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Full Length Research Paper

Dynamics of vascular plant and insect diversity as indicators in Agroecosystems and Agricultural Landscapes

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Biodiversity is a heritage of an ecosystem and especially refers to the diversity within and among living organisms, gatherings of living organisms, biotic communities and processes. It contributes a wide range of essential services to the sustainable function of all ecosystems. In this review, we summarize literature about the terrestrial biodiversity that dominated by plants and the herbivores (such as insects) that consume them, and they are one of the major conduits of energy flow up to higher trophic levels. The role that biodiversity plays in ecosystem functioning has attracted special attention during the last years due to the disturbance and change of biodiversity. Also, it is important to refer that the knowledge of the relation between plants and ecological factors can be used as an environmental indicator. Several plants are used as indicators of environment and determine the excellent use of land resources for forest, meadow and agricultural crops. Similarly, insects represent major role in influencing various activities of plants like physiological activity and population dynamics and also mediate a link between plants and ecosystem processes. In terrestrial ecosystems, insects involve in various role viz., herbivores, seed dispersers, pollinators, parasites, predators, food for other organisms, honey producer, detritivores or ecosystem engineers. These insects also serve as excellent environmental indicators for the total ecosystem maintenance. Conclusively, plants and insects constitute important parameters of the ecosystems which affect their ecological balance. Hence, it will have to estimate and monitor plant and insect dynamics, in order to effectively protect them.

Keywords: Biodiversity, sustainability, indicator, functions, agroecosystems.

INTRODUCTION

An ecosystem is a dynamic complex system composed of living organisms in relation with the nonliving components of their environment (e.g. air, water and mineral soil etc.), interacting as an accomplished system (Gurevitch et al., 2006; Smith & Smith, 2012). According to Odum (1971), the above biotic and abiotic components are regarded as

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related together through nutrient cycles and energy flows (Harrison et al., 2014).

The Mediterranean Basin covers an area of 2.5 million km2 and stretches across 34 countries and territories, having around 400 million people, of which 135 million of them live on the coast. The increasing population expansion and use of natural resources resulted in pressures on the coastal environment and, more importantly, on its biodiversity (Figure 1) (Sundseth, 2009; Valavanidis and Vlachogianni, 2011).

Mediterranean-type ecosystems are very heavily utilized by man and for the longest periods of time. They are often under stress due to increasing population pressures and unsustainable agricultural and/or land intensive management practices, urbanization and industrial activities. These anthropogenic activities, as well as, strong ecological limitations, such as long summer droughts affect their stability and biodiversity (Moreno and Oechel, 1995; Rundel et al.,1998; Williams, 2011; Valavanidis and Vlachogianni, 2011).

In the last years, a wide interest has appeared in the quantification and valuation of biological diversity. Biodiversity is increasingly recognized as one of the cornerstones of healthy ecosystems (Solomou and Sfougaris, 2011; Pinto et al., 2014). The interest is largely motivated by ascertainments from scientists that biodiversity is imperiled by human activities (Wilson, 1992), especially the disaster of natural habitats (Primack, 2000; Simpson, 2002).

Biodiversity, refers to the variety and variability of life on Earth. Specifically, frequently used definitions define it in terms of the variability within species, between species and between ecosystems (Gaston and Spicer, 2002). It is a measure of the variety of organisms present in several ecosystems. This can refer to genetic variation, ecosystem variation, or species variation within an area, biome, or planet. Terrestrial biodiversity tends to be greater near the equator, as a result of the warm climatic conditions and high primary productivity (Gaston and Kevin, 2000; Field et al., 2009).

Biodiversity studies are an important tool in conservation decision-making (Margules & Sarkar, 2007; Solomou and Sfougaris, 2011; Laurila-Pant et al., 2015). Overall, higher levels of protection will be given to regions that are physically and biologically more diverse. These decisions require detailed knowledge of the di□erent taxa living in the area, their relative abundance, and the temporal and spatial variation in their distribution. Nevertheless, an acute shortage of funding and limited time lead to partial often biased surveys of a narrow set of well-known and easily surveyed indicators that do not necessarily reflect wider diversity patterns (Balmford & Whitten, 2003). Selecting the most relevant biodiversity indicator is a controversial topic, as using unreliable indicators can lead to wrong decisions (Grand et al., 2007). Many selection criteria have been proposed and a large body of literature exists on this important topic (e.g. Pearson, 1994; McGeoch, 1998; Noss, 1999; Hilty & Merenlender, 2000).

Many hundred years ago, Darwin's concept of evolution replaced theological concepts of plenitude as an explanation for the almost boundless diversity of organisms. Since then, evolutionary biologists and ecologists have tried to understand how as diversity has come to be, how it has changed over time, and why species diversity varies among taxa and their environments. For the last decades, plants and their herbivores, especially insects, have been major topics of such inquiries, for together they account for more than half of the described species and play primarily important ecological roles (Futuyma and Agrawal, 2009).

Increasingly research suggests that the level of internal regulation of function in agroecosystems is largely dependent on the level of plant and insect biodiversity present. Terrestrial biodiversity is dominated by plants and the herbivores (such as insects) that consume them, and they are one of the major conduits of energy flow up to higher trophic levels. Conservation professional and planners are often faced with local-scale decision-making, especially in high density populated areas where only limited land is still available, and habitat loss and fragmentation are intense. Hence, the aim of study in this paper is the dynamics of plant and insect communities in the landscape ecosystems which play crucial roles in ecosystem functioning.

MATERIALS AND METHODS

In order to review and consolidate existing research on the linkages between the dynamics of plant and insect communities in the landscape ecosystems, a literature search was conducted using Scopus, Web of Science and Google scholar. The main aim of focusing on peer-reviewed academic literature was to find the best available knowledge reported by the scientific community. A systematic methodology was implemented in order to ensure that a rigorous and repeatable method was applied to each synthetic of biodiversity (plants and insects). The methodology consisted of two stages: (i) the generation of keywords and (ii) a systematic search (Harrison et al., 2014).

RESULTS AND DISCUSSION

Linkages between biodiversity attributes and ecosystem services

Ecosystem services are regularly comprised in the provisioning of clean drinking water and the decomposition of wastes. Although scientists have discussed ecosystem services doubtless for many years, the ecosystem services

Figure 1. Global map of the Earth with Mediterranean-type Ecosystems: California (northern Baja California), Australia (south), South Africa (western cape), Chile (central coast) and Mediterranean Basin between Eurasia and Africa (Underwood et al., 2009; Valavanidis and Vlachogianni, 2011).

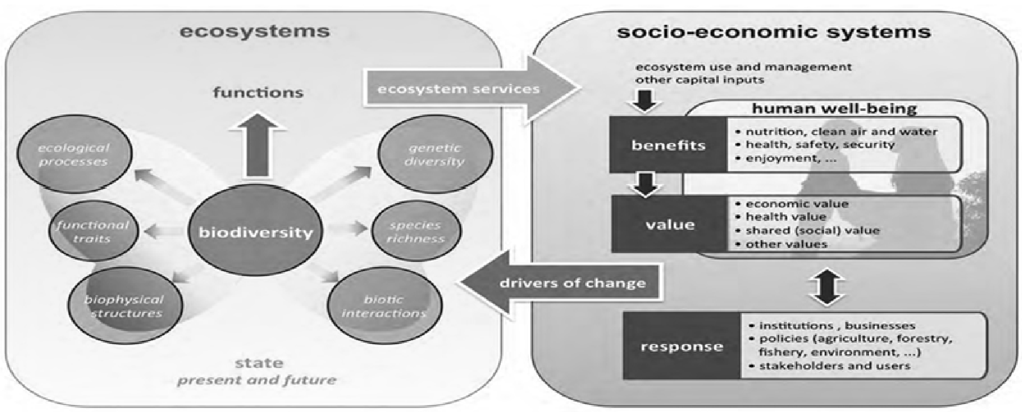

Figure 2. Link between socio-economic systems with ecosystems via the flow of ecosystem services and through the drivers of change that affect ecosystem (Maes et al., 2013; Science for Environment Policy, 2015).

concept was popularized by the Millennium Ecosystem Assessment (MA) in the early 2000s (Millennium Ecosystem Assessment-MA, 2005). Ecosystem services perceive into four categories:

a) Supporting services

The first category concerns Ecosystem services that are necessary for the production of all other Ecosystem services (Millennium Ecosystem Assessment-MA, 2005; Rudolf et al., 2002). These include services such as nutrient recycling, primary production and soil generation, food supply, flood regulation and water purification (http 1).

b) Provisioning services

The second category regards products obtained from ecosystems (Millennium Ecosystem Assessment-MA, 2005; http1):

i. food (including seafood and game), crops, wild foods, and spices,
ii. raw materials (including lumber, skins, fuel wood, organic matter, fodder, and fertilizer),
iii. genetic resources (including crop improvement genes, and health care),
iv. water,
v. minerals (including diatomite),
vi. medicinal resources (including pharmaceuticals, chemical models, and test and assay organisms),
vii. energy (hydropower, biomass fuels),
viii. ornamental resources (including fashion, , handicraft, jewelry, pets, worship, decoration and souvenirs like furs, feathers, ivory, orchids, butterflies, aquarium fish, shells, etc.).

c) Regulating services

The third category relates the Benefits obtained from the regulation of ecosystem processes (Millennium Ecosystem Assessment-MA, 2005; http1):

i. carbon sequestration and climate regulation
ii. waste decomposition and detoxification
iii. purification of water and air
iv. pest and disease control

d) Cultural services

The fourth category regards the Nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experiences (Millennium Ecosystem Assessment-MA, 2005; http1):

i. cultural (including the use of nature as a motif in books, film, painting, folklore, national symbols, architect, advertising, etc.)
ii. spiritual and historical (including the use of nature for religious or heritage value or natural)
iii. recreational experiences (including ecotourism, outdoor sports and recreation)
iv. science and education (including the use of natural systems for school excursions, and scientific discovery).

According to Constanza et al. (2007) biodiversity is the variation among living organisms from all sources. This includes diversity within species, between species and of ecosystems (Heywood, 1995). In the past, biodiversity has been decreased so dramatic and it has been recognized as a global change in its own right (Walker and Steffen, 1996). This has caused several concerns, including the possibility that the functioning of ecosystems might be threatened by biodiversity loss (Ehrlich and Ehrlich, 1981; Constanza et al., 2007).

The role that biodiversity plays in ecosystem functioning has attracted special attention during the last years (Loreau et al., 2002; Hooper et al., 2005) due to the disturbance and change of biodiversity (Pimm et al., 1995). The central question of this research area focuses on the potential consequences of biodiversity loss on ecosystem services (e.g. primary and secondary production, plant pollination, maintenance of soil fertility, etc.), and more generally on ecosystem processes (Thebault and Loreau, 2006).

The importance and value of ecosystem services for human well-being is well known (Butler and Oluoch-Kosura, 2006; Harrison et al., 2010). Ecosystems supply four types of service: provisioning (e.g. food), regulating (e.g. water quality regulation and pollination), cultural (e.g. recreation) and supporting (e.g. nutrient cycling) (Millennium Ecosystem Assessment, MA, 2005). The significance of biodiversity in underpinning the delivery of both ecosystem services and the ecosystem processes that maintain them is well recognized (Diaz et al., 2006; MA, 2005; Harisson et al., 2014).

Also, our understanding of the nature of the biodiversity–ecosystem services relation and the possible effects of biodiversity loss on the provision of ecosystem services is increasing (Balvanera et al., 2006; Cardinale et al., 2006). Therefore, there is an increasing trend to integrate ecosystem service arguments within the management plans and strategies of protected areas (Garcia-Mora and Montes, 2011), as well as the wider landscape (The Scottish Land Use Strategy, Scottish Government, 2011). Nevertheless, ecosystem service-related argumentation is undeniable (Schröter et al., 2014; Harisson et al., 2014).

Though, in spite of number of met analyses, and advances in research and understanding of this relationship (Bastian, 2013; Mace et al., 2012) there remains much dubiety over the impact of the complicacy of biodiversity components on the ecosystem functioning that underlies the provision of services (Balvanera et al., 2014; Schröter et al., 2014; Harrison et al., 2014).

Few experimental and theoretical studies have investigated the influences of species richness on ecosystem properties in multitrophic systems (Du□y et al., 2003, 2005; Ives et al., 2005; Thebault and Loreau, 2006). Several experiments and theories concern the single trophic level systems, for the most part, primary producers (Dimitrakopoulos and Schmid, 2004; van Ruijven and Berendse, 2005; Thebault and Loreau, 2006).

The study of biodiversity effect on ecosystem functions in multitrophic systems have a high value for the below reasons:

(a) multiple trophic levels are common in ecosystems, and elimination threats appear to be higher for these species at higher trophic levels (Petchey et al., 1999);

(b) alterations in the richness of consumer can have impacts on the ecosystem functions that are as great as or even greater than, comparable alterations in the primary richness of producers (Du□y, 2003). Recent studies have shown that consumers can modify the relation between diversity and primary production (Mulder et al., 1999; Paine, 2002; Du□y et al., 2003, 2005). As multitrophic diversity increases, average ecosystem properties could increase, decrease, stay the same or follow more complex non-linear patterns. A wide research tradition has examined the impact of trophic interactions on biomass and productivity at various trophic levels (Shurin et al., 2002; Schmitz, 2003) as well as at several measures of stability (Pimm, 1984; Thebault and Loreau, 2006).

Importance of plants in ecosystems

Plants are necessary for all life on Earth. As a crucial part of the ecosystem, plants provide oxygen for organisms to survive. They are able to deminish the problem of pollution, by using carbon dioxide. Also, they are the basis of most

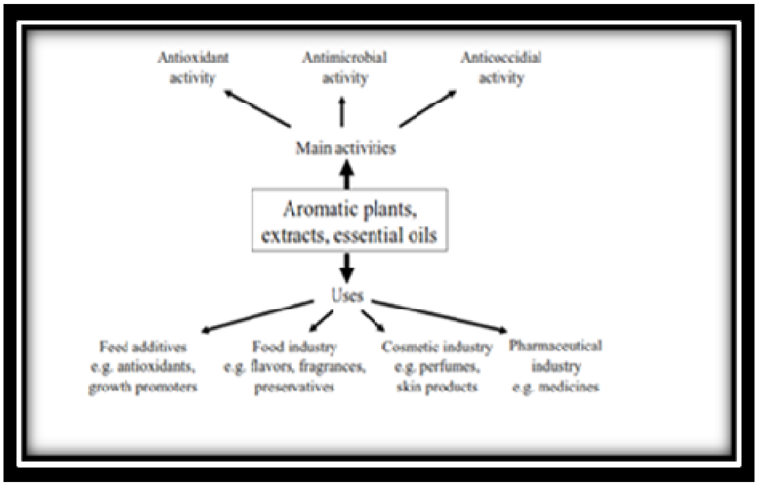

Figure 3. Main activities and uses of aromatic plants (Christaki et al., 2012; Solomou et al., 2016).

food webs as producers of food for herbivores and eventually carnivores. Moreover, plants ensure lee for animals, clean and filter water and help prevent soil erosion (Raven et al., 2005).

Specifically, much of human nutrition base on plants, either directly through foods and beverages consumed by people, or indirectly as feed for animals or the flavoring of foods. The science of agriculture counter the planting, raising, nutrition, and harvest of food crops, and it has played a critical role in the history of world civilizations.

Several plants are used to flavor foods. Such plants include herbs (e.g. rosemary and mint), which come from the green leafy parts of plants, and spices (e.g. cumin and cinnamon), which proceed from other plant parts. Some plants produce eatable flowers, which may be added to salads or used to decorate foods. Sweeteners such as sugar and stevia are originated from plants. Sugar is obtained mainly from sugar cane and sugar beet, and honey is created when bees regurgitate the nectar from flowers (Woodward, 2003).

Plants are the origin of many natural products (e.g. essential oils, natural dyes, pigments, waxes, resins, tannins, alkaloids, amber and cork). Products generated from plants include soaps, shampoos, perfumes, cosmetics, paint, varnish, turpentine, rubber, latex, lubricants, linoleum, plastics, inks, and gums. Renewable fuels from plants include firewood, peat and many other biofuels. Coal and petroleum are fossil fuels produced from the leaving of plants. Olive oil has been used in lamps for centuries to provide illumination (Chengaiah et al., 2010).

More specifically, aromatic plants are considerable factors in sustainable development, environmental protection and public health. There are more than 3000 plants used for their essential oils of which about 300 are used mercantile as flavors and fragrances (Van de Braak and Leijten, 1999). Based on Figure 3, the food industry utilizes the oils in soft drinks, food confectionary, etc., and the cosmetic industry contains them in perfumes, skin and hair care products, aromatotherapy, etc., while the pharmaceutical industry uses them for their functional properties (Lubbe and Verpoorte, 2011; Christaki et al., 2012; Solomou et al., 2016).

Finally, structural resources and fibers from plants used in the construction of dwellings and the manufacture of clothing. Wood is used for smaller items (e.g. musical instruments and sports equipment) and it may be mashed for the manufacture of paper and cardboard. Cloth is often made from cotton, flax, ramie or synthetic fibers produced from cellulose, such as rayon and acetate. The thread that is used to sew cloth likewise comes from plant fibers (http2).

Evolution and Ecology of insects in ecosystems

Nowadays, insects are the predominant element in the terrestrial faunas, both with regard to a number of individuals and biomass. Important events in insect evolution that made it possible for them to expand their diversity. Today, more than one million insects have been described.

Insects are the most successful and dominant life element in the 450 million year history of terrestrial living. They are proved to appear at the early Devonian period. Further, the first winged forms evolved 80 million years later during Carboniferous period. The metamorphosis and first complex societies were evolved during late Jurassic or Early Cretaceous, about 150–140 million years ago (Grimaldi and Engel, 2005). They also stress terrestriality, flight, complete metamorphosis and eusociality as the four major adaptive features of insects.

Theories of insect evolution

The contribution of ‘Evolution of the arthropods’ by Gamlin and Vines illustrate the arthropod fossil history of more than 600 million years ago. Recent studies on living arthropods suggest that there are three main lines which evolved independently: the Crustacea, the Uniramia and the Chelicerata’ (Gamlin and Vines, 1987). In another theory, Romoser stressed that no agreement exists on the evolutionary relationships of insects and other arthropods. Romoser and Stoffolano concluded it is more likely that myriapods and insects both evolved from some unknown common ancestor (Romoser and Stoffolano, 1998). In another theory, the authors presume that the earliest insects were similar to silverfish, since it appears in 350 million years ago fossil record (Lewin, 1982). In each theory, the opinions vary. Overall a universal view is that insects evolved from myriapod. But, this is not supported by RNA analysis (Ballard et al., 1992; Bergman, 2004).

Insects in Ecosystem

Insects play a major role in ecosystem functioning. Insects are known for its various roles like herbivores, predators, parasites and pollinators in ecosystems. They are also important food sources for a higher class of organisms in food webs [Schowalter, 2011]. Furthermore, the role of insects in biodynamics of freshwater ecosystems is notable [Chernishov,1996; Schowalter ,2011]. Insects are also involved in the biological cycling of trace elements (Golubkina et al., 2014).

Insects and Sustainability of Ecosystem Services

Insects play crucial roles in ecosystem functioning. As pollinators, they contribute to the reproduction of most flowering plants. Insects are often the first decomposers of dead plants and animals and microorganisms continue this process which releases nutrients for new plant growth and increases nitrogen content (Poveda et al., 2005).

Insects as pests

Insect pests are involved in transmitting various pathogens that affect human, farm animals and plants within the ecosystem. Examples are mosquitoes and sand flies that carry malaria, dengue, zika and visceral leishmaniasis etc from one person to another (Reegan et al., 2015, 2016). Many lepidopteran insect pests are involved in damaging various food crops throughout the world. Similarly, budworm and moth species are pests in the forest ecosystem.

Insects as food

Insects are known to be a food source for many people around the world for generations. Today, scientist and entomologist are talking about how to grow various insect species on a large scale for food. It is estimated that around 2050 that the human population will achieve the 9.7 billion people (UN DESA report 2015). As the world faces food shortages, these may offer a viable solution to food security issues. Insects not only breed quickly, they are a great source of protein.

Maintenance and regulation of plant production

Insects are one of the main organisms which make up the biological diversity of the agro-ecosystem. For example, insect pollinators contribute to the cross fertilization of many crop plants and many lepidopteron pest insects are kept in check by insect predators. Insect pollination reported enhancing the average crop yield between 18 and 71% depending on the crop (Bartomeus et al., 2014).

Nutrient cycling via defoliation and soil decomposition

Insect defoliation represents a major perturbation to the internal N cycle of the forest, but this perturbation primarily causes a redistribution of N within the ecosystem rather than a large loss of N. During defoliation, nitrogen from the canopy is diverted to green leaf fall, frass, and insect biomass. Relatively few studies of forest N cycling and defoliation have been done, and mechanistic studies have primarily examined the gypsy moth (Lymantria dispar L.)–oak interaction (Lovett et al., 2002).

Food for insectivorous birds, reptiles and mammals

Insectivorous animals including birds in the wild likely consume a wide variety of insect species. Mostly they prefer live insects. Scientists have also described dietary methods of increasing the calcium content of mealworm larvae and wax moth larvae. The calcium content and calcium-phosphorus ratio of mealworm larvae were improved by feeding vitamin/mineral supplements (Zwart and Rulkens, 1979). However, similar results may be obtained with more readily applied methods. Feeding mealworm larvae commercially available high calcium cricket diets appears to result in improved calcium content and calcium-phosphorus ratios. Wax moth larvae also may serve as a source of live food for animals in captivity. Methods for improving their calcium content and calcium-phosphorus ratio have been described (Strzelewicz et al., 1985).

Defoliators as regulators

Defoliating insects are a diverse group of forest insects that eat foliage (needles), and damage can vary depending on the insect species. The three orders; Lepidoptera (butterflies and moths), Orthoptera (grasshoppers) and Coleoptera (leaf beetles) contain many species of insect defoliators. Larvae are the damaging stage which directly reduces photosynthesis. The indirect effect of defoliation will serve as sustainability of forest ecosystem. Defoliation facilitates light penetration through the canopy. It helps to increase nutrient leaching and modify the forest plant ecosystem composition. It also increases nutrient-rich litter and enhances nutrient mineralization in the soil.

Importance of insects in ecosystems

Predators, parasites & parasitoids

Some insects perform appreciated services like pollination in agro-ecosystem and other arthropod pest population control. Examples: ladybird beetles, lacewings, parasite wasps.

Medicine

Insects are used as model organisms to discover scientific principles, diseases, specific biological phenomena and molecular pathways of any reaction. Drosophila melanogaster (fruit fly) is the best model organism used for genetic analysis. Madagascar hissing cockroaches are used as a model for learning anatomy. Insects are involved in pollination of medicinal plants are used to treat various diseases. For example insects pollinate the rosy periwinkle plant which is an important drug to treat childhood leukemia (Morebise, 2015). Insects are the sources of bioluminescent chemicals used in medical diagnostics. For example Fireflies and anglerfish produce the light-emitting pigment luciferin and the enzyme luciferase (Hoffmann, 1984).

Commercial products

Silk production:

Silk farming, is the rearing of silkworm insect for the production of silk. The insect Bombyx mori is the most widely used and intensively studied silkworm.

Fruits production:

Most of the commercially grown fruit plants require insect pollination. Hence, most of the fruit crops are generally attractive to insects such as honeybees (Apis mellifera), syrphid flies (Allograpta oblique), queen bumblebees (Bombus fervidus), bombyliid flies (Anthrax anale), solitary bees (Andrena spp.) and blow flies (Calliphora spp.). For example, fruits such as pears are predominantly attractive to blow flies and syrphid flies, while plums attract only solitary bees. Pollination by Syrphid flies occurs in many varieties of fruit trees and hence it is valuable in cross-pollination.

Cotton production:

Honeybees (Apis mellifera) are the primary insects involved in the pollination of melon crops. Cotton (Gossypium hirsutum) is largely self-fertile and can self-pollinate. Thus, cross-pollination by insects like a bumble bee (Bombus spp.) give a higher more expected yield. Another side, cross-pollination helps to produce hybrid cottonseed (Mf Gregor, 1976).

Honey production:

Honey is produced by honey bees (Apis mellifera) and harvested.

Beeswax production:

Beeswax is natural wax produced by insects of the genus Apis ans are used in candles, cosmetics and soap.

Shellac production:

The scale insect Laccifer lacca (Lacciferidae), native to India, is used to make phonograph records and varnish.

Red cochineal dye production:

This dye is produced by the scale insect *Datylopius coccus* (Dactylopiidae) and used in textiles and cosmetics. *D. coccus* is native to Mexico and *Kermes vermilio* (Kermidae) is native to Europe.

Secondary metabolites production:

Many insect species act as pests in agricultural and forests plants. These plants may produce substances that might be beneficial to humans. For example, plants synthesize toxic and deterrent metabolites in order to fight against insect pests. These deterrent compounds are helpful for other research studies and drug development (Chamarthi et al., 2011; Morant et al., 2008).

CONCLUSION

Biodiversity is important as plays an important role in ecosystem functioning, providing biological resources, such as food and medicine, and ecosystem services, such as protection of water, soil, climate and nutrients. Plants and insects are key modulators of ecosystem functions and balance. The functional role of biodiversity is important of our relations with the other living organisms, an ethical view with rights, duties and education. In order to understand better the effects of plants and insects on the temporal stability of ecosystems it is necessary to recognize that they are bound to occur. It is important to refer that improving understanding of the key relations between biodiversity and service provision will help guide effective management and protection strategies. Further, studies like plant-insect interactions, phylogenetic relationship, effects of insecticides on plant community composition and effects of climatic variations on plants and insects are needed to be explored in detail for better understanding of biodiversity inter relationship and ecosystem services.

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