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Research Article

General distribution of different arthropods species associated with sunflower in Khyber Pakhtunkhwa: (A survey of Peshawar, Mardan and Swabi District:)

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Abstract

A field survey was carried out to record different insect pests, pollinators and natural enemies associated with sunflower, in three districts of Khyber Pakhtunkhwa i.e. Peshawar, Mardan and Swabi during 2012 and 2013. The collection was focused to recored insect pest, pollinators and natural enemies in spring and autum season on weekly basis from various sunflower fields till crop maturity. The districts were assigned as Site A (Peshawar), Site B (Mardan) and Site C (Swabi). Results showed that. Seedling and root feeding pests includedcutworm, Field crickets, Black field earwig and Grasshopper spp. Stem feeders insect included stem weevil and tree hoppers. Sucking pests were Whitefly, Leaf hoppers, Aphids and Green stink bug), defoliators included leaf beetle, Tobacco caterpillar, Cabbage semilooper and Hairy caterpillar and (Capitulum borer, Thrips, Brown stink bug and Seed Weevil recorded as capitulum or seed feeders. Apart from insect pests, honeybees, bumble bees, carpenter bees and halictid bees were recorded as pollinator associated with sunflower. Among the recorded insect pest, Lepidopterous insect were the most dominant ((milkweed butterfly, cabbage butterfly, yellow butterfly, diamondback moth and swallowtail butterflies) Followed by Dipterous insect that include, syrphid fly as pollinating agent of sunflower. Furthermore, ladybird beetle, green lacewing, praying mantis, syrphid flies, tachinid flies and certain species of spiders were the natural enemies associated insect complex of sunflower.

Keywords: Arthropods; Natural enemies; Pests; Pollinators Sunflower

Introduction

Edible oil is Pakistan's largest food commodity and it ranks 2nd after petroleum. In Pakistan, the edible out production is quite low, that fulfill only 23% of our domestic demand while the rest of edible oil is

imported from different counties of the world... According Pakistan Oil Seed Development Board's (PODB), our country spent 224 billion Pakistani Rupees annually on the import of this single commodity. The considerable increase in country's population demands more edible oil that has to be substituted from local resources. Opportunities of indigenous oilseed productions have to be explored in the cropping system with future climate changes and increasing population of the country **[1]**.

Sunflower (*Helianthus annuus* L.) belongs to the family Compositae and it is generally cultivated in Pakistan as an oil producing crop **[2]**. According to **[4]** the area under cultivation of different oilseed crops in Pakistan is 3'704,940 (ha) with the production of 3'947,000 (tons), whereas area under cultivation of sunflower 155.30 thousand hectares with the production of 189.73 thousand tons annually.

Vulnerability of the sunflower insect pests and diseases is one of the main hurdles towards its production. Most of the insect pests attack on the buds and leaves, resulting in considerable yield reduction in sunflower production **[5]**. Moreover, some of these insect pests serve as vector for virus and other diseases. For instace, leaf curling, chlorosis and pre-mature senescence may be due to infestation of *Empoasca abrupta* g **[6]**. Cutworms (*Agrotis* spp.), American bollworm (*Helicoverpa armigera* Hubner), aphids (*Aphis gossypii* Glover), head caterpillar (*Tathmopoda theoris* Mayr), whitefly (*Bemisia tabaci* Gennadius) and several species of armyworms, grasshoppers, Loopers and jassids and beetles have been reported to be associated with sunflower **[7-9]** reported that whiteflies, aphids, thrips and leafhoppers are key sucking pests that contribute to yield loss of 46%

Beside the insect pests, a wide range of pollinators and natural enemies also visit sunflower during the crop growth. Honeybees (*Apis mellifera* L.) are the most important sunflower pollinators **[10]**. According to **[11-12]** honeybees may increase seed yield in sunflower by30% and oil content of seed by 6% in hybrid varieties with self-fertility. Pollinating agents are indispensable; otherwise, without their services, the yield would be drastically reduced.

In addition to pollinators, natural enemies potentially suppress the incidence of insect pests; which may include green lacewing, reduvid bug, mantids, syrphid fly larvae, spotted beetle and different species of spiders. Of these, spotted beetles are of great importance since they are generalist that may feed on whitefly, aphids, thrips, mealybugs, and scales, Lepidoptera and Coleoptera **[13-15]**. For instance, syrphid fly larvae (*Episyrphis balteatus* DeGeer) feed on many small caterpillars, aphids, scales and mealybugs **[16]**. Also, ladybird beetles (*Coccinella* spp.) are voracious insect predators of aphids and significantly suppresses aphids' infestation on sunflower crops **[17-18]** these natural enemies keep the pest population below economic injury level which ultimately increase the productivity.

Keeping in mind the economic importance of the sunflower crop in Pakistan, he current survey was therefore conducted to identify and document different arthropods species associated with sunflower in Peshawar, Mardan and Swabi districts in Khyber Pakhtunkhwa. The finding of this study may use as baseline for the taxonomist working on the arthropods fauna associated with sunflower at Peshawar valley of Khyber Pakthunkhwa.

Materials and methods

In the 2012-2013 growing season, in Peshawar (A), Mardan (B) and Swabi (C) districts, of Khyber Pakhtunkhwa, insect pests, pollinators and natural enemies were surveyed. The arthropods were collected on a weekly basis from the time of

transplantation till crop harvesting

Site A (Peshawar)

Peshawar (34.01° N, 71.53° E), is the capital of Khyber Pakhtunkhwa, with a total area of 1,257 km². It is situated at an altitude of 347 m (1,138 ft) above sea level. The mean maximum temperature exceeds 40° in summer while the mean minimum temperature is 25°C. During winter, the mean minimum temperature is 4 °C, whereas the maximum is 18.35 °C. The average annual precipitation level recorded is 400 millimeters (16 in) and the highest annual rainfall level of 904.5 millimeters (35.61 in) during 2003. The relative humidity varies from 46 to 76% during June through August.

Site B (Mardan)

Mardan is situated at 34.20° N, 72.05° E with total area of 1,632 km². Elevation of Mardan is 285 meters above the sea level. The temperature reaches its maximum in the month of June i.e. 41.5 °C. The mean minimum temperature recorded for the month of January is 2.1 °C. Maximum rainfall for August is 125.85 mm. Maximum humidity has been recorded in December at 73.33%. Due to the intensive cultivation and irrigation, the tract is generally moist and humid.

Site C (Swabi)

Swabi (34.12° N, 72.47° E) is situated at 321 metersabove the sea level. Total area of Swabi is 1543 km². Swabi is bounded by the district Buner in the north, in the east by Haripur district, on the south by district Attock, on the west by the Mardan and Nowshera Districts.

Sampling procedure

Methodologies adopted and materials used for collecting arthropods are briefed here.

Collection

Entomological nets were mainly used for collecting different arthropod species. Large and hard-bodied insects (grasshoppers and beetles) were picked by hand/ forceps and placed in the killing jar **[19]**. A sweep net was also used to collect flying insects including pollinators **[20]**. For collecting small insects, aspirator was used. The collected specimens were killed by placing them directly in the killing jar with Ethyl acetate and thus, the adult specimens were preserved directly, while the young ones were first reared to adult stage and after placing, those in killing jar were preserved.

Collection of soil insects

Soil insects like cut worm etc. were found under cracks, clods and plant residues near the base of damaged plants. For collecting cutworms, clods and soil around the newly damaged sunflower seedlings was carefully removed and collected specimens were dropped into a small jar with alcohol. Similarly, crickets and earwigs were directly collected by hands/ forceps and placed in the killing jar. Soil insects were generally inspected and collected soon after seedling emergence during initial growing stages of the crop.

Preservation

For preserving large and hard-bodied insects first, those were simply dip in boiling water for a more than one minute and then preserved in 70% alcohol. The small soft body specimens , were dip in hot water for about 30 second and then transfered themto 97% alcohol for 24 hrs before mounting on card point..

Mounting

Small size insects were kept in alcohol for 24 hours and then mounted on card points. The card was pinned through the base, and the small insects were glued to tip of the point. Each specimen was labeled with; (a) locality (b) collection date (c) collectors name and (d) host.All the collected specimens were kept in wooden collection box. To protect the specimens from museum pest attack and damp, naphthalene balls were placed in collection boxes.

Identification

Identification and labeling of the specimens were carried out in the Entomology Museum at The University of Agriculture, Peshawar. Identification was done by using standard taxonomic literature; different available keys, and comparative pictures were used. Unidentified specimens were sent to taxonomist at National Insect Museum at Agriculture Research Centre (NARC), Islamabad. Finally, all the identified specimens were deposited in the insect museum of Department of Entomology, The University of Agriculture, Peshawar.

Results and discussion

Insect pests associated with sunflower

Among the insect pests associated with sunflower crop, some of them are just occasional and infrequent pests, whereas many insect pests cause severe damage in the initial growing stages of the crop. As the crop move towards maturity, many insect pests attack on buds and leaves of the plant, which leads to increased pest incidence.

Table 1 indicates various insect pests that were recorded on sunflower crop. Sunflower pests were mainly divided into five major groups i.e. Seedling and root feeding pests, stem feeders, sucking pests, defoliators and capitulum or seed feeders.

Table 1. List of different insect pests recorded on sunflower in Peshawar, Mardan and Swabi districts of Khyber Pakhtunkhwa during 2012-2013

S. No.	Group Names	Scientific Names	Order and Family
1	**Seedling and Root Feeding Pests** (i) Cutworm spp. (ii) Black field crickets (iii) Brown field crickets (iv) Black field earwig (v) Surface Grasshopper (vi) Short Horn Grasshopper (vii) Long Horn Grasshopper	 *Agrotis ipsilon* *Teleogryllus* spp. *Lepidogyyllus* spp. *Nala lividipes* *Chrotogonus trachyptrus* *Attractomorpha crenulata* *Neoconocephalus* spp.	 Lepidoptera: Noctuidae Orthoptera: Gryllidae Orthoptera: Gryllidae Dermaptera: Labiduridae Dermaptera: Labiduridae Dermaptera: Labiduridae Dermaptera: Labiduridae
2	**Stem Feeders** (i) Stem weevil (ii) Treehoppers	*Cylindrocopturus adspersus* *Vanduzea laeta*	Coleoptera: Curculionidae Homoptera: Membracidae
3	**Sucking pests** (i) Whitefly (ii) Jassid/Leafhopper (iii) Aphids (iv) Thrips	 *Bemisia tabaci* *Amrasca devastans* *Aphis gossypii* *Thrips tabaci*	 Homoptera : Aleyrodidae Homoptera : Cicadellidae Homoptera : Aphididae Hemiptera: Thripidae
4	**Defoliators** (i) Leaf beetle (ii) Tobacco caterpillar (iii) Cabbage semilooper (iv) Hairy Caterpillar	*Zygorgama exclamationis* *Spodoptera litura* *Thysanoplusia orichalcea* *Spilosoma oblique*	Coleoptera: Chrysomelidae Lepidoptera: Noctuidae Lepidoptera: Noctuidae Lepidoptera: Arctiidae
5	**Head and Seed Feeders** (i) Capitulum borer (ii) Brown stink bug (iii) Seed weevil	*Helicoverpa armigera* *Euschistus servus* *Smicronyx* spp.	Lepidoptera: Noctuidae Hemiptera: Pentatomidae Coleoptera: Curculionidae

Seedling and root feeding pests

During the survey, it was found that seedling pests generally cut sunflower seedlings soon after emergence and pest attack was started

atearly stage of the plant development during both spring and autumn seasons. In case of spring-sown crops 2012-2013, infestation of these pests were observed during third and fourth weeks of March until second week of April. Similarly, the feeding damage of seedling and root feeding pests was recorded during end of July in autumn season.

Among seedling and root feeding pests cutworms, black field crickets, grasshoppers and black field earwigs were recorded in Peshawar, Mardan and Swabi districts. It was observed that cutworms cut off on new emerged seedlings and young plants below or above the soil surface usually at night, while rest at daytime near the freshly damaged plants inside the soil. Similar findings on seedling feeding pests of sunflower have previously report by **[21, 22]**. Because of seedling pests attack on crop, sometimes the plant stand of sunflower plant is reduced up to 30 percent **[23]**.

[24] reported that cutworm, *Agrotis ipsilon*is a devastating insect pest of sunflower. According to **[25, 26]** cutworm generally cut off the sunflower plants at the base and cause severe damage to the crop. **[27, 28]** described that cutworm, *Agrotis ipsilon* is a key insect pest of sunflower at their seedling stage. The cutworm caterpillars cut the immature seedlings just above the ground level during night times.

Field crickets recorded during the field survey had flattened bodies with long antennae, which can be confused with grasshoppers because they have similar body structure with jumping hind legs. Field crickets are normally minor and irregular insect pests of sunflowers. They tend to be nocturnal and feed on the leaves and stems of seedlings above ground level. Findings of the present study strongly corroborate earlier reports made by **[29]** who reported that a complex of soil-dwelling insect pests and different seedling insects heavily infested sunflower crop in Queensland, Australia. Two species of field crickets (*Lepidogryllus* spp. and *Teleogryllus oceanicus*) caused heavy damage to sunflower seedling plants.

Different species of grasshopper i.e. long horned grasshopper, short horned grasshopper and surface grasshopper were recorded during the course of investigation. Attack of grasshopper species was noticed in various stages of crop development. Grasshopper is polyphagous pest of different field crops including sunflower. All species of grasshoppers cause considerable damage to sunflower seedlings. Previous reports made by **[30]** stated that surface grasshopper (*Chrotogonus* spp.) is a serious pest of sunflower and cause significant losses to the crop. **[31]** also reported that Orthoptera is the largest order of insects consisting of short horned and long horned grasshoppers with widespread distribution throughout the India.

Black field earwigs were recorded as occasional and minor pests of sunflower. They were found feeding on freshly sown seeds, germinating seed and roots of the crops below ground level, which resulted in week establishment and poor population of the plants. Earwigs also chew the stems of newly emerged seedlings above ground. Our results are strongly supported by **[29]** who reported the attack of black field earwigs, *Nala lividipes* (Dermaptera: Labiduridae) on sunflower seedlings in Queensland, Australia.

Stem feeders

The sunflower crop damage during different phenological stages was observed by several stem feeding insects, which mainly included larvae of stem borer, the sunflower stem weevil and tree hoppers.It was noticed that larvae of stem borer make tunnels in the stems of sunflower. Lodging of the plants in the field is a good indicator of larvae of stem borer; however, lodging also is influenced by other factors like wind etc. Because of

stem bored larval infestation, the foliage becomes yellow in appearance and finally wilts. Damage of stem weevil was recorded in later stage of the crop development during last week of May to fourth week of June. **[32]** reported that the infested sunflower plants get dried up, turn black and have a sickly appearance. Damage is greater in plants grown in deep black soil (94.72%) than sandy soils (70.64%). **[33]** reported that the sunflower stem weevil, *Cylindrocopturus adspersus* (LeConte) is a major pest of sunflower in North and South Dakota, Minnesota, and Texas in the United States.

The treehoppers (Membracidae: Homoptera) are small sucking insect pests reported on sunflower for the first time in Pakistan. During spring season, the attack of treehoppers generally started from third week of May until third week of June, whereas their incidence was observed in the second week of September until harvesting of the crop. Infestation of treehoppers was observed at the base of the leaf stem and found on junction of leaf and stem of the plant, feeding on both portions. The distinguishing character of treehoppers is their long pronotum, which most often resembles horns. Upon feeding, they secrete sweet sticky material honeydew that most often attracts ants. The present findings are similar to that of the earlier investigations made by **[34]** that a treehopper, *Vanduzea laeta* is a common insect pest of cultivated sunflower as well as on several species of *Helianthus* in Southern latitudes. The treehoppers colonize stems of plant terminals and leaf petioles of sunflower, and usually tended by many ants because of the secretion of sweet sticky material.

Sucking pests

Sucking pests feed on stem and sap of leaves, which mainly include whitefly (*B. tabaci*), leafhopper (*Am. devastans*), aphids (*Ap. gossypii*) and green stink bug (*Nezera viridula*). Infestation of sucking insect pests starts from early stage of the crop and succeed throughout entire plant development period. During spring season, 2012-2013, the infestation of whitefly was initially noticed through 4th week of April and continued until the crop is harvested. While in case of autumn sown-crop, their incidence was observed during second week of August and remained present throughout the season. Heavy infestation of the pest was recorded in the last week of August until the first week of September. Similarly, during spring season, leafhopper infestation was started in the third week of April and continued until the end of May, whereas heavy infestation was observed in the 2nd week of May. During autumn 2012-2013, the pest appeared in small numbers during mid of August and showed their presence until the last week of September. Sucking pests damage the crop significantly and ultimately reduce the yield up to a great extent **[30]**. These are polyphagous insect pest with piercing sucking type of mouthparts and damage the crop in both the adult and immature stages. According to **[35]** they also play a fundamental role in the transmission of viral diseases. Similarly, **[36]** also reported that stunted growth of plants, cupped and crinkled leaves and burnt appearance of leaf margins are symptoms of damage by various sucking pests of sunflower. While sucking the cell sap from plant tissues, they infuse very toxic saliva into the tissues resulting into a condition known as hopper burn or toxemia. Necrotic spots appear on the leaves in case of heavy infestation and the leaves turn inward that lead the plant to yellowing, curling and wilting. **[37]** reported that *A. devastans* nymphs and adults damage plants by sucking cell sap from their leaves, which consequently result in leaf curling, drying, burning, and growth retardation. It was observed that low relative humidity and high

daily maximum temperature have significant positive correlation with their population density.

[38] reported that aphid feed on cell sap of the plants is an emerging serious insect pest in India. **[39]** also reported that aphid, *Ap. gossypii* feed on more than 70 different important host plants in Iran. The present results are in agreement with that of **[40, 41]** who reported that leafhoppers suck plant juices that results in leaf curling, burning, drying, and stunted growth of plants. **[42]** also observed that leafhopper, among all the sucking insect pests is the most important pest of sunflower. According to **[43]** the whitefly damages the crop extensively and reduces the crop yield up to a great extent. **[44]** also reported that whitefly attacks cotton, vegetables and sunflower. Whitefly not only damages the crops seriously, but also serves as carrier for viral infections and plays a vital role in the transmission of diseases **[45]**. **[46]** also reported heavy losses by Hemipterans.

Green stinkbugs are polyphagous pests of many crops, feeding usually on seeds, kernel and immature fruits of the plants. The body structure of green stinkbug is flat and shield-like, about half an inch in size and dark green color. The damage mainly results in dropping and malformation of seeds and fruits. They suck the cell sap and fluids from the tissues, buds, flowers and tender leaves by piercing their mouthparts. On each feeding site, a hard-bitten spot appears. The pest is active throughout the year, **[47]** stated that green stink bug is mainly attracted to fruit trees and pods of host plants, including corn, soybean, cotton, sunflower and sorghum. They feed on their fruiting structures, causing cost-effective losses to the crops. **[48]** demonstrated that total losses because of stink bugs during the financial year 2004 were projected at $9.7 million for the cotton industry across the United States.

Defoliators

Sunflower leaf beetle was initially observed in the last week of May and was showed their presence until maturity of the crop. Similarly, during spring season 2012-2013, heavy infestation of loopers and cabbage semilooper was observed in the second week of April, which was continued until the second week of May. The attack of cabbage semilooper was again noticed in the second week of August and their incidence remained present until harvesting of the crop. The incidence of hairy caterpillar was observed in the last week of September, which continued until the crop harvesting, however their infestation was not recorded during spring season.

Among foliage feeders or defoliators of sunflower, sunflower beetle or leaf beetle, tobacco caterpillars, cabbage or green semilooper and Loopers are the most serious and destructive insect pests. According to **[49]** the loss in seed yield due to defoliators in a rain fed Kharif crop was up to 268 kg ha^{-1}. If the defoliators attack is before flower initiation it would affect food partitioning between stem, leaves and roots and if it were later, it would affect growth of both vegetative parts and inflorescence.

Sunflower beetle is a small leaf-feeding pest that looks like Colorado potato beetle in general appearance. Because of their harsh feeding habits on leaves, defoliation occurs which may reduce sunflower yield and later on show a negative impact on seed setting. **[50, 51]** stated that both adult and larvae of sunflower beetle damage the sunflower crop. Adult sunflower beetle feed insensitively on sunflower foliage near the leaf margins mostly during day times, while their larvae are normally nocturnal and feed overall leaf surfaces. **[52]** reported that sunflower beetle is a key pest of sunflower crop in North America. Larvae of Sunflower beetle have aggregate distribution in the sunflower fields that severely damage the crop.

Tobacco caterpillars being a polyphagous pest of sunflower was observed in all sunflower growing areas. The pest was found feeding gregariously on foliage mostly during night hours, and observed burying in soil and nearby debris during daytime. Early instars larvae voraciously feed on green content of the leaves that give a mesh like look to smashed leaves, older larvae cause total defoliation of the plants. Larvae of cabbage or green semilooper are dark green in color having a thin white marginal line and two white lines on its back. They are mostly swollen at posterior end and tapers interiorly. Cabbage semiloopers are regular and serious pest of sunflower crop, mostly feed on young leaves. Loopers are rare pests of sunflower. They are similar to *Helicoverpa* but can be distinguished by making a full loop while moving.

[53] found that tobacco caterpillar *(S. liturae),* is a potential defoliator among all the sunflower insect pests. Observation made by **[54]** further confirms our findings, that cabbage semilooper, *Plusia orichalcea* is one of the major devastating pest among all different insect pests associated with sunflower in Kenya**.** **[55]** also, endorse our results, reported cabbage semilooper *(Thsanoplusia orichalcea)* as the most important and key pest of sunflower.

Hairy caterpillar is a polyphagous pest, feed on a number of plants of economic importance and can be seen throughout the year. Immature larvae feed gregariously on lower surface of sunflower leaves. In the larval stage, they have numerous hairs on their body, that is why know as hairy caterpillar. Their feeding habit is so voracious that they eat the entire chlorophyll substance of the leaves while only the veins are left.

[56] reported that heavy infestation of hairy caterpillar, *S. obliqua* on sunflower crop was recorded at Latur districts in India during 1985-86. Because of *Spilosoma* attack, the sunflower plants were severely damaged during kharif season at Latur in 1993. **[57]** strongly verify our findings that hairy caterpillar *(D. oblique)* is a major pest of sunflower, which seriously damaged sunflower plants during second week of October.

Head and seed feeders

The presence of *H. armigera* was noticed on newly emerged leaves in the second week of April and was continued until formation of buds and seeds on capitulum of sunflower. The incidence of seed weevil was noticed in the first week of June and their presence was observed until maturity of the crop. Infestation of thrips was recorded at the early stage of the crop but heavy incidence was recorded on capitulum of sunflower during June and was remained active until harvesting of the crop.

Capitulum borer or head borer is a polyphagous and potential insect pest of sunflower. The infestation of sunflower crop by *Helicoverpa* was found at young stage of the crop and it was noticed that their feeding continued up to budding and seed formation of the crop. Newly hatched larvae feed on leaves, buds and flowers while, grown up larvae bore inside the disc and feed on the developing seed. **[58]** reported the infestation of *H. armigera* on sunflower crop. Similarly, findings of **[59, 60]** also confirm our results who observed the infestation of *H. armigera* on sunflower.

Heavy incidence of thrips on seedlings and floral heads of sunflower was recorded during the present field survey in all three districts. Both adults and nymphs feed on the leaves and capitulum by rasping the surface tissues and sucking the exuded juices. Their feeding collapse plant cells and may result in deformed flowers, leaves and shoots. It was found that severe infestation of thrips on young plants caused deformation and browning of the leaves. A

number of thrip species are potential vectors of pathogens like tobacco streak virus (TSV) which is also previously reported by **[61]** thrip does not harm the sunflower crop significantly, but they serve as a vector of many viral infections and cause heavy losses indirectly. Sunflower necrosis is principle example of such association caused by tobacco streak virus. **[62]** further authenticated our investigations who stated that thrip (*T. tabaci*) is a sucking pest of sunflower observed on leaves but mostly found on capitulum portion of the crop.

The brown stinkbug, *Euschistus servus* was also found on capitulum of sunflower. It feeds on the vegetative parts, flowers, stems and foliage of sunflower. The attacked leaves contain lesions and ultimately become brown .The extent of damage mainly depends on the developmental stage of the crop.

The present research findings greatly comply with that of previous reports made by **[63-65]** who reported that stink bugs, particularly those of pentatomidae family are considered one of the most important insect pests of soybean crop thorough out the world. **[66]** also reported that brown colored stink bug, *Euschistisheros* is presently the most abundant specie of stink bugs particularly in the central states of Brazil.

Pollinators associated with sunflower

Table 2 shows pollinator species associated with sunflower, which mainly include different *Apis* and non-*Apis* species. Lepidopterous comprised of milkweed butterfly, cabbage butterfly, yellow butterfly, diamondback moth and swallowtail butterflies. Among the dipterans, syrphid fly was recorded as pollinating agent of sunflower. During the course of survey, it was revealed that all these insect visitors were equally distributed in Peshawar, Mardan and Swabi districts of Khyber Pakhtunkhwa and no specific pollinating species was recorded to be confined to any specific district.

Table 2. List of different pollinator species recorded on sunflower in Peshawar, Mardan and Swabi districts of Khyber Pakhtunkhwa during 2012-2013

S. No.	Common Name	Scientific Name	Order and Family
1	European Honeybee	*Apismellifera*	Hymenoptera:Apidae
2	Small Honeybee	*Apisflorea*	Hymenoptera:Apidae
3	Local Honeybee	*Apiscerana*	Hymenoptera:Apidae
4	The Giant Honeybee	*Apisdorsata*	Hymenoptera:Apidae
5	Carpenter bee	*Xylocopairridipinis*	Hymenoptera: Apidae
6	Green Metalic bee/ (*Halictus* bee)	*Halictus* spp.	Hymenoptera: Apidae
7	Syrphid fly	*Eristalinnus* spp.	Diptera: Syrphidae
8	**Other pollinator species** (i) Milkweed butterfly (ii) Cabbage butterfly (iii) Swallowtail butterfly (iv) Diamondback moth (v) Yellow butterfly	*Danauschrysippus* *Pierisbrassicae* *Papiliopolystes* *Plutellaxylostella* *Catopsillacorrcle*	Lepidoptera:Danaidae Lepidoptera:Pieridae Lepidoptera:Papilionidae Lepidoptera:Plutellidae Lepidoptera:Pieridae

Among all the observed pollinator species on sunflower, honeybees recorded the most active and principal group of insect visitors of sunflower and constituted major species involved in sunflower pollination. Honeybee is a highly social insect classified as *A.*

cerana, A. mellifera, A. florea, and *A. dorsata.* They are famous for its honey production and can be easily domesticated. They are very important pollinators, adoptable to a wide range of habitats and play a vital role in providing pollination for many plants of economic importance. Pollens of sunflower are heavy and sticky in nature, and cannot be carried by wind **[66]**. Therefore, honeybees are the primary source of pollination for better yield and improved seed setting. Capitulum or floral heads of sunflowers are very conspicuous that attract a large number of pollinators fauna, but among all pollinators the most fundamental, efficient and commercially important pollinator are the honeybee species.

Besides honeybees, other pollinator species like *Xylocopa* spp., *Halictus* spp., wasps, syrphid fly etc. were also recorded on the crop during the course of survey. Visitation by other pollinator species, like Dipterans (flies) and Lepidopteron (milkweed butterfly, cabbage butterfly, yellow butterfly, diamondback moth and swallowtail butterflies), their incidence were also recorded.

[67] reported that in Viamão (Brazil), 96% of the total sunflower insect visitors have been recorded as honeybee, *A. mellifera* L. Similarly, **[68]** stated that the European honeybee, *A. mellifera* L. is a typical and a standard for pollination of many crops. **[69, 70]** stated that the bumblebees nest or colonies are not as large and well managed as those of honeybees. The bumblebees are strongly built and tough-bodied pollinators, and are capable to work even under cooler and moist environmental conditions than do honeybees. **[71]** also elaborated that bumblebees are excellent pollinators of sunflower. Due to pollination services provided by these two potential pollinators, total number of seed, seed weight, and relative seed set has significantly increased. Unfortunately bumblebees were not found visiting the sunflower.

[72, 73] stated that Non-*Apis* bees have also been reported to pollinate sunflower and significantly improve the crop yield by enhancing the effectiveness of *A. mellifera.* **[74]** also reported that carpenter bees help in pollination of many economically important crops, including blackberry, canola, corn, pepper, pole bean, and sunflower. The findings of present research study are in agreement with that of **[75]** who reported that the Syrphidae are among the most essential pollinating flies in Ontario. The larval stage of syrphid fly have a very unusual ecology, since some species can grant supplementary advantage to crops as the larvae prey on slow-moving and soft-bodied insects like aphids. Similarly according to the previous reports of **[76-84]** syrphid flies are widespread pollinators and can be found wherever flowers are existing. **[85]** reported that halictids (Hymenopetra) also known as sweat bees are good pollinators of sunflower.

Natural enemies associated with sunflower

Table 3 indicates list of different predators and parasites associated with sunflower, whichmainly consisted of ladybird beetle, green lacewing, praying mantis, syrphid flies, tachinid flies and certain species of spiders. All these beneficial faunawere equally occured in Peshawar, Mardan and swabi districts of Khyber Pakhtunkhwa and no predator species was confined to a specific area.

Natural enemies are classified broadly as parasites, predators or parasitoids. Both the adult as well as immature stages of a beneficial insect play an important role in consuming many insect pests as their prey during their development. Natural enemies associated with sunflower include ladybird beetle, green lacewing, praying mantis and syrphid flies and tachinid flies. All these

insect species are important predators, which feed on majority of insect prey.

Among all the different species of natural enemies found on sunflower, lady bird beetles and spiders were the most abundant species, which constituted major group of all beneficial insects of the crop, followed by syrphid fly, praying mantids and green lace wing. Most of the ladybird beetles are beneficial natural enemies as both adults and larvae and feed on aphids, mites, soft-bodied insects, and eggs of many small insects.

Table 3. List of different beneficial fauna (Biocontrol agents) recorded on sunflower in Peshawar, Mardan and Swabi districts of Khyber Pakhtunkhwa during 2012-2013

S. No	Common Names	Scientific Names	Order and Family
1	Ladybird Beetle	*Coccinella*spp.	Coccinellidae:Coleoptera
2	Green Lacewing	*Chrysoperlacarnea*	Neuroptera:Chrysopidae
3	Tachinid Flies	*Trichopodapennipes*	Diptera:Tachinidae
4	Preying Mantid	*Mantis religiosa*	Insecta:Mantodea
5	Syrphid fly	*Toxomerus geminates*	Diptera:Syrphidae
6	Spider species	*(i) Thomisusprojectus* *(ii) Lycosakempi* *(iii) Hippasaagelenoides* *(iv) Lycosatesta* *(v) Lycosa Mackenzie*	Araneae:Thomisidae Araneae:Lycosoidae Araneae:Lycosidae Araneae:Lycosidae Araneae:Lycosidae

Majority of spiders found on sunflower were useful because they feed on small insects and other arthropods. Spiders are generally less noticeable arthropods found on sunflower. Similarly, green lacewing feed on a large number of small insect pests including aphids, whiteflies, thrips, psyllids and leafhoppers etc. and larvae are also known as aphid loins. Tachinid flies are similar in appearance to common houseflies, but differ clearly in their habits than common flies. Color of tachinid flies varies from brown to gray and its body is covered with small hair like spines. Praying mantids are commonly green or brown colored insect, large and much prominent in appearance because of their well-modified frontal legs use for holding the preys.

[86] described that majority of the predaceous coccinellids are entirely efficient predators of aphids, mealybugs, scale insects, whiteflies, thrips, leafhoppers, mites and other small and soft-bodied insect pest species. **[87, 88]** also stated that ladybird beetles are the most important biological control agents of aphids, mealybugs, scales, mites and other soft-bodied insect pests. Findings of **[89]** are in agreement with that of our present results who reported that *C. carnea* effectively controlled the Population density of *B. tabaci* in different cotton genotypes in Pakistan. Likewise, according to **[90-92]** green lacewing, *C. carnea*is a good biological control agent which feed on a variety of different pest species like aphids, thrips, whiteflies and mites etc. **[93]** reported that larval stage of tachinid flies are potential parasitoids and feed on different arthropods species. Tachinid fly species *Trichopoda pennipes*is the most victorious natural enemy of geen stink bug, *Nezara viridula* nymphs and adults **[94-98]**.

[99] reported that that praying mantids are efficient predators of many insect pests. Findings of **[100]** strongly verified our results on lady bird beetles and stated that larval stage of lady bird require aphid consumption for their development. **[93]** further endorsed our findings about syrphid flies that the syrphid flies or hover flies have been recorded as one of the competent bio control agents of aphids. **[99, 100]**

investigated that the spider are efficient predators in reducing small and soft-bodied insects. Similarly**,** **[83]** also reported that spiders associated with maize crop voraciously feed on leafhoppers, thrips, and aphids.

Conclusion

Based on survey in three districts of Khyber Pakhtunkhwa, different pests associated with sunflower were mainly divided into five groups i.e. seedlings pests, stem feeders, sucking pests, defoliators/foliage feeders and capitulum feeders. In addition to insect pests, many other beneficial insect species were also recorded on the crop. The collected fauna were also comprised of insect visitors such as Hymenoptera, Lepidoptera and Diptera however, Honeybees were recorded the leading group of pollinators on sunflower.

Authors' contributions

Conceived and designed the experiments: F Said, Performed the experiments: F Said, Analyzed the data: F Jalal, Contributed materials/ analysis/ tools: M Imtiaz, MA Khan & S Hussain, Wrote the paper: F Said.

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