal soils, coupled with lack of appropriate and timely plant protection measures, which makes it highly vulnerable to the vagaries of pest and disease attack. The poor sunflower farmer cannot take the risk of going for an additional investment on plant protection, since this crop is regularly at the mercy of biotic and abiotic stress factor/s , which is one of the primary reasons for the dwindling sunflower area and productivity in the current oilseed scenario.Therefore, this document is a comprehensive compilation of information which has been generated on sunflower pest management, giving a consolidated account of the status of different pests, their bio-ecology and different approaches that have been focussed upon in pest management research in sunflower in Karnataka during the last four decades.

Sunflower, *Helianthus annuus* Linn. originated in North America many centuries ago. It was taken to Europe and Asia in the late 16th century. Sunflower output rose in response to growing demand for sunflower seed oil because of its higher nutritional value, easy adaptability of the crop in different agro-climatic conditions and comparatively less cost of cultivation (Gangappa *et al.*, 1993a). Among the biotic stress factors hindering the successful production of this crop in country, insect pests and diseases are the most lethal ones. More than 114 insect and non insect pests have been recorded on sunflower in India. Among insects, 30 species belong to the order Hemiptera, 18 belong to Lepidoptera and 22 to Coleoptera and the remaining species belonged to six other orders (Bilapate and Chakravarthy, 1999). In Karnataka, on sunflower, among the different insect pests, the capitulum borer, *Helicoverpa armigera* Hub., the green semilooper, *Thysanoplusia orichalcea* Fab. and occasionally the leaf eating *Spodoptera litura* Fab. are the most important ones. However, the thrips (*Thrips palmi* Karni) transmitted necrosis virus disease has attained serious magnitudes. Moreover, the green leaf hopper, *Amrasca biguttula biguttula* Ishida and the other defoliator, *Spilarctia obliqua* Walker, are the other major pests (Jagadish *et al.*, 2003). In Southern Karnataka, five species of thrips infesting sunflower were identified, *viz.*, *Thrips palmi* (Karny), *Thrips hawaiiensis* (Morgan), *Scirtothrips dorsalis* (Hood), *Frankliniella schultzei* (Trybom) and *Haplothrips* spp., of which, *T. palmi* was predominant on the leaves, while, *T. hawaiiensis* was predominant on the flowers (Jagadish *et al.*, 2005). Shankergoud *et al.* (2006) reported three species of thrips as major ones in Northern Karnataka *viz.*, *T. tabaci*, *T. palmi* and *F. schultzei*. Recently, the mite, *Tetranychus ludeni* Zacher. was also reported as a pest on sunflower (Jagadish *et al.*, (2013b). Totally, ten species of insect pests were reported on sunflower at Bengaluru, of which the percentage of infestation of *Heliothis armigera* was 83.60,while almost fifty per cent of the leaves were damaged by the weevils, *Myllocerous viridanus* (Fabricius). The infestation level of termites was two per cent. (Thontadarya and Jayaramaiah,1973).

Crop loss inflicted by different pests : The gram caterpillar (*H. armigera* Hub.) and tobacco caterpillar (*S. litura* Fab.) in sunflower caused near total loss. *H. armigera* directly inflicts damage to sunflower by depriving the plant of ovaries and developing seeds (Bhat and Virupakshappa, 1993). Gram podborer (*Heliothis* sp.) and tobacco caterpillar (*Spodoptera* sp.) in sunflower cause near total loss. *H. armigera* directly inflicts damage to sunflower by depriving the plant of ovaries and developing seeds. The loss is greater if infestation occurs at the bud and bloom stages of the crop. As less as one *H. armigera* larva per head may cause economic damage to the crop (Margal, 1990). According to Panchabhavi *et al.*, (1977a), *H. armigera* might destroy more than 50 per cent of seed. Panchabhavi and Krishnamoorthy (1978) reported 267.2 kg / ha reduction in sunflower yield by defoliating insects, while, 120 kg/ha by *H. armigera*. They also reported that defoliating insects and *H. armigera* together reduced sunflower yields by upto 120 to 388 kg/ha. Monetary losses caused by insect pests on sunflower was estimated to be Rs. 321.23 / ha. (Thontadarya and Hiremath,1983). Rajagopal and Veeresh (1983) reported 91 per cent loss of root stubbles due to *Odontotermes obesus* Wasmann.The loss in seed yield due to defoliators in a rainfed *kharif* crop was upto 268 kg per ha at Bengaluru (Anon., 1976). Thontadarya and Jayaramaiah (1973) reported that 50 per cent of the leaves were damaged by *Myllocerus viridanus* (Fab.).

Crop loss estimation by releasing different levels of *S. obliqua* larvae under field conditions at peak vegetative stage revealed highly significant and positive correlation between the number of larvae per plant and loss in grain weight per head. The unit increase in larval population caused 0.49 g and 0.35 g reduction in grain weight per head, when released at peak vegetative and flower-opening stage, respectively. The magnitude of loss was low at flower opening stage than at peak vegetative stage (Kadapatti *et al.,* 1996). When the extent of defoliation was varied artificially, the yields also differed significantly *viz.,* 7.76 q./ha. and 6.91q./ha at no defoliation and 25 per cent defoliation, respectively (Yelshetty *et al.*, 1996).

Grasshoppers caused 10 to 70 per cent damage to seedlings and severely damaged seedlings were denuded of leaves. Due to severity of grasshopper and other seedling pests, the plant stand of sunflower crop could be reduced by more than 30 per cent (Basappa and Bhat, 1998). Artificial infestation of sunflower with mealybug proved that, 20 and 40 days after sowing were the most critical stages for mealy bug damage, wherein the plants showed severe yield loss, averaging only 1.55 and 35.53 g/plant, respectively (Chandrashekar, 2011).

1. Capitulum borer, *Helicoverpa (= Heliothis) armigera* Hubner

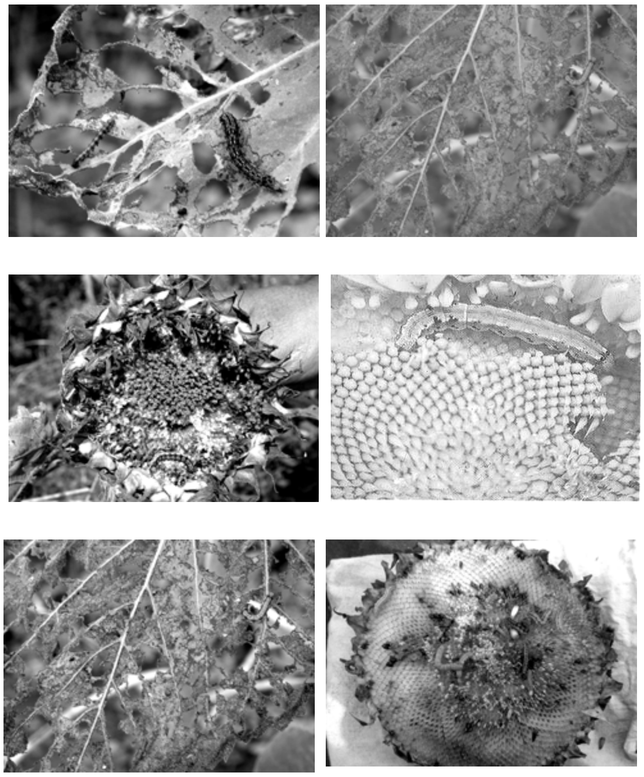


Fig. 1: Damage caused by *Helicoverpa armigera*

Bio-ecology : The full grown caterpillar reaches the ground for pupation and roams for about 15-20 minutes, locating a suitable site for pupation. The mean larval pupation on sunflower is 80 per cent. Pupa is obtect type, broadly rounded anteriorly and tapered posteriorly. The light green yellowish colour of the freshly formed pupa becomes light brown within 16 hours and gets further darkened prior to emergence of the moth. The abdomen is distinctly marked into 10 segments. The terminal segment is provided with a dark brown small sharp spine. The mean pupal duration on sunflower is 15.10 days for male and 14.57 days for female. Comparatively, male pupa is smaller (1.85 cm) than the female (1.81 cm) in length and weighs 279.06 mg. The moth emergence takes place in the evening, after 18 hrs. In general, female emerges earlier than male and mean per cent adult emergence ranges from 85.18 to 100 per cent. The moth is brownish grey in colour, having wing spread of about 4.2 cm in females and 3.6 cm in males. Forewings are pale brown with a marginal series of black dots. There is a black kidney shaped mark on the underside of each forewing. The hind wings are light in colour with a dark path at outer end. A tuft of hair is present at the tip of the abdomen in case of female.The larval weights of *H. armigera* ,reared on artificial diet added with protienase inhibitors from sunflower at 0.0380, 0.0760 and 0.1140 per cent w/w of the diet showed a significant decrease in weight gain on successive days of development , with larval survivability being 100, 66.66 and 50 per cent, respectively (Puttarangappa,1993).

Heavy *H. armigera* infestation (83.6 %) was observed with as many as six larvae per head (Thontadarya and Jayaramaiah, 1973). On the hybrid, KBSH-1 the larvae of *H. armigera*, moulted faster, bio-mass accumulation per stadia was significantly higher, larval growth was healthier, coupled with the highest larval biomass accumulation, mean stadial relative growth rate, mean stadial approximate digestibility (AD) , efficiency of conversion of ingested food (ECI) to body bio-mass on fresh weight basis, efficiency of conversion of digested food (ECD) on dry weight basis, so also the preference for oviposition as compared to the other genotypes *viz.*, 6D-1, BRS-3 and BRS-1. Survival percentage of larvae of *H. armigera* was maximum on ray florets, followed by immature ovary, half filled achenes and matured achenes in the decreasing order (Manjunatha, 2002). Adult female moths preferred to deposit 87.5 per cent of their eggs on the flower / head region, of which 73.19 per cent were on the calyx and 21.29 and 5.52 per cent were on the ray and disc florets, respectively (Pramod Katti *et al*., 2002a). At Bengaluru, peak incidence of *H. armigera* was observed during September – October (Bilapate and Chakravarthy, 1999). Outbreak of *H. armigera* is common in northern parts of Karnataka usually during late *kharif* and *rabi*, with a peak population during October (Shankergoud *et al*., 2006). Monitoring of *Helicoverpa* and through pheromone traps (pooled mean of 5 year data) indicated peak moth catches of *H. armigera* (49.90 / trap) in October, which coincided with maximum rainfall (225.7mm). Thus, rainfall has a positive influence on the trap catches of *H. armigera* (Jagadish *et al*., 2007) estimable equations to predict the trap catches of *H. armigera* and *S. litura* were constructed (Jagadish *et al.*, 2010a ; 2010b).

Economic injury level (EIL) and Economic Thresold level (ETL)

EIL for the cultivar Morden was 0.8 *Heliothis* larva / splant (Margal, 1990). Artificial infestation of sunflower heads were made at 0, 20, 40, 60, 80 and 100 per cent levels with the release of single first instar *Heliothis* larva / head to assess the crop loss and economic threshold level (ETL), the yield-loss / plant / *Heliothis* larva was 7.86 g (Anon, 1972). The ETL was 0.40 larva / plant in Bengaluru (Anon., 1972-93).

Management

(i) Cultural practices: Sole crop of sunflower attracted higher incidence of *H. armigera* than the crop mixed with redgram in 4:2 and 2:4 ratios (Anon, 1972-93). In contrast, intercropping increased the incidence of *Heliothis* on sunflower as compared to redgram. Sunflower is recommended to be grown as inter crop with red gram (2:1), groundnut (1:5) and also with ragi and soybean (Seetharam and Virupakshappa, 1989). Incidence of *H. armigera* was lower in the December and January sowings, highest in August sowings and moderate in September and November sowings (Meenakshi, 2006).

*(ii) Host plant resistance:*Unfortunately, sufficient genetic variability in resistance against mandibulate defoliator pests is lacking in sunflower that makes the development of resistant cultivars a near impossible task. Secondly, conventional host-plant resistance to insects calls for manipulation of quantitative traits at several loci, that slows down the progress and is difficult to achieve. So, conventional plant breeding techniques are unlikely to provide reasonable pest management solutions. Recent trends of pest management technologies provide reliable and viable options that revolve around the recombinant DNA technology.

Transgenic sunflower plants were developed through *Agrobacterium* mediated, *in planta* transformation protocol by incorporating *cry1AcF* gene into fertility restoring parental sunflower line RHA 95 C-1. These putative T1 transgenic plants were further analyzed by adopting evaluation strategies, *viz.*, ELISA, PCR and insect bioassays with *H. armigera* and *S. litura* larvae. From the detached leaf bioassay of PCR positive T1 generation transformants, the mean per cent leaf damage caused by *H. armigera* or *S. litura* was significantly more in non-transgenic plants as compared to transgenic plants of RHA 95 C-1 (Sakragoudra, 2010; Sakragoudra *et al.*, 2011). At Dharwad, in two different screening trials comprising of eight and 22 sunflower genotypes, the entries VRF-23 and DSH- 4 recorded the least damage by *H. peltigera* (Patil *et al*., 2000a; 2000b). At Bengaluru, in various screening trials, the entries, EC 101497, EC 101495 (Panchabhavi *et al*., 1977), KBSH-6, 7, 8, 9, TNSU-3, RHA-263, 291 B, 296, 460, EC-109281, 107285 and BRS-3 (Bhat *et al.,* 1996). Based on head damage, the entries 263, 274, 291, 296, 460, 418,422, 425, 437, 454, 409, 81, KBSH-1, 716 and 901 were found to be less susceptible to *H. armigera* from among the 250 entries screened (Basavaraja, 1990). From among the 15 entries screened, Panchabhavi *et al*. (1977a) observed lesser incidence of *H. armigera* on varieties EC 101497 and EC 101495. Bhat *et al.* (1996) screened a few hundred germplasm accessions and cultivars against *H. armigera*, among them KBSH-6, 7, 8, 9, TNSU-3, RHA-263, 291 B, 296, 460, EC-109281, 107285 and BRS-3 were superior.

(iii) Biological control: *Chrysoperla carnea* (Stephens) and nuclear polyhedrosis virus (NPV) were found to be more effective on *H. armigera*. Surveys conducted in various districts of Karnataka, revealed that *C. carnea* was the more predominant predator (Anon., 1992 ; Bhat *et al.*, 1993b). Release of early instar grubs of *C. carnea* @ 1 to 2 larva / head gave marginal reduction in egg and larval density (Bhat *et al.*, 1993b; Bhat *et al*.,1995). and by *Trichogramma chilonis* Ishii it was 50.1 per cent. Both *T. chilonis* and *T. pretiosum* Riley were more effective than *T. brasiliense* (Ashmead) in suppressing *H. armigera* (Ballal and Singh, 2003). Besides, 7 parasitoids, 3 pathogens and 20 predators of *H. armigera* were recorded, of which 3, 2 and 16 species, respectively, regulate pest incidence (Ballal, 1998; Singh and Ballal, 1999). *H armigera* larvae were free from parasitoids and pathogens in summer and *T. chilonis* formed an important mortality factor in *kharif* (Ballal, 1998). During good rain, entomopathogens like NPV, *Bacillus thuringiensis* Berliner, green muscardine fungus (*Metarrhizium anisopliae* Metschnikoff) Sorokin and white muscardine fungus, *Beauveria bassiana* (Balsamo)Vuillemin play a key role in suppressing *H. armigera* and defoliators (Bhat *et al*., 1993b). The mean number of eggs laid by *C.carnea* in the absence and presence of *H. armigera* was significantly highest on KBSH-1 and Morden and it laid least number of eggs of VRF-21 and DSF-2, whereas, *H. armigera* laid significantly lower number of eggs on VRF-21. *C. carnea* in absence and presence of *H. armigera* laid more eggs at flowering stage, followed by capitulum stage. *H. armigera* also followed the similar trend in oviposition pattern. The feeding potential of *C. carnea* was significantly higher on KBSH-1, Morden and RSFH-1 (Hanumantharaya, 2006). Ballal and Singh (2001) found that egg populations of *H. armigera* and percentage of plants with pest stages were significantly higher in the insecticide sprayed situation than in the unsprayed areas and the natural enemy populations, in most of the cases were on par in the treated and untreated areas. *T. chilonis* and the predators - ants, spiders and anthocorids were important biocontrol agents.

Altogether, 77 parasitoids and 33 predators have been reported on *H. armigera* infesting different crops The mortality of early instar larvae of *H. armigera* due to *Campoletis* may exceed 50 per cent in certain seasons. Diseases such as NPV and muscardine (white and green) fungi have been often noticed in the field on *H. armigera*. A number of other insect and bird predators are also found on *H.armigera* infesting sunflower (Manjunath *et al.*, 1985).

Surveys conducted in Chamarajnagar, Chikkaballapura, Mandya and Chikkamagaluru revealed the occurrence of three entomophagous coccinellid species (*Cheilomenes sexmaculata* Fab., *Coccinella transversalis* Fab. and *Coccinella septumpunctata* L.) and one mycophagous coccinellid (*Illeis cincta* Fab.) species. Entomophagous coccinellids were more predominant during vegetative stage of the crop and under irrigated conditions than during the flowering stage and under rainfed condition, whereas, maximum mycophagous beetle (*I. cincta*) population and its prey (powdery mildew) was found during flowering stage of the crop than in vegetative stage, besides, its occurrence was maximum under irrigated situation than under rainfed cropping situation (Dharshini and Jagadish, 2015).

(*iv) Effect of bio-pesticides* : Biradar *et al.* (1996) reported that application of *H. armigera* NPV (250LE / ha), followed by either endosulfan 35EC (1.0 l / ha) or methomyl 12.5L (0.5 litres/ha) was significantly more effective in reducing head damage by *H. armigera* and increasing yield than other treatments.

Flyash based dust NPV formulation was found to be more effective, though all other three dust formulations (Chalk powder, talc and lignite) were found significantly less effective compared to aqueous formulation. Starch based WP formulation was found to be more effective followed by bentonite and talc. Neem oil based formulation was significantly more effective compared to aqueous formulation. Besides, HaNPV @ 250 LE per ha was found to be significantly more effective which was at par with the NSKE five per cent followed by *Nomuraea rileyi* (1kg/ha), *Bacillus thuringiensis* (1kg / ha) and *Beauveria bassiana* (1kg / ha). However, two sprays of endosulfan (2ml / l) at 15 days interval was found significantly more effective compared to all the bioagents (Sireesha, 2000). Application of neem based pesticides did not affect the *C. carnea* population, but toxic chemicals like synthetic pyrethroids adversely affected the population of *Chrysoperla* (Hanumantharaya, 2006). Effective control of *H. armigera* was achieved by application of NPV (250LE/ ha) followed by insecticidal application (endosulfan 35EC @1.0 l/ha or methomyl 12.5L @0.5 lit./ha.) which increased the virulence of the pathogen and crop yield (Biradar *et al.*, 1996; Sajjanar *et al*., 1999 ; Bijjur *et al.*, 1991 and 1994, Balikai *et al.*, 1998 ; Balikai and Sattigi, 2000). Among the six biopesticides evaluated, NSKE (5%) , prosopan (10ml/lt) and both the chemical insecticides (endosulphan 35 EC @ 0.07% and profenophos 50 EC @ 0.05%) were significantly superior against *H. armigera* (Jagadish *et al*., 2010b).

(v) Chemical control: Insecticidal application at 40 DAS is most critical to suppress *H. armigera* and based on yield and B: C ratio, endosulfan (0.07%) spray on 25 and 45 DAS is ideal for its management (Bhat *et al*., 1993). Similar results were obtained by two sprays with endosulfan (0.05%) (Panchabhavi *et al*., 1977b; Gangappa *et al*., 1993b). Moreover, among dust and spray formulations, deltamethrin (0.002%) or cypermethrin (0.005%) or fenvalerate (0.005%) or malathion 5D or methyl parathion 2D (25 kg/ha.) at the bud stage were effective in suppressing *H. armigera* (Gangappa *et al*., 1993a). Consistent control of the sunflower pest complex was obtained with starthene 75SP application at 750 and 1000 g.a.i./ha, which also recorded highest yield (Chakravarthy,1999). Flubendiamide 20WDG (0.004%), indoxacarb (0.015%) and spinosad (0.0025%) recorded significantly lower population of *Helicoverpa* and higher yield, followed by profenophos (0.05%), *B. thuringiensis* (5.2 $\times 10^7$ spores / ml) and IPM module. Endosulfan and profenophos recorded highest cost: benefit ratio (Anitha, 2008)

II. Defoliators

1. Tobacco caterpillar (*Spodoptera litura* Fab.)

Bioecology : This pest usually appears in September. Under laboratory conditions, the incubation period of the eggs of *S. litura* was 3.01±0.06, larvae took 15.12±0.93 days to complete five instars, pupal period was 10.07±0.16 days and the longevity of male moths was 6.03 ± 1.12 days. Female moths lived longer (9.40 ± 1.81 days) than the male moths. The life fecundity data indicated that pre-oviposition period ranged from 28th to 30th day of pivotal age. Females deposited first batch of eggs on 31st day and continued up to 39th day. The first female mortality was observed on 7th day (lx=0.63) after the emergence of adult female. The females contributed highest birth (mx=266.16) in the life cycle on 34th day of pivotal age. The mean time required to complete the generation (T) was 45.72 days. The innate capacity (rm) and finite rate (λ) for increase in number was calculated to be 0.18 and 1.15 females / female / day, respectively. At this rate, the population of *S. litura* was capable to multiply 2.59 times / week under the given set of conditions. The hypothetical F2 values were estimated as 256339. Adults contributed only 1.17 per cent to the population of stable age, whereas, eggs, larvae and pupae contributed 54.4, 42.4 and 2.6 per cent, respectively for the laboratory population. Field collected population of *S. litura* recorded 88.01 per cent mortality. The highest mortality was observed in the larval stage (75.44%), followed by pupal stage (33.03%), egg stage (17.40%) and adult stage (13.33%). The survivorship and death rate curves indicated, high mortality rate in late larval instar and pupal stage. The major mortality factor in larval stage was *Sl* NPV and braconids (Geetha and Jagadish, 2014; 2015). Kulkarni and Hugar (1999) observed that for *S. litura*, castor and groundnut were the most preferred host plants, followed by mulberry > cabbage > strawberry > potato > tomato > sunflower, while, cotton was the least preferred host

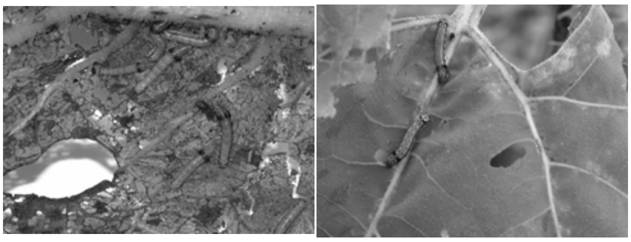


Fig. 2: *Spodoptera litura* damage

Peak incidence of *S. litura* and *S. obliqua* appears in September at Bengaluru (Bilapate and Chakravarthy, 1999). Defoliator incidence had a significant negative correlation with the minimum temperature and sunshine hours. Defoliator damage had a significant positive correlation with relative humidity, minimum temperature, rainy days, rainfall and negatively correlated with bright sunshine hours (Meenakshi, 2006; Meenakshi and Jagadish, 2006). Multiple regression analysis revealed that, weather parameters (maximum temperature, relative humidity, sunshine hours and rainy days put together) had an impact of 56, 71, 28 and 56 per cent on the incidence of leafhopper, thrips, defoliators and defoliator damage, respectively (Meenakshi and Jagadish, 2006). Sex pheromone trap catches of *S. litura* were observed to be maximum during first week of October and second week of December (Geetha, 2013).

Monitoring of *S. litura* moths through pheromone traps (pooled mean of 5 year data) indicated a bimodal peak in the pheromone trap catches of *S.litura i.e.*, September (81.6 / trap) and November (81.2 / trap), however, October recorded maximum rainfall (225.7mm, implying that rainfall does not have much bearing on the trap catches of *S.litura* (Jagadish *et al.*, 2007). Jagadish *et al.* (2010a) constructed the estimable equations to predict the peak moth activity of *S. litura* moths ,which can help to plan management interventions against *S. litura*.

Management

(i) Mechanical and cultural control: The gregarious phase of *S. litura* larvae is the weak link in the life cycle of this pest which can be collected on large scale and burned in soil. Summer ploughing also helps in reducing pest incidence. Light trap can be used to attract moth of this pest which inturn reduces egg laying and consequent pest population (Basappa, *et al.*,1999).

(ii) Chemical control: Spinosad (0.0025 %), novaluron (0.01%) and IPM module registered significantly lower pest population at seven days after first spray. At seven days after second spray, thiodicarb (0.075 %), profenophos (0.05%), chlorpyriphos (0.05 %) and endosulfan (0.07 %) proved effective. Endosulfan and Profenophos recorded highest cost: benefit ratio (Anitha, 2008).

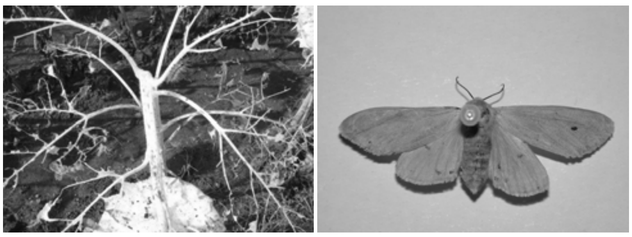
iii) Biopesticides: Panchagavya, an organic pesticide was found very effective in controlling several pests of sunflower and green gram (Anon., 2005). All the six biopesticides evaluated under field conditions *viz.*, *Spodoptera* NPV @ 2×10^8 POBs / ml, *Helicoverpa* NPV @ 2×10^8 POBs / ml, Pongamia seed kernal extract @ 5 per cent, Neem gold 0.03 EC (300 ppm) @ 0.5 per cent, NSKE @ 5 per cent and prosopan (*Prosopis juliflora* extract) @ 10 ml / lt were on par with the two insecticidal checks (endosulphan 35 EC @ 0.07 per cent and profenophos 50 EC @ 0.05 %) for the suppression of *S. litura*, semilooper and weevils (Jagadish *et al.*, 2010b). Among different bio-rationals evaluated against sunflower defoliators , NSKE proved to be the best bio-rational, followed by GCKE, V-Bt and Bt-Halt, compared to panchagavya, *Parthenium* leaf extract, *Sl* NPV and PSKE treatments. The treatment V-Bt recorded highest seed yield (3528 kg / ha.), volume weight (55.14 g / 100ml) and oil content (37.78 %), which was followed by the NSKE (3346 kg / ha seed yield) with a volume weight of 51.13 g / 100ml when compared to the other bio-rationals (Geetha, 2013).

2. Bihar hairy caterpillar - *Spilaractia obliqua* Walker

Bioecology : The defoliators, *S. litura* and *S. obliqua* usually appear in September at Bengaluru, (Bilapate and Chakravarthy, 1999). A significant positive correlation existed between the number of *S. obliqua* larvae per plant and loss in grain weight per head, when they were released at peak vegetative stage (Kadapatti *et al.*, 1996a). When the extent of defoliation was varied artificially, the yields also differed significantly *viz*., 7.76 q. / ha. and 6.91 q. / ha at no defoliation and 25 per cent defoliation, respectively (Yelshetty *et al.*, 1996)

Gregarious phase of Bihar hairy caterpiller (BHC)

Egg mass of BHC　　Pupae of BHC



Defeliation caused by BHC　　Adult BHC

Fig. 3: Life stages and damage caused by Bihar hairy caterpillar

Management

(i) Mechanical and cultural control: In the gregarious phase the life cycle of this pest, the larval masses can be collected on large scale at fortnightly intervals and destroyed 4 to 5 times during the season(Basappa *et al.*,1999).

(ii) Chemical control : Against *S. obiqua,* out of ten insecticidal formulations (EC, dust and poison bait) evaluated,fenvalerate spray (0.01 %) and dust (0.04 %), endosulfan spray (0.07 %) and dust (4.00 %) were most effective (Kadapatti, 1993; Kadapatti *et al.*, 1996b); methomyl 12.5 SL (3ml / lit.) gave significantly higher grain yield (1562.47 kg / ha) than endosulfan 4 per cent dust (20 kg / ha) and fenvalerate 20 EC (0.5ml / lit.) (Peerjade *et al.*, 1999). Indoxacarb 14.5 SC (@ 0.015 and 0.0075%), profenophos 50 EC (@ 0.05 and 0.025 %) and endosulfan 35 EC (@ 0.07 and 0.035 %) proved to be most effective against *S. obiqua* (Anitha, 2008).

3. Semiloopers (*Thysanoplusia orichalcea* and *Trichoplusia ni*)

Bioecology : T. orichalcea was one of the major pests to occur on sunflower, with its peak during the 37th meteorological week. Only rainfall had an impact on its incidence and while, humidity, wind speed and temperature had practically no impact. Only heavy rainfall of about (or) over 10 mm per week reduced its incidence drastically (Anon., 1989).

Total defoliation by semilooper

Semilooper damage on capitulum

Fig. 4: Semilooper damage and devastation

Management

i) Biological control: At Bengaluru, Revanna *et al.* (2003a;2003b) recorded seven parasitoids, three predators and three entomopathogens on *T. orichalcea*. Predation by the myna (*Acridotheres tristis* Linn.) was capable of reducing semilooper number from 3.95± 2.37 to 1.80± 1.32 in sunflower, in a span of 11 days, during October (Jagadish *et al.*, 2013a).

ii) Host plant resistance: Basappa *et al.* (1999) reported that the entries like No.213, 218, 220, 224 were reported to be promising against *T. orichalcea*.

iii) Chemical control: Thiodicarb 70 WP (0.075 %), indoxacarb 14.5 SC (0.015 %), novaluron 10 EC (0.01%) and IPM module proved to be effective in reducing the population of semilooper, *T. orichalcea* (Anitha, 2008).

4. Weevils (*Myllocerus* spp.)

Management

Spinosad 2.5 SC (0.0025%), novaluron 10 EC (0.01%), IPM module and endosulfan (0.07%) recorded slightly lower weevil populations, followed by chlorpyriphos 20 EC (0.05%), indoxacarb 14.5 SC (0.015 %) and thiodicarb 75 WP (0.075%) (Anitha, 2008).

III. SUCKING PESTS

Leaf hopper, thrips, aphids, whiteflies and of late the mealybugs are the important sucking pests of sunflower, of which, leaf hopper (*Amrasca biguttula biguttula* Ishida) and thrips are most important. They suck sap from the most of the plant parts which results in disfiguration and shrinkage of the plants. Among thrips , *Thrips palmi* (Karny) is the vector of necrosis virus disease.

1. Leaf hopper

Amrasca biguttula biguttula Ishida causes injury to the leaves by sucking cell sap. The edge of the damaged leaves turns pale green yellow and finally brick red or brown (hopper burn). The colour changes are accompanied by cupping of leaves.

Bio-ecology : The pest undergoes five nymphal instars, longevity of adult male was 22.80 days and 26.00 days for female, which laid 16-22 eggs, maximum leafhopper activity was during second and third week of November. This pest exhibited a significant negative relationship with maximum and minimum temperature and a significant positive relationship with morning and afternoon relative humidity (Madar, 2003).The mean incubation period, total nymphal period and adult longevity of *A. biguttula biguttula* was 7.20, 17.22 and 28.96 days, respectively (Kumar and Bhat, 2003). At 30 days after sowing the leaf hopper population was maximum in the middle leaves (0.217 nymphs / leaf), while it was lower in the top (0.038 / leaf) and bottom leaves (0.032 / leaf) (Jagadish *et al.*, 2004a). At Bengaluru, leafhopper population had a significant positive correlation with the maximum temperature and negative correlation with relative humidity (Meenakshi and Jagadish, 2006). Maximum temperature had significant positive influence (r = 0.788 to 0.892) on the build up of leafhopper on all sunflower lines tested. The daily minimum temperature also registered significant positive correlation with leafhopper population on five genotypes *viz.,* MSFH-17, KBSH-1, PAC-1091, GAUSUF-15 and TNAUSUF-7. Relative humidity had a significant negative influence on leafhopper population. The stage of the crop influenced the leaf hopper population level on the lines irrespective of sowing time. The flowering stage (55 DAE) followed by bud stage (40 DAE) and seedling stage (25 DAE) had 6.05, 5.48 and 4.24 leafhopper per leaf averaged over time and sowing date (Kumar, 2000).

At Raichur, leafhopper reached a peak population during December-January. Low relative humidity and high daily maximum temperature was found to have significant positive correlation with leafhopper population (Shankergoud *et al.*, 2006). The incidence of leafhoppers was high in *Rabi* and incidence was significantly and negatively correlated with maximum temperature, minimum temperature and wind (Pramod Katti, 2007).

Management

i) Host plant resistance: Bhat and Virupakshappa (1993) reported that 18 germplasm lines showed promise against jassids (Entries No.771, 775, 892, 1009, 1035, 1042, 1407, 1055, 1134, 702R, KBSH-8, BSH-1, S-55, EC-61039, 75268M, 77195, 10737 and 35811), either by supporting comparatively lesser population or not expressing cupping symptoms compared to the susceptible ones.

ii) Cultural Control: The eight sunflower lines were sown on different dates i.e., 13th September, 20th October, 22nd November, 12th January and 24th February. Leafhopper incidence averaged over sunflower lines were 5.41, 5.36, 5.00, 5.50, 5.61, 4.71, 5.21 and 5.99 against the crop sown on dates corresponding to the above dates. February sown crop was the most susceptible irrespective of the lines. The eight sunflower lines tested were on par with respect to leafhopper incidence (Kumar, 2000). Incidence of sucking pests *viz*., thrips, whiteflies, leafhoppers and aphids was higher in the early sown (30^{th}July) crop as compared to the late sown (27^{th}August) crop. Between the two cultivars tested, higher number of thrips, aphids, defoliators and head borer was recorded on Morden as compared to KBSH-1 (Jagadish *et al*., 2004b).

ii) Chemical control: Seed treatment with imidacloprid (7.5 g / kg. / ha.) recorded least population of leaf hoppers (Pramod Katti, 2001) while that with carbosulfan 25 DS (80g / kg seed) recorded least population of sucking pests (Pramod Katti *et al*., 2002b). Bhat *et al*. (2003) reported that sunflower seeds treated with imidacloprid (Goucho) @ 5, 7.5 and 10.0 g per kg of seeds gave significant control of sucking pests in sunflower upto 45 DAS.

Out of the seven insecticides screened as seed treatment, imidacloprid (5 g / kg) was effective in reducing leafhopper population, with highest grain yield (Madar, 2003).

2. Thrips

Several species of thrips are associated with sunflower crop at different phenological stages, their direct damage as a pest is insignificant, but they cause enormous loss indirectly, as vectors of necrosis virus disease. *Frankliniella schultzei* (Tryb.), *Scirtothrips dorsalis* (Hood), *Thrips palmi* (Karny) and *Megalurothrips usitatus* (Bagnall) were found to be associated with sunflower necrosis disease. *Microcephalothrips abdominalis* (Crawford), *Frankliniella damfi* (Priesn), *Thrips hawaiiensis* (Morgan) and *Thrips tabaci* (Lind.) are the other species recorded on sunflower(Basappa and Prasad, 2005). In Southern Karnataka, five species of thrips infesting sunflower were identified, *viz*., *T.palmi*, *T.hawaiiensis*, *S.dorsalis*, *F.schultzei* and *Haplothrips* spp., of which, *T. palmi* was predominant on the leaves, while *T. hawaiiensis* was predominant on flowers (Jagadish *et al*., 2003; 2005),while in Northern Karnataka three species of thrips were predominant on sunflower *viz*., *Thrips tabaci*, *T. palmi* and *F. schultzei* (Shankergoud *et al*., 2006).

Bioecology : Sunflower crop is infected by sunflower necrosis virus disease since 1997, seriously affecting the yield. The disease is transmitted through sap inoculation and also by thrips vector, *T. palmi*. At Bengaluru, incidence of the disease ranged from 0 to 34.6 per cent, with moderate incidence in *Kharif*- sown crop, negligible or no incidence on *Rabi*- sown crops and highest in summer crop (Shivasharanayya and Nagaraju, 2003). The population of *T. palmi*, showed a significant positive correlation with maximum and minimum temperature, bright sunshine hours and disease incidence (Shivasharanayya and Nagaraju, 2003; Meenakshi, 2006; Meenakshi and Jagadish, 2006; Pramod Katti, 2007). At 30 days after sowing the thrips number was highest in the middle canopy (0.198 / leaf) followed by the top (0.150 / leaf) and bottom canopy (0.021 / leaf) (Jagadish *et al*., 2004a). *H. ganglbaueri* was recorded on eight weeds and one crop plant, while, *T. hawaiiensis* was found infesting two weed species (Meenakshi, 2006). In Raichur district, 7 to 36 per cent incidence of the necrosis disease was recorded around Raichur, Manvi and Devdurg during *kharif* 1998 (Anon., 1998).

Anil Kumar (1999) reported that the sunflower necrosis virus disease was prevalent in all the sunflower fields visited during survey with the maximum per cent incidence (21.1) during the June. It was also observed that the incidence was more in crops sown during summer months, followed by *kharif* and *rabi* sown crops. Similar findings were also reported by Anjula (2000) and Aravind (2002). The disease incidence in the crop sown at different dates varied, ranging from 1.7 per cent in the crop sown in the September month to as high as 31.2 per cent in the crop sown in February. It clearly revealed that the incidence was very low in the crops sown during rainy period (September to October) and started increasing in the crop sown from December onwards (*Rabi*-summer). Further, the incidence was moderate in the crop sown from December onwards (Nagaraju *et al.*, 2003a). Nagaraju *et al*. (2003b) conducted an experiment during early *kharif* 1999, there was no incidence of the disease at 15 DAS, whereas, it ranged from 0.7 to 10.40 per cent at 30 DAS, 13.7 to 24.8 per cent at 45 DAS and from 3.70 to 31.30 per cent at 60 DAS. The incidence of the disease ranged from 0.0 to 34.60 per cent, with moderate incidence on *kharif* sown crop, negligible or no incidence on *Rabi* season crop and highest in summer season crop. Further, the thrips population (number / leaf) varied from 0.09 to 2.49, without much variation among seasons except on rainy days / 2 weeks.

Transmission of SND was carried out on 39 different crop plants belonging to different families, both by mechanical sap inoculation and through *Thrips palmi*. Mean per cent transmission of SNV through *T. palmi* ranged from 6.67 to 26.67. Highest mean per cent transmission of 26.67 was observed in case of *Helianthus annuus* (cv. KBSH-44), Arachis *hypogaea* (cv. JL-24) and *Citrullus lanatus* (cv. Arka Manik), followed by 23.33 per cent in *Macrotyloma uniflorum* (cv. PHG-9), *Vigna unguiculata* (cv. C-152) (16.67), *Cucurbita moschata* (cv. Arka Suryamukhi) (13.33) and *Nicotiana tabacum* (cv. Xanthi) (Pankaja, 2007).

Management

i) Cultural practices: Incidence of all the sucking pests was higher in the early sowing (30th July) as compared to the late sowing (27th August), whereas, the population of defoliators and head borer was more in the 27th August sowing (Jagadish *et al.*, 2004b). Incidence of major sucking pests was lower in the July, August and September sowings and higher in the December and January sowings. Defoliator incidence was lower in *rabi* - summer sowings and maximum in *kharif* sowings. The necrosis disease incidence was lowest in November and December sowings and higher in the January sowings (Meenakshi, 2006).

ii) Host plant resistance: Bhat and Virupakshappa (1993) reported that two entries (EC-101287 and EC-68414) were promising against thrips either by supporting comparatively lesser population or not expressing damage symptoms compared to the susceptible ones.

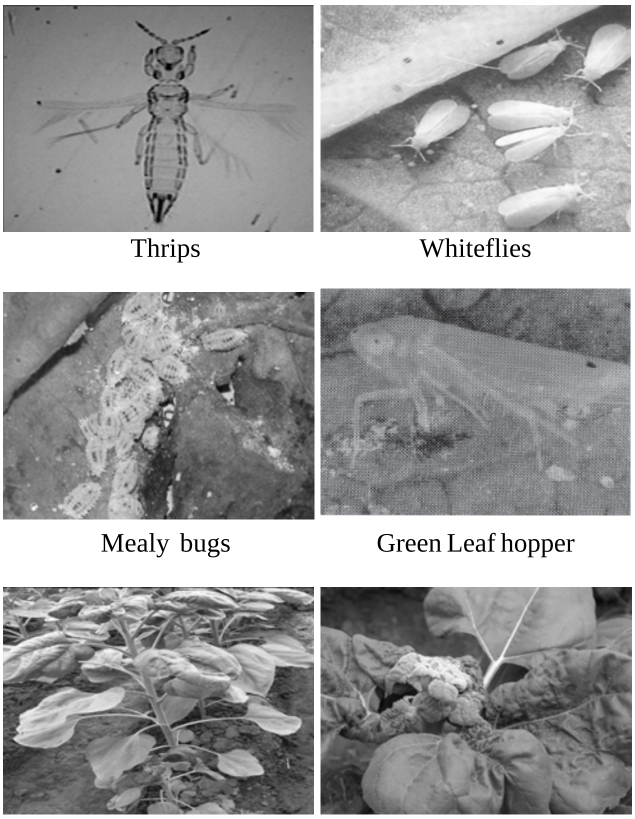
Among the cultivars, Morden was more susceptible to thrips, aphids, defoliators and head borer as compared to KBSH-1 (Jagadish *et al.,* 2004b). Out of 100 GMU entries screened, 25 entries were free from the incidence of thrips, 31 entries recorded thrips in the range of 0.01 to 0.10 per leaf, 34 entries carried a mean thrips number of 0.11 to 0.30 per leaf, while, 7 lines had a mean thrips number of 0.31 to 0.50 per leaf and three entries *viz.*, GMU 2, GMU 46 and GMU 84 were highly susceptible (Jagadish *et al.*, 2004a).

Out of 96 sunflower genotypes screened, eight genotypes *viz.*, RHA-284, RHA-6D-1, RHA-265, RHA-859, CR-1, RHA-297, R-214-NBR and RHA - 365 were free from the necrosis disease. Further, out of 167 sunflower genotypes screened, 39 genotypes were free from necrosis disease (Ajith Prasad, 2003). Out of 100 germplasm lines screened GMU 306, 318, 352, 359 and 374 were free from thrips incidence. In the varietal screening, DRSF-113 was most promising against leafhoppers, thrips and defoliators. Among the 17 initial level hybrids screened, Sunbred - Atul was most promising against sucking pests. Among the seven advanced hybrids screened, K-678, KBSH-44, PAC-1091 and MLSFH-93 were promising against leafhopper, KBSH-1 was promising against thrips population (Meenakshi, 2006).

Field screening of 106 sunflower genotypes revealed that the incidence of *T. palmi* ranged from 0.00 to 2.25 / plant and that of sunflower necrosis disease (SND) ranged between 0.00 to 100.00 per cent. The resistant entries recorded greater trichome density and length as compared to susceptible entries. Trichome density was significantly and negatively correlated with thrips population and SND. The total soluble sugar (TSS) content was significantly and positively correlated with the incidence of thrips at 30th, 45th, 60th DAS and pooled mean of these 3 observations. Total soluble protein content was positively correlated (but non-significant) with thrips incidence at 45th and 60th DAS, but, at 30th DAS it was significantly and positively correlated with thrips incidence. The total phenol content was negatively correlated with thrips incidence at 45th, 60th DAS (Shadhanaikural, 2009).

3. Mealybugs

On sunflower two species of mealybugs have been reported so far *i.e., Phenacoccus solenopsis* Tinsley and *Paracoccus marginatus* Williams and Granara DeWillink (Jagadish and Shadakshari, 2009; Jagadish *et al.,* 2010). In addition to sunflower, *P. solenopsis* was also infesting *Parthenium hysterophorus*, mulberry, *Morus alba* L. (Moraceae), *H. rosasinensis*, okra, *Abelmoschus esculentus* L. (Malvaceae) and a weed, *Blumea lacera* L. (Asteraceae) (Jagadish and Shadakshari, 2009). Sunflower is highly susceptible to mealy bug attack in the seedling stage. One adult can cause typical symptoms of curling of leaves, stunted growth, deformation and death of plants, within 30 days of germination. Infestation at vegetative stage, showed symptoms of leaf curling, stunted growth, deformation of leaf, leaf stalk and stem and there was no death of plants. If incidence was in the reproductive stage, there was no death of plant, but it affected flower buds and flowers leading to deformation and low or no seed setting (Anon., 2011).



Thrips   Whiteflies

Mealy bugs   Green Leaf hopper

Mealybug damaged plant

Fig. 5: Important sucking pests and their damage

Bioecology : Mealybug infestation started appearing in the month of September and gradually increased as crop growth advanced. The mealy bug population was significantly and positively correlated with maximum temperature and negatively correlated with the remaining weather parameters (Hanchinal *et al*., 2010). On sunflower, at Raichur, peak infestation of *P. solenopsis* was observed from October to November, while no incidence was found from June to September (Anon., 2011). *P. solenopsis* female exhibited three nymphal instars, without pupal stage, while the male had two nymphal instars and a pupal stage. Fecundity was highest on sunflower (658.58), moderate on cotton (615.58) and lowest on *Parthenium* (568.89) (Chandrashekar, *et. al*., 2013). Totally, 59 plant species belonging to 24 botanical families were recorded as hosts of the mealy bug, majority of them belonged to the families Malvaceae, Asteraceae, Euphorbiaceae and Solanaceae. Ten species of ants belonging to three subfamilies under family Formicidae *viz*., Formicinae, Myrmicinae, Dolichoderinae were found attending to *P. solenopsis*, which transfer the nymphs from infested to uninfested hosts. Infestation on *Parthenium* commenced during the 1st week of January and gradually increased as the season progressed, reaching 156.20 / plant in 15th standard week (9th –15th April). No incidence of mealy bug was observed during 9th July-31st December, 2010. The mealy bug population was significantly and positively correlated with maximum temperature (0.870**) and sunshine hours (0.509**) and negatively correlated with rainfall (-0.177), morning (-0.627**) and evening (-0.743**) relative humidity (Chandrashekar, 2011).

Management

i) Biological control: Seven species of predators and parasitoids were recorded on *P. solenopsis*, of which the activity of the encyrtid parasitoid, *Aenasius bambawalei* Hayat was more pronounced (Chandrashekar, 2011). At Bengaluru, *P. solenopsis* was parasitized by the encyrtid *A. bambawalei*. In course of time the parasitized mealy bugs lost their mealy matter, became mummified and turned reddish brown. The extent of parasitisation ranged from 0.00-60.00 per cent on *Parthenium* and it was negligible (<10.00 %) on sunflower (Jagadish and

Shadakshari, 2009). Coccinellids like *Cheilomenes sexmaculata* (F.), *Coccinella transversalis* (F.), *C. septumpuncata* Fab., *Hyperaspis maindroni* Sycard were predominant predators on mealy bug. Predominant Coccinellid predator, *Brumoides suturalis* Fabricius and encyrtid parasitoid *A. bambawalei* caused mummification of *P. solenopsis* (Anon., 2011).

ii) Chemical control: Profenophos 50 EC (0.05 %) and buprofezin 25 SC (0.025 %) under glass house conditions, whereas, methomyl 40 SP (0.04 %), dimethoate 35 EC (0.05 %) and profenophos 50 EC (0.05 %) under field conditions were significantly superior in reducing the mealy bug population, besides registering higher C:B ratio (Chandrashekar, 2011).

IV. Vertebrate Pests

Sunflower seed is a preferred bird food because the seed contains many nutritious contents including proteins and fats essential for their growth, moult, fat storage and weight maintenance. In Bengaluru, 17 species of birds have been recorded in sunflower fields, of which 7 are seed eaters. Many other species frequently visit sunflower fields (Besser, 1978).

Rose ringed parakeet, *Psittacula krameri* is a slim,, grass-green parakeet with the typical short, heavy, deeply hooked, red bill It's main breeding season is between January-April / May. Hollow space in a tree trunk is the nest of this bird. Eggs, 3 to 4 hatch and developing nestlings are fed by both the parents. Young ones leave nest about 4 weeks after the egg laying (Ali and Repley, 1983). The feeding activity on sunflower begins at 8.00 a.m. and extends upto 6 p.m. In Chickmagalur (Karnataka), 14 per cent heads have been found to be damaged at the edges compared to 9 per cent at middle of the field. The damage period extends upto 7 weeks. Other bird species involved are Western Turtle Dove, *Streptopelia orientalis* Sykes locally called as 'Belavanahakki'. This species is not originally adapted for feeding on sunflower. According to farmers, this bird was first sighted depredating sunflower in 1989 at Sakrayapatna. Its beak is not too strong and therefore it does not directly feed on the seeds from head as done by parakeets. However, the bird has been observed perching on head and removing rind first, followed by seed picking in its beak, splitting of the seed coat and feeding on internal contents. The bird is seen feeding on the crop from 6.15 a.m. to 3.00 p.m. The feeding rate is 8-10 seed / 2 mm compared to 6-7 seeds / mm in the parakeet. Spotted dove, *Streptopelia chinensis* Gmelin and red headed bunting, *Emberiza bruniceps* Brandt are also observed extracting seeds from the heads. House sparrow feeds on the ripe and developing seeds. Crow and dove dig out and eat away the seeds before and after germination. For protecting sunflower crop from bird damage, location of the crop in relation to best bird habitat is important. Sunflower should not be planted within 400m of a roost, shelter belts, groves, orchards or other woody areas regularly used by birds. Lower planting rates to produce large heads, timing of planting to assure uniform ripening of the crop in the community and also mass cultivation of the crop by farmers of the area to avoid targeting of single plot or few plots by a large roost of birds are important actions to avert crop damage by birds. A major portion of the harvested cropland near bird roosts should not be ploughed until most or all of the sunflower fields are harvested. The stubble with shattered seeds serves an alternate bird feeding area until all sunflower crops in the area are harvested (Besser, 1978).

VI. Storage pests

In stored sunflower seeds, *Tribolium castaneum* (Herbst.) eggs were laid singly attached to the seeds on their cracks and cervices. Each stage *viz.*, egg, first, second, third, fourth, fifth, sixth instar larval and pupal periods lasted for 6.07 ± 0.8 , 2.23 ± 0.43, 6.15 ± 0.55, 4.30 ± 0.48, 5.83 ± 0.75, 6.38 ±0.96, 16.9 ±1.89 and 8.01 ± 1.95 days, respectively. Biology of *Ephetia cautella* (Walker) revealed that the mean egg, first, second, third, fourth larval instars and pupal periods were 4.03 ± 0.69, 3.09 ± 0.81, 3.78 ± 0.78, 8.34 ± 0.98, 10.78±0.73 and 6.97 ± 0.55 days, respectively. The total developmental period from egg to adult occupied 38.98 days. In case of *Corcyra cephalonoica* (Stainton), the pest took 52.31 ± 3.04 days to complete its lifecycle and the mean egg, first, second, third, fourth, fifth, sixth larval instars and pupal period were 5.95 ± 0.99, 4.80 ± 0.92, 6.52 ± 0.51, 5.04 ± 0.74, 3.71 ± 0.84, 5.09 ± 0.83, 10.47 ± 0.67 and 13.09 ± 2.23 days, respectively (Kumaranag, 2008). All the cracked grains, including soyabean and sunflower were found to be support the normal development of all the larval instars of *E. cautella*. Sunflower seeds of parental line RHA-273 also supported the pest development on the whole grains owing to its thin seed coat and it incurred 3.83 per cent loss in grain weight (Raviprasad, 1988).

Management

Proper sanitation and treatment with malathion+ thiram (2g / kg of seeds) were more effective in suppressing both *T. castaneum* and *E. cautella*, even after storing the treated seeds for upto 90 days after imposition of treatments (Kumaranag, 2008; Kumarnag *et al*., 2010b).

Integrated Pest Management in Sunflower

Efforts should be stepped-up to replace toxic chemicals with botanicals as far as possible. Introduction of plant species having insecticidal, antifeedant, repellent and ovicidal action on insect pests of sunflower may help to formulate a sound and sustainable IPM strategy (Lingappa *et al*., 1993). Because of the abundance of pollinators and their role in crop production, pesticide application (Bhat *et al*., 1993a) should be avoided as long as it could be. Under situation of the severe infestations of insect pests, timely application of environment friendly insecticides once or if need be, twice may be applied (Anon., 1972-93; Gangappa *et al.*, 1993a). Eco-friendly IPM technology was demonstrated in farmer fields at Raichur. IPM package involving sunflower KBSH-1 hybrid, seed treatment with thiram @ 3 g / kg seed, application of monocrotophos 0.05 per cent against sucking pests and mechanical collection of egg masses and gregarious stages larvae of *S. obliqua* proved superior than farmers practice of two rounds of spray with endosulfan (0.07 %) and monocrotophos (0.04 %) (Lingappa *et al*., 2003). Jagadish *et al.* (2006) reported that IPM module comprising of imidacloprid at 5g / kg seed treatment + two sprays of NSKE 5 per cent + two sprays of HaNPV at 250LE / ha led to significant decrease in population of leaf hopper, thrips, aphids and defoliators as compared to the insecticidal check and untreated control. In addition, higher incidence of predatory fauna , lower incidence of *H. armigera*, highest grain yield and cost:benefit ratio (1:2.32) was also obtained in IPM module, which demonstrated its superiority over chemical control.

The IPM module comprising of seed treatment with imidachloprid 70WS@ 10g / kg of seeds + NSKE 5 per cent spray + Release of *C. carnea* at 60,000 / ha (1/2 dose) + Ha pheromone trap @ 5 / ha was found superior which recorded lower incidence of all the sucking pests compared to other treatments. Protection offered by seed treatment, chrysopids, NSKE and chemical treatment against sucking pests and head borer was evidently reflected in the significantly higher seed yield of 9.40 q per ha (Hanumantharaya *et al.*, 2008). For the management of sucking pests and necrosis virus disease, the treatment comprising of RDF (100 %) + RPP was superior followed by treatment with vermicompost (2.5 t ha^{-1}) + RDF (50 %) + GCK (1 %) + vermiwash for leafhoppers, thrips and necrosis disease with higher yields. In another experiment, Treatment comprising of oxydemeton methyl @ 1.5 ml / l spray recorded lowest thrips population and lesser necrosis followed by treatment with sorghum leaf extract (10 %) + imidacloprid 17.8 SL @ 0.25 ml / l spray. Module-I comprising of growing sorghum along border (four rows) sown before 15 days of main crop followed by seed treatment with imidachloprid 70 WS @ 5 g / kg of seed and application of vermicompost (2.5 t ha-1) + 50 per cent RDF and application of two sprays of neem formulation was best IPM module in managing sucking pests and necrosis virus disease (Pramod Katti, 2007). Among the different IPM modules, bio-intensive module was significantly superior in suppressing leaf hopper, thrips and necrosis virus disease, while the adaptive and bio-intensive modules were superior against *H. armigera*, whereas, all the three modules were superior and on par against *T. orichalcea* and *S. litura* (Rajanna, 2008). Jagadish *et al*. (2015) reported that the bio-intensive IPM (BIPM) module comprising of seed treatment with imidachloprid (5g per kg) + metalaxyl (5g per kg) + hand picking and destruction of early instar caterpillars *S.litura* and *S.obliqua* + two sprays of spinosad 45 SC (0.0045%) was the most superior module by virtue of significantly lower incidence of all major pests, highest seed yield (2680 kg / ha), volume weight (43.28g) and oil content (39.45 %) , besides registering the highest IBC ratio of 5.74.

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