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Insect fauna associated with small millets in mid hills of Uttarakhand

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Abstract

India is the largest producer of small millets, which are often referred to as coarse cereals. Various biotic variables significantly affect the output and productivity of these small millets and among them, insect pests are major production barriers that cause high crop losses from sowing to crop harvesting. Although the current status of all the pests affecting small millet crops in Uttarakhand is unknown but shoot fly and stem borer have been identified as major pests of small millets in mid hills of Uttarakhand. Major small millets growing areas as well as various trials conducted under AICRP on Small Millets at Ranichauri Centre, VCSG UHF, Bharsar, Uttarakhand were surveyed at different crop stages in ten different locations during *Kharif*- 2019 and *Kharif*- 2020 to ascertain the status of insect fauna associated with the small millets. A total of sixteen species of insect pests damaging small millets from seedling stage to harvesting were reported. During survey, it was found that shoot fly caused infestation during early crop stage while stem borer induced infestation was noticed during the later crop stage. Shoot fly infestation contributed to stunted crop growth and side tillering with dead heart structure with potential to inflict damage up to 36.67 percent in state varieties of barnyard millet when control measures were not intervened at Gaja farm while stem borer infestation produced white ear heads and stem tunneling with maximum infestation of 33.33 percent in finger millet at Gaja farm and 20.00 percent infestation in barnyard millet at Gunogi village. Grasshopper caused infestation was in the range of 13.33 to 26.67 percent and 13.33 to 33.33 percent and aphid infestation ranged between 10.00 to 20.83 percent and 6.67 to 20.00 percent in finger millet and barnyard millet, respectively at different locations. The flea beetle, semilooper, chaffer beetle, sting bug and other pests were also reported in surveyed small millet crops as occasional occurrence. The present study thus contributed in the data available on insect fauna associated with small millets, major insect pests causing damage from seedling to harvesting stage along with average per cent infestation and their respective nature of damage and damaging stage in mid hills of Uttarakhand.

Keywords: small millets, survey, infestation, shoot fly, stem borer and grasshopper

Introduction

In recent years, millet production has risen. The millions of people living in arid and semi-arid tropical areas in Asia and Africa depend on millets as a food source ^[1, 2]. Millets are a sustainable food for economically poor people in rural areas and are also appreciated by urban populations for their rich mineral and vitamin content. Increasing market demand for millet has encouraged farmers to cultivate millet either alone or intercropped with legumes. In fact, millets are underutilized in developing countries, where food security is becoming increasingly important with a rising human population ^[3]. In addition, millets are resilient crops, making them appropriate for mitigating the agricultural effects of drought and climate change and solving nutritional deficiencies in rural areas ^[4]. They are now universally known as healthy cereals or nutri-cereals due to the realization of the nutritional supremacy of these grains and they represent a significant source of energy and protein for millions of people ^[5].

Eight millet species are cultivated worldwide. Small millets grown in India are finger millet, kodo millet, foxtail millet, barnyard millet, proso millet, little millet and brown top millet. The resilience exhibited by this crop is not only helpful in its adjustment to different ecological situations but makes it an ideal crop for climate change and contingency planting. This crop, being eco-friendly, is highly suitable for fragile and vulnerable agroecosystem of Uttarakhand. It is, therefore, preferred for sustainable agriculture and grown under organic farming in the hilly regions of Uttarakhand.

In Uttarakhand, small millets are grown under rainfed and low fertile soil conditions. The crop is known to cope up with various abiotic and biotic stresses, nevertheless, at least 150 insect species are recorded as feeding on millets [6]; of these, 116 species have been recorded from India. In recent years, the production of small millets has been strongly affected by various insect pests. Although the current status of all of these pests is not known, shoot flies, stem borers, ear head midges, leaf-sucking, and the panicle-attacking insects are considered economically important major pests. White grubs are also important in India in some of the regions. Sporadic attacks of blister beetles, armyworms, grasshoppers, chinch bugs, leaf beetles, head caterpillars and head bugs result in severe yield losses in certain seasons. However, occasional or minor pests are becoming a menace in some regions due to changes in ecology and cultural practices. The major pests across the millets at different stages need to be tackled by various means [7]. However, most of the pests are common to all species of millet [8].

Despite the economic importance of millet pests, information on possible control measures is limited because there has been little crop protection research and data available is less due to low crop value and the variation in species attack rates, especially on the less common millets. Under vulnerable conditions, some of the insects may cause heavy losses and can damage the entire crop. Research and survey in many parts of the country have confirmed that seed yield and seed quality are being adversely affected by various insect pests affecting the crop [9]. Several insect pests that can be widely grouped as defoliators, stem borers, root feeders, and sap feeders have been found to infest the barnyard millet crop.

In Uttarakhand, from sowing until harvesting, small millets suffer from various insect pests [10, 11]. Among the insect-pests, shoot fly and stem borer are the most damaging reported insect-pests in Uttarakhand. Now days, shoot fly and stem borer have become a major threat to barnyard and finger millet production in state Uttarakhand, however the other defoliators and sucking insect not only reduce yield but also deteriorate the final produce [10]. There is need to have resistance sources as these vital but underestimated crops are generally grown by poor and marginal farmers who cannot afford the application of insecticides. Very scanty information on the status of insect pests of small millets in mid hills of Uttarakhand is available. Most of the defoliators are minor pests, but their intermittent attack may necessitate appropriate and timely control measures against them. Looking to the status of the pests in changing climate, an integrated approach for management of these pests is need of the hour. Taking into account the present scenario of enhancement in the degree of destruction of small millets in Uttarakhand due to insect pests, the present investigation was therefore undertaken with an aim to record the information on status of insect fauna associated with small millets, major insect pests damaging small millets from sowing to harvesting and per cent infestation caused by them in mid hills of Uttarakhand as monitoring of pest occurrence and population dynamics with per cent infestation and more data on available is needed to formulate location specific suitable IPM strategies for specific agro-ecosystem on priority basis.

Materials and methods

During the cropping season of *kharif*- 2019 and *kharif*- 2020, roving surveys were carried out at ten different locations located in the mid-hills of Uttarakhand at different crop stages

to determine the status of insect pests associated with small millet crops and their percentage of infestation. By visual observations, status of insect pests and damage caused by them were recorded. The insect pests associated with different small millets are presented in Table 1. During survey, data on visible natural enemies were also recorded.

The sampling was thereafter carried out by selecting five small plots from fields at each location and consequently six plants were randomly observed from each small plot and the per cent infestation caused by target pest was estimated by using following formula:

$$\text{Per cent Infestation} = \frac{\text{Number of plants infested}}{\text{Total number of plants observed}} \times 100$$

The recorded data pertaining to percent infestation caused by major pests in finger and barnyard millet crops at different locations are presented in Table 2.

Results

Insect fauna associated with small millets growing in mid hills of Uttarakhand

A total of sixteen species of insect pests damaging small millets from seedling stage to harvesting were reported during survey conducted for two consecutive years on small millets (Table 1), four of these pests were found major pests are shoot fly, stem borer, shoot aphid and grasshopper that caused economic harm to millets crop at farmers' fields.

The major insect pests and their nature of damage while infesting small millets that observed during survey are described below:-

Shoot fly

The injury by shoot fly results in a loss of grain yield and dry fodder. Shoot fly primarily attacks barnyard millet among small millets followed by proso millet and somewhat in finger millet. This pest causes damage from sowing till six weeks of old crop stage. Maggot feeds on the growing tip and as a result of its feeding, the central shoot starts drying and shows the typical symptoms of dead heart in the early stage and profuse side tillering in the later stage, which are also infested (Fig. 1). Damaged tillers may produce ear heads, but with no grains (white ears). In case of Barnyard millet, pest attacks the crop both in seedlings and boot leaf stage. It causes dead hearts in young millet seedlings and chaffy grains in terminal portion of panicle in the mature crop. Maximum incidence occurs during late July or early August in rainy season.

Identification: Dark grey housefly like 3-4 mm long flies. A female fly lays whitish cigar shaped (eggs singly on lower surface of the leaves). On hatching, the maggot enters the seedling whorl and destroys the growing point causing dead heart formation. Mature larva is yellowish with prominent and pupation takes place either at the plant base or in dead hearts. The fly population tends to increase in July and reaches the peak in August.

Stem Borer

Stem borer infests the crop from 2nd week after sowing till the crop maturity. Initially, the larvae feed on the upper surface of whorl leaves leaving the lower surface intact as transparent windows. As the severity of the feeding increases, blend of punctures and scratches of epidermal feeding appears prominently. Sometimes, dead hearts symptoms also develop

in younger plants due to early attack. Subsequently, the larvae bore into the stem resulting in extensive stem tunneling (Fig. 2a). Peduncle tunneling results in either breakage or complete or partial chaffy panicle (Fig. 2c). The female lays eggs in masses on the under surface of the leaf near the midrib. During the dry season, the larva enters into diapause and survives in harvested stalks/stems as well as stubbles left in the field. The moth is medium sized and straw coloured (Fig. 2b).

Aphid

Adults and nymphs suck sap from the tender leaves and spikelets and spread to entire plants. The leaf aphid is also called rusty plum aphid. It is brown to dark black coloured concentrated along the midrib of leaves, fingers of finger millet (Fig. 3a) and in barnyard millet on spikelets (Fig. 3b). The infestation was highest during dry spell continues throughout crop growth stage. In severely infested crop the ear heads are colonized by the aphids which are usually attended by the ants.

Grasshopper

Adult female lays egg pods in soil bund. The small nymphs come out from these egg pods during early rainy showers. In nymphs' wings, pads are present and they move by jumping from one place to another. The nymphs and adults of grasshoppers feed on the leaf by making marginal notching or holes on the leaves (Fig. 4a). Different species of grasshopper were found damaging the small millets (Fig. 4b) during survey. In severe infestation, they defoliate complete leaves and the field gives grazed appearance. Grasshoppers feed on foliage and on grain during grain filling stage which completely devastate crop.

Shoot bug

The adult is yellowish brown to dark brown with translucent wings. The brachypterous female is yellowish while macropterous female is yellowish brown and male is dark brown. Infestation was recorded from the 30 days crop stage. Both the adult types and nymphs suck the plant sap dwelling in leaf whorl causing reduced plant vigour and yellowing. It also causes damage to ear head during grain filling stage (Fig. 5). When ear head is touched, they try to hide inside it or jump away. In severe cases, the younger leaves start drying and this gradually extends to older leaves. Heavy infestation at vegetative stage may twist the top leaves and prevent either the formation or emergence of panicles.

Flea beetle

Flea beetle, recorded from finger and barnyard millet, showed different pattern of colouration on adult elytral portion (Fig. 7). Various coloured adults were observed comprising white adult with black spots, red adult with black spots and white coloured with red head and black markings on abdomen. Adult bites and makes holes in the leaves of young plants and affects the vigour in the young crop. Adults also feed on grains during milky stage as noticed in both finger and barnyard millet. Adult beetles are oblong in shape and dark blue with enlarged hind femur.

Ear head bug

The adults and nymphs damage the ear heads by piercing the stout proboscis and suck juice from the milky stage grains (Fig. 6). The sucked out grains, shrivel and turn black in

colour and become poorly filled or chaffy. Older sucked out grains show distinct feeding punctures that reduce grain quality. The level of injury usually depends on the number of bugs per panicle, extent of infestation and stage of grain development and infestation decreases as the grain becomes hard during dough stage.

Chaffer beetle

The adult beetle is metallic shiny colored which causes damage to leaf sheath and developing grains (Fig. 8). The half fed grains become whitish in appearance. Adults show the less mobility which hanging on ear heads or sitting on leaf like dead. These chaffer beetles majorly infesting the proso millet, finger millet and barnyard millet.

Semilooper

The larva is green to dark brown coloured that occurs on leaf margin which resembles to leaf (Fig. 9). Larva feeds marginally on leaves which results in notch like appearance. The heavy infestation leads to severe defoliation.

Earwig

The earwig has highly sclerotized body having forcep like prominent cerci, an identification character. In early crop stage, it feeds in leaf whorls and in later crop stages it causes damage to grains of both finger millet and barnyard millet (Fig. 10).

White grub

The white grubs feed on by cutting the roots resulting in wilting of plants in patches (Fig. 11) and plants die in severe attack. Infested plants remain stunted. The adults beetle feeds on leaves of tress adjacent to field during night time.

Leaf Folder

Larva folds a leaf blade together and glues it with silk thread. The larvae hide in leaf fold and feed inside folded leaf creating longitudinal whitish patches on leaf blade. Severe infestation hinders the photosynthesis due to reduced leaf area.

Hairy caterpillar

Due to gregarious habit and voracious feeding, complete defoliation of millet plants or destruction of seedlings may occur in a short time. Dark larvae feed gregariously on the lower surface of leaves scraping.

Ear head worm

The larvae feed on developing grains in the ear head. They produce network of silken thread that remain on and inside the ear head.

Grey weevil

Adults feed on leaf margins by notching resulting in wilting of plants in patches. Grubs feed on roots which results in stunted growth of plants.

Sting bug

Nymphs and adults feed on leaf by sucking sap in early stages of crop and later feed on developing grains (Fig. 12).

Natural enemies

The natural enemies associated with these pests belong to two orders Coleoptera and Diptera. The coccinellids are dominant

throughout the cropping season. The coccinellids predators such as *Coccinella septempunctata*, *Coccinella transversallis*, *Oenopia kirbyi*, *Oenopia sexareata* were observed from these crops (Fig. 13).

Percent Infestation caused by major Insect Pests of Small Millets

The observations on infestation of major insect pests (average of two consecutive years' data) at different locations in finger millet and barnyard millet are represented in Table 2.

The variability was observed in per cent infestation caused by major insect pests at different locations. The highest infestation of shoot fly in finger millet was recorded at Gaja farm and Salamkhet village (26.67%) followed by Tegna village, Kotdwara village, Gunogi village and Plant Breeding Block (20% in all places), whereas, maximum infestation of stem borer was recorded at Gaja farm (33.33%) followed by Kotdwara and Gunogi villages with 23.33 percent infestation in each location. At Gaja farm location, highest grasshopper infestation (26.67%) was recorded followed by Kenchu, Kotdwara and Maun villages where 23.33 percent infestation was recorded in all locations. The highest (20.83%) shoot aphid infestation was noticed at Salamkhet village followed Gaja farm with 20.00 percent infestation. Kenchu and Gunogi villages were at third position with 16.67 percent shoot aphid infestation

The infestation of shoot fly in barnyard millet was recorded highest at Gaja farm (36.67%) followed by at Chopariyal and Salamkhet villages (30% in each), whereas, maximum stem borer infestation was reported at Gunogi village (20.00%) followed by Gaja farm, Chopariyal village and Salamkhet village (16.67% in each). The maximum infestation (33.33%) of grasshopper was recorded at Gaja farm followed by 26.67 percent at Kenchu, Kotdwara and Maun villages. The 20 percent plants infested with aphid was recorded at Gaja farm followed by 16.67 percent aphid infestation at Tegna, Kotdwara and Salamkhet villages.

Discussion

In the present study, the major biotic threat to small millets seems to be shoot flies followed by the stem borer in mid hills

of Uttarakhand and the results are in agreement with the results of previous workers [12, 13, 14, 15]. In the current study, grasshopper was found as the dominant pest, among the defoliators, in both finger millet and barnyard millet and the results are in close concurrence with the results of Kalaisekar *et al.*, 2017; Jago *et al.*, 1993; Maiga *et al.*, 2008; [13, 16, 17] in small millet crops. The other pests recorded are remain as minor pests in small millet crops throughout the cropping season. The current results on the natural enemies feeding on the insect pests from small millets are corroborated with the findings of Sathish *et al.*, 2017; Sow *et al.*, 2018 [18, 19]. Nwanze and Harris (1992) [6] recorded about 150 insect species feeding globally on millets whereas, in India Kishore and Soloman (1989) [20] have reported that around 100 insect pests devastating the millets crop and 116 insect pest associated with millet have been reported by Kishore (1996) [21]. In present study, the variation identified in percent infestation data of shoot fly and stem borer may be attributed due to altitudinal gradient at different locations as these villages and experimental fields are located at different altitudes.

In barnyard millet the highest stem borer infestation was 20.00 percent at Gunogi village followed by Gaja farm with 16.67 percent infestation, these results in confirmatory with findings of Rawat *et al.*, 2019 [10] that reported 22.96 percent infestation in barnyard millet due to stem borer at Gaja location. Twenty percent infestation due to stem borer in finger millet was also reported by Sasmal (2015) [22].

Kishore and Soloman (1989) [20], who reported that more than 100 insect pest species are associated with the millet-based cropping method, partially confirmed the current findings. Although shoot fly is comparatively more serious insect attacking at vegetative and ear head stage in barnyard millet crop, as stated by Parmar *et al* (2015) [23]. Rawat *et al.*, (2019)[10] also recorded damage percentage of shoot fly in barnyard millet that ranged from 5.28 to 19.33 percent at Plant Breeding Block and from 7.22 percent to 25.00 percent at Gaja Research Station. The recorded damage percentage for stem borer ranged from 2.63 to 16.36 percent and from 4.07 percent to 22.96 percent at Plant Breeding block and Gaja Research Station, respectively.

Table 1: Insect fauna associated with small millets growing in mid hills of Uttarakhand

| Sl. No. | Common name | Scientific name | Family: Order | Occurrence | Damaging stage of insect | Host plant | Host part attacked |
|---------|--------------------|--|--------------------------|------------|--------------------------|--|----------------------|
| 1 | Shoot fly | <i>Atherigona</i> sp. | Muscidae: Diptera | Regular | Maggot | Barnyard millet, Finger millet, Proso millet, Foxtail millet | Central shoot |
| 2 | Pink or stem borer | <i>Sesamia inferens</i> | Noctuidae: Lepidoptera | Regular | Larvae | Barnyard millet, Finger millet, Proso millet | Stem |
| 3 | Shoot aphid | <i>Hysteroneura setariae</i> | Aphididae: Hemiptera | Regular | Nymph and Adult | Barnyard millet, Finger millet | Leaf, stem, ear head |
| 4 | Grasshopper | <i>Hieroglyphus</i> sp., <i>Cataloipus</i> sp. | Acridae: Orthoptera | Regular | Nymph and Adult | Finger millet, Barnyard millet, Proso millet, Foxtail millet | Leaf and ear head |
| 5 | Shoot bug | <i>Peregrinus maidis</i> | Fulgoroidea: Hemiptera | Occasional | Nymph and Adult | Barnyard millet | Whorl and ear head |
| 6 | Flea beetle | <i>Chaetocnema basalis</i> , <i>Chaetocnema pusaensis</i> | Alticidae: Coleoptera | Occasional | Adult | Barnyard millet, Finger millet | Leaf and ear head |
| 7 | Ear head bug | <i>Calocoris angustatus</i> | Miridae: Hemiptera | Occasional | Nymph and Adult | Finger millet | Ear head |
| 8 | Chaffer Beetle | <i>Popillia japonica</i> , <i>Cetonia aurata</i> | Scarabaeidae: Coleoptera | Occasional | Adult | Barnyard millet, Finger millet, Proso millet | Leaf and ear head |
| 9 | Semilooper | <i>Chrysodexis</i> sp. | Noctuidae: Lepidoptera | Occasional | Larvae | Finger millet | Leaf |
| 10 | Earwig | <i>Forficula</i> sp. | Forficulidae: Dermaptera | Occasional | Nymph and Adult | Barnyard millet, Finger millet | Grain |
| 11 | White grub | <i>Anomala dimidiata</i> | Scarabaeidae: Coleoptera | Occasional | Grub | Finger millet, Barnyard millet, Proso millet, Foxtail millet | Root |
| 12 | Sting bug | <i>Nizara viridula</i> | Pentatomidae: Hemiptera | Occasional | Nymph and Adult | Finger millet, Barnyard millet, Proso millet, Foxtail millet | Whorl and ear head |

| | | | | | | | |
|----|-------------------|----------------------------------|---------------------------|------------|----------------|--|----------------|
| 13 | Leaf folder | <i>Nephrosclerosis medinalis</i> | Crambidae: Lepidoptera | Occasional | Larvae | Finger millet | Leaf |
| 14 | Hairy caterpillar | <i>Amsacta lactinea</i> | Arctiidae: Lepidoptera | Occasional | Larvae | Finger millet, Barnyard millet, Proso millet, Foxtail millet | Leaf |
| 15 | Grey weevil | <i>Mylocherus</i> sp. | Curculionidae: Coleoptera | Occasional | Grub and Adult | Finger millet, Barnyard millet, Proso millet, Foxtail millet | Roots and leaf |
| 16 | Ear head worm | <i>Sitotroga cerealella</i> | Gelechiidae: Lepidoptera | Occasional | Larvae | Finger millet, Barnyard millet, Proso millet, Foxtail millet | Ear head |

Table 2: Average per cent infestation caused by major insect pests in finger millet and barnyard millet recorded during *Kharif*- 2019 and *Kharif*- 2020 from different locations in mid hills of Uttarakhand

| Sl. No. | Location | Finger millet (per cent infestation) | | | | Barnyard millet (per cent infestation) | | | |
|---------|-----------------------|--------------------------------------|------------|--------------|-------|--|------------|--------------|-------|
| | | Shoot fly | Stem borer | Grass hopper | Aphid | Shoot fly | Stem borer | Grass hopper | Aphid |
| 1. | Plant Pathology Block | 16.67 | 16.67 | 13.33 | 10.00 | 16.67 | 13.33 | 13.33 | 13.33 |
| 2. | Plant Breeding Block | 20.00 | 20.00 | 16.67 | 13.33 | 20.00 | 10.00 | 16.67 | 6.67 |
| 3. | Gaja Farm | 26.67 | 33.33 | 26.67 | 20.00 | 36.67 | 16.67 | 33.33 | 20.00 |
| 4. | Tegna Village | 20.00 | 20.00 | 16.67 | 13.33 | 23.33 | 10.00 | 20.00 | 16.67 |
| 5. | Kenchu Village | 16.67 | 20.00 | 23.33 | 16.67 | 20.00 | 13.33 | 26.67 | 10.00 |
| 6. | Kotdwara Village | 20.00 | 23.33 | 23.33 | 10.00 | 26.67 | 13.33 | 26.67 | 16.67 |
| 7. | Chopariyal Village | 16.67 | 20.00 | 20.00 | 10.00 | 30.00 | 16.67 | 23.33 | 10.00 |
| 8. | Gunogi Village | 20.00 | 23.33 | 20.00 | 16.67 | 23.33 | 20.00 | 23.33 | 10.00 |
| 9. | Salamkhet Village | 26.67 | 20.00 | 16.67 | 20.83 | 30.00 | 16.67 | 20.00 | 16.67 |
| 10. | Maun Village | 16.67 | 16.67 | 23.33 | 13.33 | 20.00 | 13.33 | 26.67 | 10.00 |

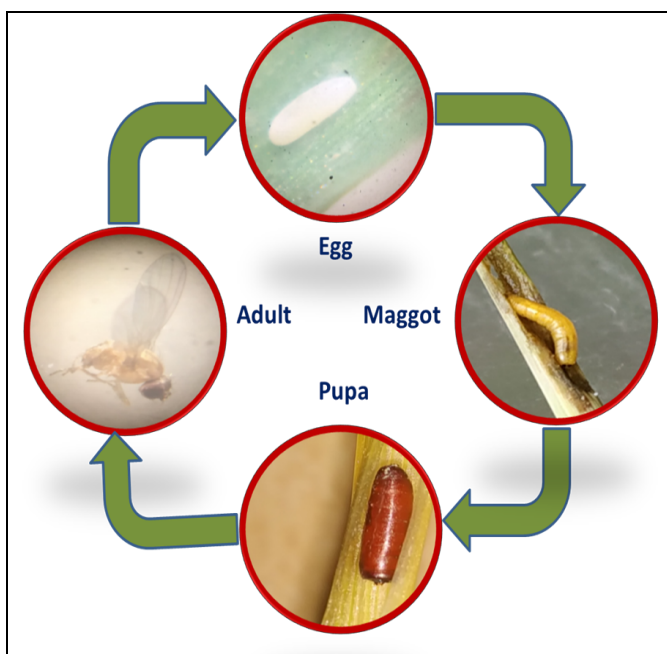


Fig 1: Different stages of shoot fly life cycle



Fig 2b: Adult of stem borer



Fig 2a: Stem borer of barnyard millet (Larva; Holes on penduncle; Tunnelling of stem; Pupae inside stem)



Fig 2c: White ear head caused due to larval feeding of stem borer



Fig 3a: Aphids on finger millet and ants feeding on honey dew secreted by aphids



Fig 3b: Aphids on barnyard millet ear head



Fig 4a: Feeding pattern of grasshopper on finger millet by notching the leaf margins



Fig 4b: Different species of grasshopper feeding on small millets



Fig 5: Shoot bug feeding on barnyard millet ear head



Fig 6: Earhead bug sucking the juice from milky stage of grains in finger millet and barnyard millet



Fig 7: Flea beetle feeding on leaf of barnyard millet and ear head of finger millet



Fig 8: Different coloured mettalic chaffer beetles feeding on leaves and grains of small millets



Fig 9: Semilooper larva feeds marginally on leaves of finger millet



Fig 10: Earwig feeding on grains of finger millet and barnyard millet



Fig 11: White grubs collected from small millets' fields



Fig 12: Sting bug feeding on developing grains of proso millet

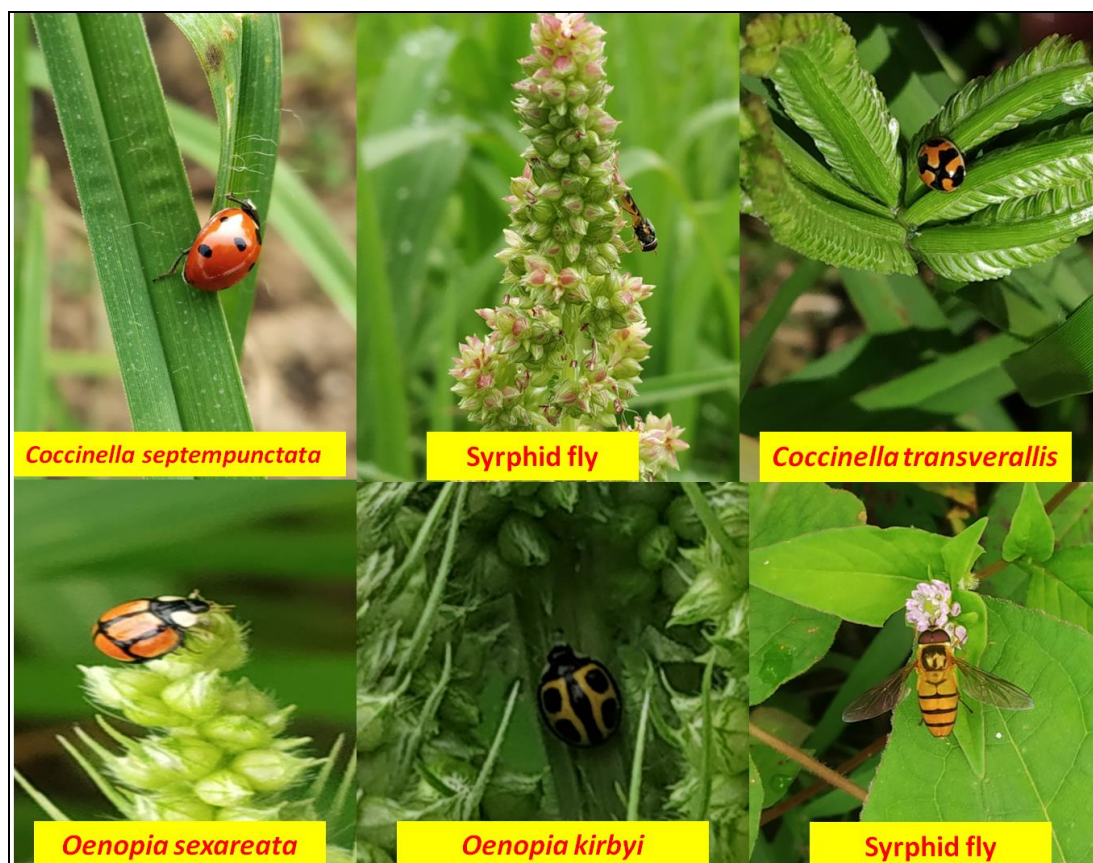


Fig 13: Diversity of natural enemies associated with the pests of small millets

Conclusion

In all millet growing areas of Uttarakhand, the production and final produce is greatly influenced by insect pests. The present study contributed in the data available on insect fauna associated with small millet crops, various insect pests causing damage to small millets and their respective nature of damage and damaging stage in mid hills of Uttarakhand. The gathered information might help in curbing insect pests' population and the known nature of damage in crop before sowing will help to tackle with this menace.

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