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Diversity of Invertebrates Living on Greenhouse Tomato Crops on the Azzefoun Region (Tizi-Ouzou, Algeria)

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Abstract
Cultivated environments provide a habitat as well as various food resources for a large number of species of invertebrates, which can be phytophagous, predators and parasites, which act as natural enemies of agricultural pests, thus constituting means of biological control in agrosystems. An inventory of invertebrates, in particular arthropods, was made during the greenhouse tomato cultivation season of the Dawson variety in the region of Azeffoun, on the coast of Kabylia. The use of the sweep net, Barber pots and aerial or colored traps allowed us to capture 76 species divided into 46 families, belonging to 16 orders and 06 classes of invertebrates. Values of the Shannon diversity index are quite high, they vary from H'= 2.68 bits to H'= 4.84 bits. The equitability obtained for each type of trap varies from E=0.53 to E = 0.87. These values tend towards 1, which reflects a balance between the species living in the tomato crop.

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1. INTRODUCTION

A large number of invertebrate species which can be phytophagous, predatory and parasitic, as well as microbial pathogens which act as natural enemies of agricultural pests, provide the habitat and various food resources necessary in cultivated environments. Kennedy (2003) ; Zappala and *al.* (2012) ; Lozano et *al*. (2013) recall that among the functional group predatory insects and parasitoids play an essential role in the natural control of insect pest populations. Hill (1997) adds that most of the time these natural enemies make it possible to reduce the frequency of appearance of pest population peaks involving colossal economic damage. Choudourou *et al*. (2012) state that the preliminary step to successful crop protection is knowledge of the pests. The same authors add that this should be combined with knowledge of the auxiliary fauna which participates in the regulation of pests. In this context, we carried out an inventory of the invertebrates associated with the cultivation of tomato (*Lycopersicon esculentum*) arthropods and their classifications according to the different trophic regimes.

2. MATERIAL AND METHODS

2.1. Sampling of invertebrate populations

To carry out the inventory of the invertebrates and in particular the arthropods living on the greenhouse tomato crop, weekly sampling in a greenhouse of Dawson variety tomatoes in the Azeffoun region. To do this, three sampling methods are used, the sweep net for hunting Barber pots and colored traps for trapping. According to Ramade (2003), the different sampling methods depend on the environment to which the population studied is subservient. Roth (1963) adds that the trap must account for the relative proportion of the various species, genera or families.

For the realization of the inventory we placed the traps in a way to control all the directions of our study greenhouse, they are thus placed in quadra.

2.1.1 Sweep net

The sweep net is the tool of the professional entomologist. The method of mowing in the vegetation, is quite simply a so-called random hunt, its purpose is to dislodge insects from plants, in particular those which are on the tops of tomato plants in our case. The pocket of the sweep net must be made with a thick, strong, tightly meshed canvas, the depth of the bag of which varies between 40 and 50 cm, and a solid wooden handle. It makes it possible to capture insects in flight or on the ground to get an idea of the species existing in a given environment (Benkhelil, 1992). To obtain the entire stand, the mowing net must be used over the entire height of the vegetation by scraping the ground. This tool must be used by the same person to avoid fluctuation in results (Lamotte and Bourliere, 1969).

The contents of the bag are examined regularly after a few strokes of the net and the species captured are removed with the fingers, the flexible pliers or using the oral aspirator in order not to damage the fragile individuals.

2.1.2 Pot traps or Barber pots

According to Benkhellil (1992), Barber pots are interception traps which are used for the capture of fauna which circulate on the surface of the ground. We used, for the harvest of the walking invertebrates, in the studied greenhouse, 9 plastic containers of approximately 20 cm in diameter. The traps are buried vertically, so that the opening is level with the ground, the earth well packed around to avoid the barrier effect for small species. The traps are then filled to 1/3 of their content with water to which a wetting liquid has been added to prevent water evaporation and fix the trapped insects.

Each week the contents of the traps are poured through a fine-mesh strainer then transported to the laboratory in glass jars each bearing a label, on which are mentioned the date and the type of trap. Remember that with each sample, the water in the traps is renewed.

2.1.3 Colored traps

Color traps are yellow plastic containers. These traps have a double attraction for insects by their color and the presence of water which is a vital element (Roth, 1971; Benkhellil, 1992). The method of colored traps was chosen because it has the advantage of being specific to flying insects, it makes it possible to capture purely hygrophilous insects for which yellow radiation is particularly attractive, it is easy to use and is of lower financial cost. For the capture of arthropods from the tomato plot, we used 9 traps of yellow color, 15 cm in diameter and 10 cm deep. They are placed at a height of 1.5 meters, fixed with iron wires to the pegs placed for the device. The traps are filled to 3/4 of their content with water to which a detergent has been added to fix the captured arthropods. The wetting product reduces the surface tension of the water and causes the drowning of the trapped animals.

2.2 Laboratory working methods

2.2.1 Sampling and data collection on invertebrates

After each outing and according to the different capture methods, the recognition and identification of invertebrate species in the field is most often difficult in relation to the size and number of individuals. Thus, after the harvest, the analysis of the samples is done at the laboratory level using the following methods:

2.2.2. Sorting

For samples collected in the field, sorting begins with the separation of specimens belonging to different zoological classes. The second step consists in sorting the insects by order then by family to manage to define up to the generic or specific rank when possible.

2.2.3 Counting

After having counted them, the small individuals are kept in bottles containing alcohol at 70°, with the following information: the date; order; the family and the type of trap. The same indications are mentioned on Petri dishes in which medium to large individuals are dried; fixed and spread out for subsequent identification.

2.2.4 Identification

With the collaboration and precious help of specialist colleagues in certain zoological groups and the use of keys for insects determining like Seguy (1923), Perrier (1927, 1932; 1961), Pihan (1986), Chinery (1988); Delvare and Aberlenc (1989), the identification of the species is carried out for all the individuals collected in the greenhouse of tomato.

The determination of the arthropods is done by observing and comparing the chitinous parts such as the legs, the elytra, the mandibles etc.

2.2.5 Use of inventory results by ecological indices

In order to exploit the results relating to the species harvested, the ecological indices of composition and structure are used.

2.2.5.1 Exploitation of the results obtained by the quality of sampling

Sampling quality is determined by the ratio of the number of species contracted only once and in a single copy (a) to the total number of records (N). The ratio (a/N) lets know if the quality of the sampling is good. The smaller a/N simse the better quality of the sampling (Ramade, 2003). Remembering that according to this author, the closer the a/N ratio is to zero, the better the quality.

Q=a/N

a: number of species seen only once and in a single copy per survey

N: total number of readings

2.2.5.2 Exploitation of the results by ecological indices of composition

We used the following ecological indices: the total specific richness (S), the centesimal frequency.

2.2.5.2.1. Total species richness (S)

The total species richness (S) is the total number of species in the stand under consideration in a given ecosystem. It represents one of the fundamental parameters characterizing a stand (Ramade, 2003).

2.2.5.2.2. Centesimal frequency (relative abundance)

According to Dajoz (1971), the percentage frequency is the percentage of individuals of a given species in relation to the total number of individuals. It is calculated by the following formula:

F (%)= (ni/N)*100

ni: number of individuals of a given species.

N: total number of individuals of all species combined.

2.2.5.3. Ecological indices of structures applied to the fauna sampled

2.2.5.3.1. Shannon index

According to Ramade (2003), the diversity of a stand informs on the way individuals are distributed among the various species. The Shannon index takes into account the number of species present in the environment and the abundance of each of them. It is calculated using the formula:

H′= - ∑ pi log2 pi

H′: diversity index expressed in bit units.

Pi: relative abundance of each species Pi=ni/N.

log2: natural logarithm to the base of 2.

According to Blondel (1979), this index measures the degree of complexity of a stand.

- H′ is high: The population is made up of a large number of species with low representativeness.
- H′ is low: the population is dominated by one species or by a small number of species with a high representativeness.

This index provides information on the diversity of each environment taken into consideration. If this value is low, close to 0 or 1, the environment is poor in species, or that the environment is not favorable. On the other hand, if this index is high, greater than 2 implies that the environment is very populated with species and that the environment is favorable. This index varies both according to the number of species present and according to the abundance of each of them (Barbault, 2008)

2.2.5.3.2. Peilou equitability Index (E)
It is the ratio between the real diversity of the community H' and the maximum theoretical diversity H' max (Log2S) (Ramade, 2003).

E=H/(〖Log〗_2S)

The **equitability** index varies between 0 and 1.

Pélou's equitability E tends towards 0 when one species largely dominates the population and it is equal to 1 when all the species have the same abundance (tends towards equilibrium) (Dajoz, 2003).

3. RESULTS

The species identified in the Dawson variety tomato plot in the Azeffoun region by three sampling techniques are identified up to the generic or specific rank when possible and collated in Table 1.

3.1 Qualitative and quantitative inventory of living invertebrates in the greenhouse tomato plot Dawson variety in the Azeffoun region

The invertebrate species captured in the Dawson variety tomato greenhouse are presented in the following table:

Table 1: General table representative of the species captured by the different sampling techniques at the Dawson Variety tomato greenhouse

Classes	Ordres	Familles	Espèces	Ni	Sweep net	Barber Pots	Colored traps
Enthognate	Collembola	Entomobreidae	*Entomobrya nivalis*	08	-	+	-
Crustacea	Isopoda	Armadillidae	*Armadillidium vulgare*	13	-	+	-
		Glomeridae	*Glomeris sp*	06	-	+	-
Myriapoda	Scutigeromorpha	*Scutigeridae*	*Scutigeridae sp*	04	-	+	-
Mollusqua	Gasteropoda	Trochilidae	*Trochilus flavus*	11	-	+	-
Arachnida	Araignea	Philodromidae	*Tibellus sp*	21	+	+	+
		Lycosidae	*Lycosa narbonensis*	46	+	+	-
		Salticidae	*Salticidae sp*	14	+	+	+
		Thomisidae	*Thomisus sp*	10	+	+	+
	Araignea Trombidiformes	Tetranichydae	*Tetranychus urticae*	2	+	+	-
Insecta	Dermaptera	Forficulidae	*Forficula auricularia*	6	-	+	-
	Hymenoptera	Formicidae	*Cataglyphis bicolor*	203	-	+	+
			Messor barbarus	87	+	+	+
			Formica sp	06	+	+	-
			Pheidol pallidula	40	+	+	+
		Andrenidae	*Andrena labiata*	03	-	+	+
			Panurgus calcaratus	03	-	+	+
			Andrena fulvago	05	-	+	-
		Halictidae	*Halictus quadricintus*	02	+	-	+
			Lasioglos sumcalceatum	06	+	+	+
		Eupelmidae	*Eupelmus sp*	29	+	-	+
		Trichogrammatidae	*Trichogrammatidae sp*	07	-	-	+
		Ichneumonidae	*Ichneumonidae sp*	03	+	-	+
			Aphion luteus	10	+	-	+
		Apidae	*Apis mellifera*	57	+	+	+
	Coleoptera	Carabidae	*Macrothorax morbilusus*	09	-	+	-
			Harpalus paratus	22	-	+	-
			Harpalus latus	08	-	+	-
			Carabus auratus	06	-	+	-
			Bembidion sp	18	-	+	-
		Aphodidae	*Aphodius sp*	05	-	+	+
		Curculionidae	*Curculionidae sp*	03	-	+	+
		Nitidulidae	*Carpophilus sp*	33	-	+	-
		Chrysomelidae	*Longitarsus sp*	09	-	+	+

			Altica sp	16	-	+	-
		Coccinellidae	*Coccinella quatuordecimpunctata*	04	-	+	+
			Harmonia axyridis	13	-	+	+
			Hippodamia variegata	17	-	+	+
			Thea vigintiduopunctata	03	-	+	+
			Adalia bipunctata	02	+	-	+
	Diptera	Calliphoridae	*Calliphora vicina*	05	-	+	+
			Calliphora vomitoria	09	-	-	+
		Syrphidae	*Eristalis tenax*	10	+	+	+
			Syrphus ribesii	17	+	+	+
			Episyrphus balteatus	07	+	+	-
			Melanostoma scalarae	03	+	+	+
		Chloropidae	*Thaumatomyia notata*	02	-	+	+
		Empididae	*Hilara sp*	03	-	+	-
		Sciaridae	*Sciara sp*	04	-	+	+
			Zygoneura sp	04	-	+	+
			Sciara thaumae	01	-	-	+
			Sciara maura	05	+	+	+
		Muscidae	*Musca domestica*	27	-	+	+
		Culicidae	*Cules sp*	15	+	+	+
			Culex pipiens	31	-	+	+
			Anopheles sp.	03	-	+	-
		Drosophilidae	*Drosophila sp*	01	-	+	-
		Lauxanidae	*Lauxanidae sp*	10	+	+	-
	Heteroptera	Lygaeidae	*Nysius sp*	12	+	+	+
		Pentatomidae	*Dolycoris baccum*	03	-	+	+
		Reduvidae	*Reduvius sp*	09	-	+	-
		Triatominae	*Triatomina sp*	02	-	+	-
	Homoptera	Aphididae	*Aphis fabae*	43	-	+	+
			Dysaphis plantaginea	14	-	+	-
			Aphis citricola	24	-	+	+
			Myzus persicae	08	-	+	+
			Hyperomyzus lactucae	14	+	+	-
			Macrosiphum rosae	12	+	+	-
		Caccopsillidae	*Caccopsilla sp*	06	+	+	-
	Trichoptera	Trichoptera	*Trichoptera sp*	04	+	+	+
	Lepidoptera	Pieridae	*Pieris brassicae*	04	+	-	+
		Gelechiidae	*Tuta absoluta*	15	+	-	+
	Orthoptera	Gryllidae	*Grillus campestris*	04	-	+	-
	Neuroptera	Chrysopidae	*Chrysperla carnea*	06	-	+	+
	Odonatoptera	Calopterygidae	*Calopteryx splendens*	04	+	-	-
		Libellulidae	*Orthetrum coerulescens*	02	+	-	-
06	**16**	**46**	**76**	**1113**	**31**	**64**	**45**

The inventory carried out in the greenhouse tomato plot of the Dawson variety during the period of presence of the culture enabled us to capture 1113 individuals belonging to 76 species distributed over 46 families, 16 orders and 06 animal classes which are the Gastropoda, the Arachnida, Crustacea, Myriapoda, Enthognata and Insecta. We count a single species for Enthognata, myriapoda and mollusqua, two species for crustacea, 5 for Arachnida and 66 species for insecta (Figure 1).

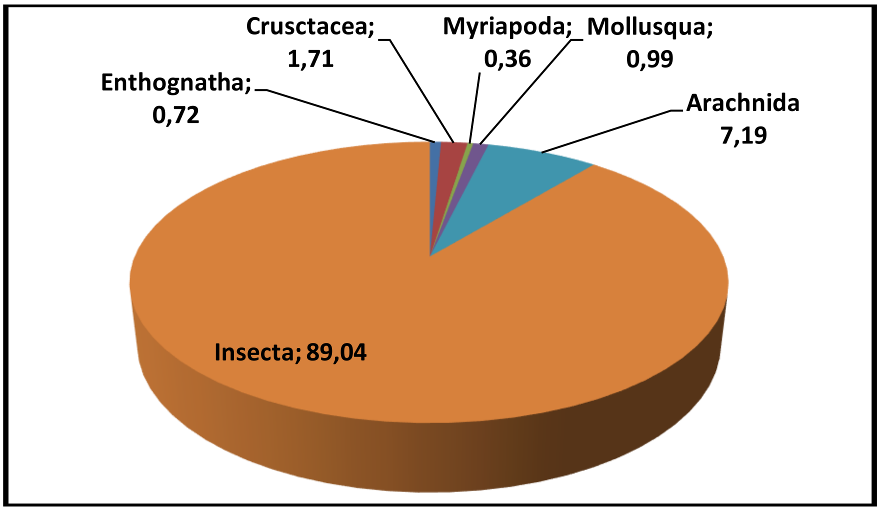


Figure 1: Percentage frequencies of invertebrate classes captured in the greenhouse on Dawson variety by the three sampling methods

The recorded results are evaluated by the quality of sampling, then exploited by the ecological indices of composition and structure.

3.2 Exploitation of the results by the quality of sampling by the use of different methods at the level of the different study plots

The values of the sampling quality of the species captured using the different sampling methods at the level of the study greenhouse are presented in the following table.

Table 2: Sampling quality values of the species captured using the different capture methods in the study greenhouse.

Methods	Sweep net	Barber Pots	Colored traps
Sampling quality (Q)	0.66	0.53	0.48

The values of the species captured only once and in a single specimen by the different sampling methods at the level of the study greenhouse are between 0.48 and 0.66, which indicates that the sampling quality is considered very good, because the values approach zero.

3.3 Exploitation of the results by the ecological indices of composition

The results obtained are exploited using ecological indices of composition, namely total richness and relative abundance.

Total richness of arthropod species captured using the three sampling methods at the study greenhouse The total richness of species captured using the different sampling methods is expressed in the following table:

Table 3: Total species richness captured by the different sampling methods at the study greenhouse

Methods	Sweep net	Barber Pots	Colored traps
Total richness S	32	64	45

Using the sweep net, the total richness is 32 species. Barber pots or land traps captured a total of 64 species. A total richness of 45 species is harvested with colored or aerial traps.

Percentage frequencies or relative abundances AR (%) applied to the orders of arthropods identified at the level of the study greenhouse by the use of the three sampling methods.

The relative abundances of the invertebrates harvested at the level of the study greenhouse by the application of the three capture methods (sweep net, colored traps and Barber pots) vary from one method to another (Figure 2). The dominance of some species over others depends on the capture method used.

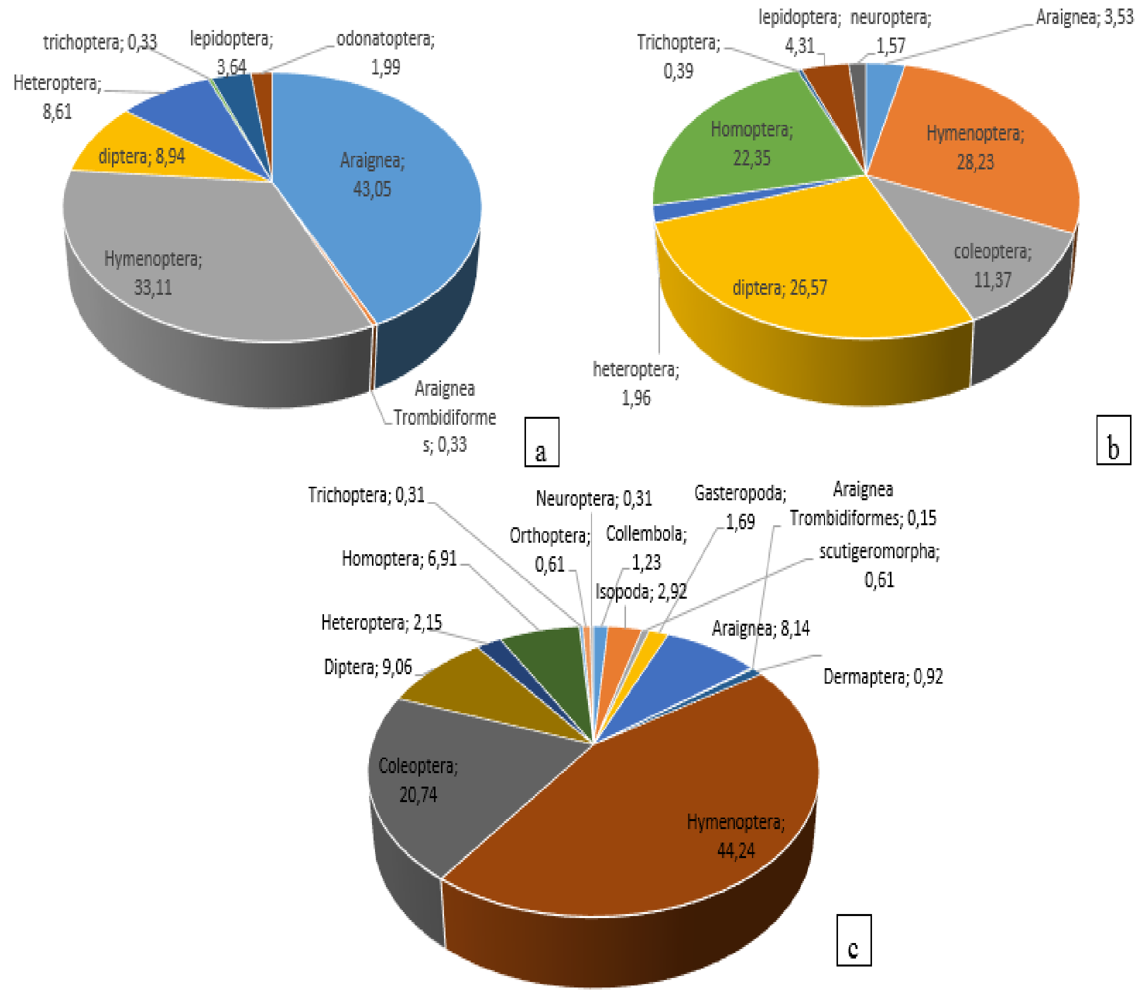


Figure 2: Centesimal frequencies of invertebrate orders captured in the study greenhouse using different sampling techniques.
a: Centesimal frequencies of invertebrate orders captured by sweep nets.
b: Centesimal frequencies of invertebrate orders captured by aerial traps.
c: Centesimal frequencies of invertebrate orders captured by terrestrial traps.

The order best represented by the use of the sweep net is that of Spiders and Hymenoptera with a relative frequency of 43.05% and 33.11% respectively, followed by Diptera and Heteroptera with respectively 8.94% and 8.61%. Next come Lepidoptera and Odonatoptera with a percentage of 3.64% and 1.99 each. Spiders and Heteroptera are present with a relative frequency of 6.32% and 3.96% respectively, Orthoptera are represented with a percentage of 2.75%; Trichoptera are poorly represented with only 0.33%.

Hymenoptera, Diptera and Homoptera are abundant through the use of aerial yellow trappings, with a relative frequency equal to 28.23%; 26.57% and 22.35% respectively, followed by Coleoptera with a relative frequency equal to 11.37%. Lepidoptera, Spiders, Neuroptera are represented with respectively 4.31%, 3.53% and 1, 57%. Trichoptera are represented with a low percentage equal to 0.39%.

Species belonging to the order Hymenoptera are the most counted in terrestrial traps or Barber pots. This order presents a relative frequency of 44.24%, followed by Coleoptera with a percentage of 20.74%, then come Diptera, Spiders and Homoptera with percentages of 9.06%, 8.14% and 6, 91% respectively. Isopods, Heteroptera, Gastropods and Collembola present a percentage equal to 2.92%, 2.15%, 1.69% and 1.23% respectively. Dermaptera, Orthoptera, Scutigeromorpha, Neuroptera and Trichoptera present a relative abundance equal to 0.92%, 0.61%, 0.61%, 0.31% and 0.31% respectively. Trombidiform spiders are poorly represented with only 0.15%.

Percentage frequencies or relative abundances AR (%) applied to the families of arthropods identified at the level of the study greenhouse by the use of three sampling methods.

The relative abundances of arthropods harvested at the level of the study greenhouse by applying the three capture methods (sweep net, colored traps and Barber pots) vary from one method to another (Figure 3). The dominance of some species over others depends on the capture method used.

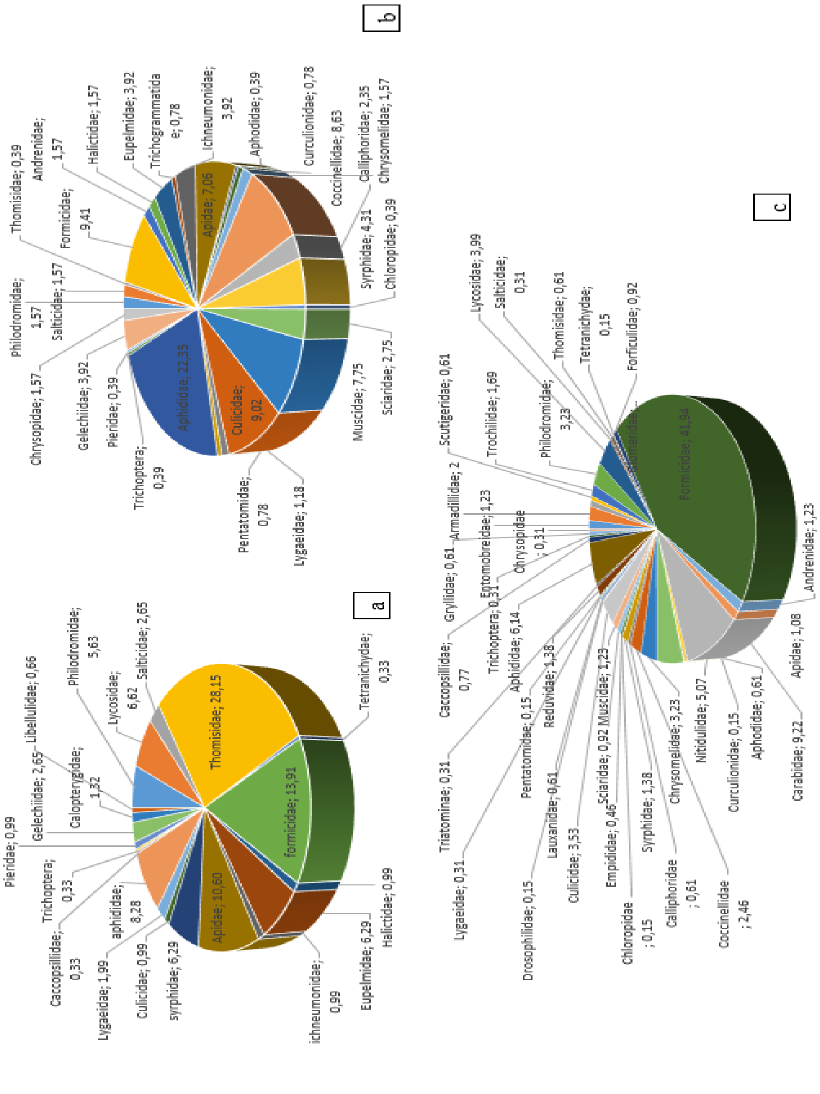


Figure 3: Percentage frequencies of invertebrate orders captured in the study greenhouse using different sampling techniques.
a: centesimal frequencies of invertebrate orders captured by sweep nets.
b: centesimal frequencies of invertebrate orders captured by aerial traps.
c: centesimal frequencies of invertebrate orders captured by terrestrial traps.

The family best represented by the use of the sweep net is that of the Thomisidae with a relative frequency of 28.15%, followed by the Formicidae and the Apidae with respectively 13.91% and 10.60%. Then come the Aphididae and the Lycosidae and the Eupelmidae with a percentage of 8.28%, 6.62% and 6.02% respectively. Caccopsyllidae and Trichopteridae are poorly represented with only 0.33% each.

Aphididae are abundant through the use of aerial yellow trapping, with a relative frequency of 22.15%; follow the Formicidae, Culicidae, Coccinellidae, Muscidae and Apidae with a relative frequency equal to 9.42%, 9.02%, 8.63%, 7.75%, and 7.06% respectively. Chloromidae and Thomisidae are represented with low percentages equal to 0.39% each.

The Formicidae family is the most accounted for in terrestrial trappings or Barber pots. This family presents a relative frequency of 41.94%, followed by the Carabidae with a percentage of 9.42% and the Aphididae with a percentage of 6.14%. Tetranychidae, Chloropidae and Curculionidae are poorly represented with only 0.15%.

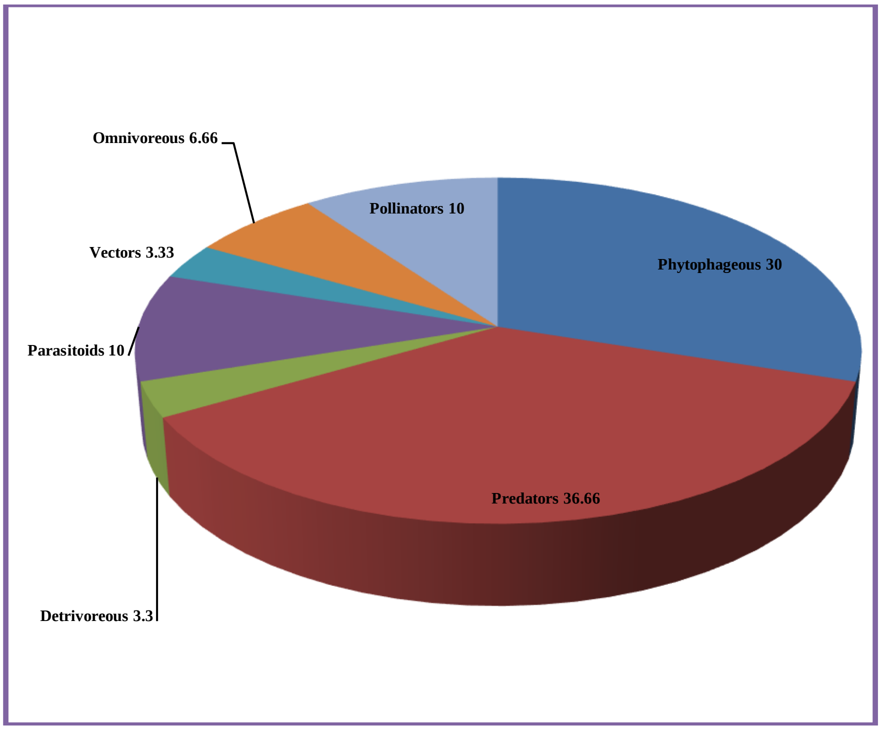
Centesimal frequency of arthropod species obtained in the tomato greenhouse according to their trophic regime

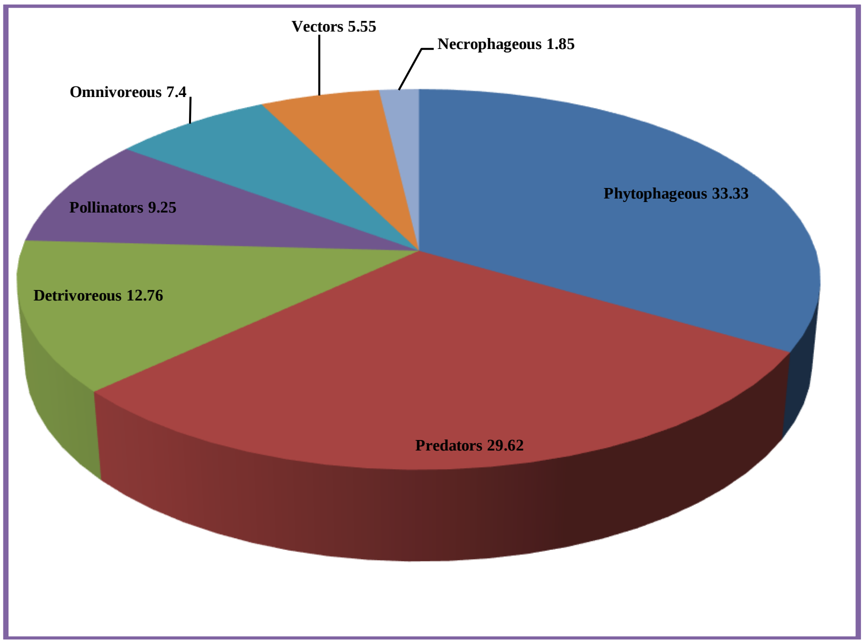
The distribution of invertebrate species captured according to their trophic level using the three sampling methods (snuff net, colored traps and Barber pots) is illustrated in figure 4.

The group best represented by the use of the sweep net is that of predators and phytophagous with 36.66% and 30% respectively. Then follow pollinators, parasites and omnivores with 10%, 10% and 6.66% respectively. Scavengers and vectors account for low rates equal to 3.33% of all catches.

The phytophagous and predatory groups are the most abundant by the use of aerial yellow trappings, with a relative frequency equal to 33.33% and 21.42% respectively. Pollinators follow with 10%, and omnivores with 6.66%. Vectors and detritivores are poorly represented with 3.33% each.

The Phytophaga group is the most accounted for in terrestrial trappings or Barber pots with a relative frequency equal to 33.33%. The predators follow with 29.62%. Scavengers, pollinators, omnivores and vectors are estimated at 12.76%, 9.25%, 7.40% and 5.55% respectively. Finally, scavengers show low rates with 1.84% of all catches.


Omnivoreous 6.66
Pollinators 10
Vectors 3.33
Phytophageous 30
Parasitoids 10
Predators 36.66
Detrivoreous 3.3


Vectors 5.55
Necrophageous 1.85
Omnivoreous 7.4
Phytophageous 33.33
Pollinators 9.25
Detrivoreous 12.76
Predators 29.62

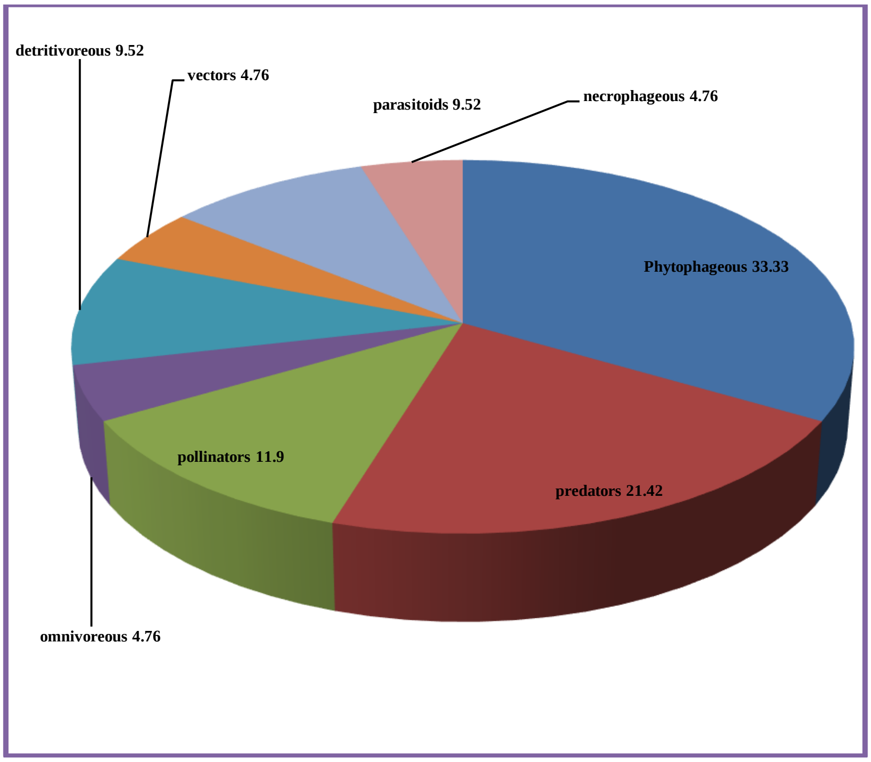


Figure 4: Percentage frequencies of invertebrate species captured in the study greenhouse using different sampling techniques according to their trophic regime.
a: Centesimal frequencies of invertebrate species captured by sweep nets.
c: Centesimal frequencies of invertebrate species captured by terrestrial traps.
b: Centesimal frequencies of invertebrate species captured by aerial traps.
Among the species identified, many of them have a phytophagous diet and live at the expense of tomato (*L. esculentum*) cultivation.

Diets of species caught
Species with a phytophagous diet
Among the 76 species identified, 26 of them have an exclusively phytophagous diet such as *Trochilus flavus, Tetranychus urticae, Pheidole pallidula, Aphodius sp,* Curculionidae *sp, Carpophilus sp, Longitarsus sp, Altica sp, Hilara sp, Sciara sp, Zygoneura sp, Sciara thaumae, Sciara maura, Aphisfabae,* Lauxanidae *sp, Dolycoris baccum, Dysaphis plantaginea, Aphis citricola, Caccopsylla sp, Hyperomyzuslactucae, Macrosiphum rosae, Misuspercicae, Pieris* brassicae, *Tuta absoluta, Grillus campestris* and *Calopteryx splendens.*

Species with an insectivorous diet
Spiders with family Dysderidae and other undetermined species *Tibellus sp, Lycosanar bonensis, Salticidae sp, Thomisus sp,*

Myriapods: Scutigeridae sp this plays an important role in the decomposition of organic matter.

Insects :
Macrothoraxmorbilusus, Harpalus paratus, Harpeaus latus, Carabus auratus, Bembidion sp, Coccinella quatuordecimpunctata, Harmonia axyridis, Theavigintiduo punctata, Hippodamia variegata, Adalia bipunctata, Eristalis tenax, Syrphusribesii, Episyrphus balteatus, Melanostoma scalarae, Nysius sp, Reduvius sp, Triatomina sp, Chrysperla carnea, Orthetrum coerulescens

The species have an insectivorous diet and thus intervene in the natural balance of ecosystems.

Spiders represent a group of predatory species. Invertebrates are the most common prey of spiders, and among these, insects occupy an important place. In this group, we have identified a species that belongs to the Dysderidae family and several other species whose identification could not be made.

The Coccinellidae family is represented by *Coccinella algerica* predatory of aphids, the abundance of this aphidophagous ladybird is explained, according to the scientific literature, by the fact that the majority of ladybirds, particularly in northern Algeria, appear in the middle of spring, when the minimum temperatures are around 15°C (Saharaoui and Gourreau, 1998). These same authors add that *C.algerica* has intense activity in April and May.

Caraboidea are carnivorous Coleoptera, essentially predators of primary consumers. Their prey is diversified and consists mainly of oligochaetes, slugs, adult insects and larvae.

Forficula auricularia, *Messor barbarus* and *Formica sp*. are omnivorous species. As for *Cataclyphis bicolor*, it is a carnivorous species that feeds on insect corpses but can also fall back on a few plant species for its food.

Andrena labiata, *Panurgus calcaratus*, *Andrena fulvago*, *Halictus quadricintus*, *Lasioglossum calceatum* and *Apis mellifera intermissa* are apoïds which play a very important role for the environment by transporting pollen from one plant to another during foraging, thus achieving fertilization in flowering plants.

Cules sp., *Culex pipiens* and *Anopheles sp.* are hematophagous insects especially for females which express the protein requirement for their vitellogenesis. The presence of these insects in the greenhouse is encouraged by the abundance of watering water.

Calliphora vicina and *Calliphora vomitoria* are necrophagous Diptera identified in the greenhouse following the presence of dead animal cadavers.

Entomobrya nivalis, *Armadillidium vulgare*, *Glomeris sp*., *Carpophilus sp*., *Thaumatomyia notate*, *Musca domestica*, *Drosophila sp*. and *Trichoptera sp*. are detritivorous species present in the greenhouse and are used for the decomposition of plant and animal organic matter.

Eupelmus sp, *Trichogrammatidae sp*., *Ichneumonidae sp.* and *Aphion luteus* are parasitoids involved in the regulation of insect pest populations.

3.4 Exploitation of the results by ecological indices of structure for the sampled species

The results obtained are exploited using ecological indices of structure; see Shannon's diversity and equitability indices.

Shannon diversity index and evenness applied to sampled species

The results relating the indices of diversity of Shannon (H'), of the maximum diversity (H'max) and of the equitability (E) applied to the species of arthropods sampled by the different types of traps at the level of the different greenhouses of studies are illustrated in the tables.

Table 4: Shannon H′ diversity values of invertebrate species captured using different sampling methods at the study greenhouse.

Methods	Sweep net	Barber Pots	Colored traps
H′ (bits)	2.68	4. 84	4.55
H max (bits)	5.25	5.54	6.02

The values of the Shannon diversity index are quite high at the level of the study laser, they are equal to H'= 2.68 bits for the sweep net, H'= 4.84 bits for the yellow traps and H '= 4.55bits for Barber jars. The maximum diversity is equal to Hmax= 5.02 bits for the sweep net, Hmax= 5.54 bits for the yellow traps and Hmax= 6.02 bits for the Barber pots.

Table 5: Equitability values of invertebrate species captured using different sampling methods at the study laser level.

Methods	Sweep net	Barber Pots	Colored traps
Equitabilité	0.53	0.87	0.75

The equitability obtained for each type of trap varies from E= 0.53 to E= 0.87, these values tend towards 1, which reflects a balance between the species in the environment.

1. DISCUSSION

The invertebrate species inventoried are the result of outings carried out on tomato cultivation in a Dawson variety greenhouse in the Azeffoun region.

During this sampling period, 76 species are captured, divided into 46 families, belonging to 16 orders and 6 classes of invertebrates (enthognata, crustacea, myriapoda, arachnida, mollusqua and insecta). The best represented class is that of insecta with a percentage frequency of 89.04%, followed by the class of Arachnida with a percentage frequency of 7.19% and crustaceans with a value equal to 1.71%. Enthognata, Mollusqua and Myriapoda are poorly represented with a centesimal frequency equal to 0.72%, 0.99% and 0.36% respectively.

These results corroborate those of the work carried out during three years of study in a tomato greenhouse in Burkina Faso by Son and *al*. (2018) highlighting the collection of 1447 individuals classified into 42 families. Those authors add that the natural enemies are in low abundance such as the Coccinellidae family.

Son and *al*. (2018) highlighted the presence of 08 families of harmful insects. The same results are reported by Choudourou and *al*. (2012) in Nigeria and OfFori *et al*. (2004) in Ghana. Indeed these last authors have inventoried on tomato cultivation, a multitude of insect pests belonging to various families. Among the families most devoted to tomato cultivation, they find the Agromizidae, the Aleyrodidae, the Aphydidae, the Gelichiidae, the Noctuidae. Shiffers (2011); Mailafiya *et al*. (2014) report that the majority of these pests are present in the vegetative stage of the plant and seriously affect its growth and development.

The values of the species captured only once and in a single specimen by the different sampling methods at the level of the study greenhouse are between 0.48 and 0.66, which indicates that the sampling quality is considered very good because the values approach zero.

The total richness of species harvested using the three capture methods in the prospected greenhouse depends on the type of trap used.

By using the sweep net, the total richness is 32 species, the Barber pots or terrestrial traps made it possible to capture a total of 64 species, the aerial traps made it possible to capture 45 species.

Vayssieres *et al*. (2001) counted 123 species of arthropod pests and 128 species of beneficial arthropods on market garden crops in Reunion Island. These same authors report that the most damaging pests of the Solanaceae are: *Bemisia tabaci* (Homoptera: Aleyrodidae), *Frankliniella occidentalis* (Thysanoptera: Thripidae), *Neoceratitis cyanescens* (Diptera: Tephritidae).

The damage caused by homopterans is direct and is characterized by sap with drawals and honeydew secretions, thus reducing photosynthesis and therefore the development of the plant and its production.

The species *Myzus persicae* transmits viruses in the non-persistent mode (Messiaen *et al*., 1991). The high efficiency of this mode of transmission allows viral diseases to spread with low aphid populations. *M. persicae* is also a vector of viral diseases. The production of honeydew by the larvae also causes burns on the foliage and promotes the development of sooty mold (Hulle *et al*., 1998).

Mondedji *et al.* (2015) report a strong dominance of Homoptera through a study in southern Togo. These authors indicated that the main insects harmful to vegetable crops are Lepidoptera larvae, Homoptera (aphids), Coleoptera and Orthoptera (locusts).

The captures of insects revealed a significant diversity of insects on tomato plants. This diversity has been reported by several authors, including Choudourou *et al.* (2012) and it is this high diversity that underlies the overuse of chemical insecticides during tomato production.

The relative abundances of invertebrates harvested at the level of the study greenhouse by the application of the three capture methods vary from one method to another. The dominance of some species over others depends on the capture method used.

The values of the centesimal frequencies applied to the orders of invertebrates listed vary from one type of trapping to another, each sampling method is relative to a group of representative orders; thus by the use of the sweep net, the order of Spiders and Hymenoptera dominates with a relative frequency of 43.05% and 33.11% respectively, followed by Diptera and Heteroptera with respectively 8.94% and 8.61%.

Hymenoptera, Diptera and Homoptera are abundant through the use of aerial yellow trappings, with a relative frequency equal to 28.23%; 26.57% and 22.35% respectively, followed by Beetles with a relative frequency equal to 11.37%.

Species belonging to the order Hymenoptera are the most counted in terrestrial traps or Barber pots. This order has a relative frequency of 44.24%, followed by Coleoptera with a percentage of 20.74%, then come Diptera, Spiders and Homoptera with percentages of 9.06%, 8.14% and 6 .91% respectively.

The inventory allowed the capture of 6 species of aphids which are *Aphis fabae*, *Dysaphis plantaginea*, *Aphis citricola*, *Myzus persicae*, *Hyperomyzus lactucae*, *Macrosiphum rosae*, which cause significant damage to tomato crops. Our results corroborate those of Benhalima-Kamel and Benhamouda (2001) in the region of Sousse in Tunisia. According to the same authors, *M.persicae* and *M.rosae* can transmit viruses to attacked plants. These aphid populations are regulated by predators including ladybugs such as *Coccinella quatuor decimpunctata*, Harmonia axyridis, Hippodamia variegata, Thea vigintiduopunctata and *Adalia bipunctata*, also the *C.bicolor* ant. Lofinda-Lifake (2018) after an inventory on three host plants sampled three species of aphids on tomatoes (*Aphis gossipi*, *Macrosiphum euphoribae* and *Myzus persicae*), as well as several species of auxiliaries including *Adalia punctata* and *Calvia guttata*.

The diets of insects are extremely diverse, due to the structures and functioning of the mouthparts, the structural and functional division of the digestive tract. Thus we established a distribution according to the various trophic categories according to our personal observations and the consulted bibliography. We were able to distinguish 8 large groups among the 76 species of invertebrates retained.

The values of the centesimal frequencies applied to the species of invertebrates sampled at the level of the greenhouse studied according to their trophic regimes vary from one type of trapping to another.

The group best represented by the use of the sweep net is that of predators and phytophagous with 36.66% and 30% respectively. Then follow pollinators, parasites and omnivores with 10%, 10% and 6.66% respectively. Scavengers and vectors account for low rates equal to 3.33% of all catches.

The groups of phytophagous and predators are the most abundant by the use of aerial yellow trappings, with a relative frequency equal to 33.33% and 21.42% respectively. Pollinators follow with 10%, and omnivores with 6.66%. Vectors and detritivores are poorly represented with 3.33% each.

The groups of phytophagous are the most accounted for in terrestrial trappings or Barber pots with a relative frequency equal to 33.33%. The predators follow with 29.62%. Scavengers, pollinators, omnivores and vectors are estimated at 12.76%, 9.25%, 7.40% and 5.55% respectively. Finally, scavengers show low rates with 1.84% of all catches.

The species of Gastropoda cited is phytophagous. Its damage according to Tracol et Montagneux (1987) is very visible on the blade. They appear as large indentations. Terrestrial molluscs can cause considerable damage to vegetable crops; moreover, the genus Trochylus is the most harmful species (Faes *et al*., 1947).

The class Crustacea is represented by the families Glomeridae and Armadillidae, the latter often causing damage to the tender young shoots of plants (Alford, 2013).

Coleoptera are represented by several phytophagous species, in particular the Curculionidae family which cause damage to tomato cultivation.

Choudourou *et al*. (2012), during a preliminary inventory of the entomofauna of tomato fields in Benin, identified 37 genera and species of insects. In total, 32 genera and species of insects are recognized as pests of tomato cultivation. This large number of pests shows that vegetable crops in general and tomato crops in particular harbor enough enemies. These results are similar to those obtained by Atachi *et al*. (1989) in Benin; Djieto-Lordon and *al*. (2007) in Cameroon who in their different samplings demonstrated that the tomato crop harbors a multitude of insects belonging to different orders.

The inventories carried out by James and *al*. (2010) showed that the tomato crop is particularly attacked by various insect pests, strongly compromising its yield. The main orders of membership of the species obtained by these authors are Orthoptera, Coleoptera, Homoptera, Lepidoptera, Heteroptera and Diptera. Furthermore, Tendeng *et al.* (2017) carried out an inventory that contributed to the exploration of four families of vegetable crops, which are Solanaceae, Cucurbitaceae, Brassicaceae and Malvaceacea in Senegal over a period of one year. This study identified 38 genera with 35 species of pests divided into 17 families of insects and one family of mites. It also made it possible to obtain 13 genera with 11 auxiliary species divided into 05 different families. On the Solanaceae, the species listed on tomato crops are *T. evansi*, *T. absoluta*, *B. tabaci* and *C. chalcites*. In addition, inventories of shea-dependent insects in Ghana enabled Dwomoh (2003) to identify 53 pest genera and species. As for Odebiyi and *al*. (2004), they managed to classify 33 genera and species for the same plant in Nigeria. The inventory of insect pests and vectors of rice yellow mottle in northern Cameroon by Sadou *et al*. (2008) identified 46 species belonging to seven orders and 26 families. The orders Lepidoptera and Hemiptera are the most dominant.

Alongside pests, many useful insects (pollinators, predators, parasitoids) coexist in the tomato plot, so pollinators play a key role in productivity (Klein *et al*., 2007). Indeed, You *et al*. (2005) add that pollinating species play an important role in the pollination of market gardening plants. They estimate that in China, 85% of phanerogam plants are pollinated by insects. On the other hand, according to Williams (1994), another study in Europe demonstrated that the production of 84% of cultivated plants depends directly on pollination by insects. As for the roles of predators and parasitoids, it is reported by Chailleux *et al*. (2013) who attest that these auxiliary insects contribute to the reduction of the numbers of pest populations, reducing the need to intervene to control their development. Breitenmoser et Baur (2013) confirm the important role of auxiliary fauna in the regulation of pests.

Caraboidea are carnivorous beetles, essentially predators of primary consumers. Their prey is diverse and consists mainly of oligochaetes, slugs, adult insects and larvae.

The Coccinellidae family is represented by *Adalia bipunctata*, an aphid predator. The abundance of this aphidophagous ladybug is explained, according to the scientific literature, by the fact that the majority of ladybirds, particularly in northern Algeria, appear in the middle of spring, when minimum temperatures are around 15°C (Saharaoui and Gourreau, 1998). These same authors add that *Adalia bipunctata* has intense activity in April and May.

Vayssieres *et al.* (2001) note that the largest groups of beneficial insects, and those of biological interest, are parasitoids, generally more specific to a host or a group of hosts. The species of parasitoids identified are exclusively made up of Hymenoptera.

In French Polynesia on tomato cultivation Ryckwart (2004) reports numerous leafminer damage as well as the presence of the whitefly *Bemissia tabaci* and the tomato fruitworm *Helicoverpa armigera*.

In agricultural ecosystems there are interactions between plants and phytophagous insects (De Moraes *et al*., 2001).

Lofinda Lifake *et al*. (2018) suggest an attraction between auxiliaries and plants due to the recognition of the molecules emitted by the latter. Beneficiaries can help reduce pest pressure in agrosystems (Altieri, 1991; Stamps and Linit, 1998).

Hou *et al*. (2002) attest that the intensive application of synthetic insecticides causes a significant reduction in the entomological diversity present in market garden crops.

The values of the Shannon diversity index are quite high at the level of the study greenhouse, it is equal to H'= 2.68 bits for the sweep net; H'= 4.55 bits for ground traps and H'= 4.84 bits for aerial traps.

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