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Dual Role of Millipedes in Agroecosystems: From Decomposers to Pests

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Abstract

Millipedes (class: Diplopoda), long considered helpful decomposers, have turned out to be opportunistic agricultural pests in certain environmental circumstances, especially in areas with high organic matters and other areas with too much moisture. Some species such as *Spinotarsus*, *Oxidus* and *Spirostreptus* shift their feeding habitats and become crop pests, feeding on roots, stems, seeds and tubers of crops like groundnut, sweet potato, maize and cassava. The monsoons or heavy irrigation is often linked to outbreaks which cause massive losses in yields in countries such as India, Uganda and parts of Africa. The existing control measures include handpicking, baited pitfall traps, grass heap traps, and botanical extracts; however, these methods require improvement through future studies. This review aims to determine the ecological value and potential of millipedes as pests and the fact that the balance is very weak and its sustainable control is essential. Notably, it advocates for the application of Integrated Pest Management (IPM) because it upholds context-specific methods to avoid massive crop losses while preserving the valuable activities of millipedes in maintaining soil health and the ecosystem.

Keywords: Diplopoda, Millipede, Moult, Pest

Introduction

Millipede species are classified under Diplopoda are believed to be among the earliest land animals although this is enshrined in fossil records dating over 400 million years ago. However, about 12,000 species are described, but the diversity of the world is estimated to be much more than 80,000. They are mostly identified by their ecological association as detritivores that thrive on decaying vegetation materials. Also, due to environmental condition some species of millipedes do become an opportunistic pest and damage the crop plants. Such pestiferous habit is especially pronounced in areas of high organic matters and during intensive cultivation where the favourable microclimatic conditions allow fast population accumulation. Millipedes are the traditionally overlooked focus of pest management regulations historically, although this has been altered after major infestations in some of the important crop regions. These are night-active and slow-moving arthropods that prove to be a problem especially, during monsoons or in excess irrigated and mulched fields. Genera like *Spinotarsus*, *Ommatoiulus*, *Orthomorpha*, *Tibiomus*, *Arthrosphaera* and *Spirostreptus* have all been involved in crop losses in the tropical and subtropical areas especially in India, some parts of Southeast Asia and Africa. The losses caused are feeding on soft roots, stems, seeds and tubers of various crops like groundnut, potato, sugarcane, banana, turmeric and many horticultural plants. Since millipede infestation is usually noticed under the soil or in mulch layers, it is hard to detect till the time when they have caused considerable harm. The global climate change is leading to the rise of millipede populations because there is an increase in the global yearly average temperature of 1.5 ºC compared to the pre-industrial period which has also made their survival and reproduction more favorable. Mass occurrence can be blamed on habitat disruption and alteration of local environments since millipedes are compelled to migrate due to changes in their natural habitats or destruction of these habitats. Although millipedes play a dual ecological role, being both very useful as decomposers and detrimental as pests, they still lack representation in Integrated Pest

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Management (IPM) schemes. The effective strategies should thus strike a balance between the benefits they bring about to the soil health and the likelihood of undermining crop productivity.

General Structure of Millipede

Millipedes are segmented arthropods whose typical features include a trunk with many body segments (These are referred to as diplosegments, a unique morphological attribute where each segment possesses two pairs of legs). The front end of the head is pyriform and consists of sensory and feeding appendages, *i.e.*, a pair of antennae, simple eyes, mandibles, a mouth and a labrum (Figure 1). The collum is also legless and it is located just behind the head and it serves as a protective cover. The further subdivision of these segments is into tergites (dorsal plates) and sternites (ventral plates) and the body concludes with anal segment. Millipedes have in fact, 30-400 legs (not a thousand as myths suggest) and are encapsulated with an unbiased, chitinous outer skin which prevents high moisture loss which permits them to survive in moist environments like the soil and the leaf litter. The process of breathing is conducted through spiracles that extend into a system of trachea that is internal. Millipedes usually react to danger by coiling up into a kind of ball-like structure that acts as protection. Only in case this does not scare the predator, the second line of defense of these animals is to excrete some chemical compounds which in this case are the presence of hydrogen cyanide. The Millipedes are primarily sexually prolific with males depositing sperm through modified and specialized set of legs known as gonopods. This healthy morphological and behavioral evolution makes millipedes, ecologically stable detritivores on land.

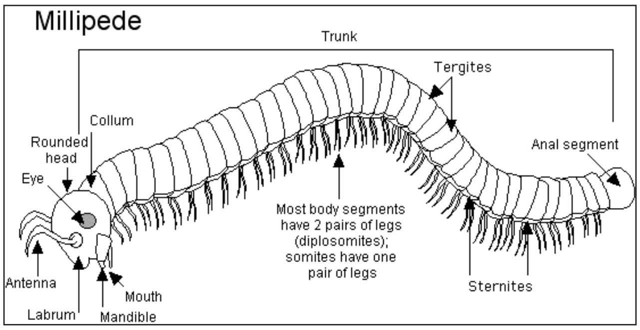

Figure 1: General structure of Millepedes

Life Cycle

Millipedes undergo gradual metamorphosis of three big stages *i.e.*, egg, juvenile (instar) and adult. The copulation is reached with the help of gonopods in which the sperm is exchanged in between male and female as they mature.

Egg

The females lay their eggs in wet soil most often among organic matter on mating. The clutch size is not definite and may attain to 300 eggs year^{-1}. The eggs are hatched into small and pale instars with few segments and three pairs of legs.

Juveniles

With every subsequent moult, these juveniles will add the segments and legs until 1-5 years later; they will become mature by going through a number of instar stages.

Adults

Millipedes have a lifespan of 2-10 years based on the size of the adults and certain large millipedes can live longer given good conditions. The majority of the species cease moulting at the adulthood though there exist the species that continued to be moulted even at the adulthood stage. These millipedes play a very crucial role in the process of breaking down of materials and the dynamics of soil nutrient at any given single stage of their existence.

Pest Status and Host Range

Millipedes are generally detritivores though they have turned out to be agricultural pests in several regions (Table 1). Millipede as a pest causing crop losses have been noticed in cassava, sweet potato, maize, groundnut and soybean in India, Uganda and parts of Africa and the USA include species of *Spinotarsus caboverdus* (now *Bandeirenica caboverda*), *Oxidus sudanica*, *Spirostreptusi banda* and *Tibiomus* spp. (Douglas *et al*., 2019). In Uganda, *O. sudanica* inflicted catastrophic damages in sweet potato plots, with up to 84% of the cuttings planted in the early onsets of rains being destroyed. In groundnut crops, there was a 12-29% seedlings loss and up to 39% of the seeds that were maturing were destroyed (Ebregt *et al*., 2004). Similarly, maize incurred losses in the form of damaged germinating seeds of 34 and 29% in the case of the first and the second rainy season, respectively (Ebregt *et al*., 2004). The millipede activity has been noticed on soybean fields on cotyledons and seeds particularly when the soil was cool and favored the delay of germination. The cassava plants were susceptible in different manners - sprouting of buds on the cutting to the full-grown root tubers being bored. The wet and organically enriched soils have been connected to the outbreaks which have also been related to the onset of rainy seasons that transforms millipedes into valuable detritivores to costly pests.

Management of Millipedes

A. Non-Chemical Methods (Ebregt *et al*., 2004; Elango *et al*., 2022)

1. Handpicking of Millipedes

Millipedes are highly active and can be seen on the surface of the soil mostly early in the morning and during rainy cloudy days and mostly at the onset of rainy seasons (*e.g.*, March-April in northeastern Uganda). It can be controlled by handpicking, which is labor-intensive and effective control method, particularly in small plot or nursery beds where millipedes are abundant.

2. Trapping Millipedes using Baited Pitfall Traps

Since the millipedes are nocturnal creatures, pitfall traps baited with food extracts can be deployed successfully as a control method since the millipedes retreat during daytime. The preliminary tests on the baits made of sweet potato, groundnut, cassava, maize and molasses have been used to attract the millipedes in crop fields. Further improvements of bait formulation and large-scale field tests can increase the efficiency.

Table 1: Host range of the Millipede as pest in different crops

Millipede Species	Host Plants	Damaged Plant Parts	Severity (% Damage)	Country/ Region Observed	References
Spinotarsus caboverdus (*Bandeirenica caboverda*)	Potato, sweet potato, cassava, beans, maize, pumpkins, papaya, mango, banana, pineapple	Seedlings, fallen fruits	Up to 50% yield loss in outbreaks	Cape Verde Island, West Africa	Ebregt *et al*., 2004; Elango *et al*., 2022
Oxidus sudanica	Sweet potato, groundnut, maize	Cuttings, germinating seeds, cotyledons, mature seeds	Sweet potato: up to 84% cuttings destroyed; Groundnut: 12-29% seedling loss, up to 39% mature seeds destroyed; Maize: 29-34% germinating seeds damaged	Uganda, India	Douglas *et al*., 2019
Spirostreptus banda	Groundnut, maize	Germinating seeds, seedlings	Not quantified; significant stand loss reported	Uganda	Douglas *et al*., 2019
Tibiomus spp.	Groundnut, maize	Germinating seeds, seedlings	Not quantified; localized outbreaks	Uganda	Douglas *et al*., 2019
Ommatoiulus moreleti (Portuguese millipede)	Lupin, canola, other seedlings	Seedlings	Up to 20% seedling loss in outbreaks	Australia	Douglas *et al*., 2019
Cylindroiulus caeruleocinctus	Sweet potato, carrot	Roots, tubers	Not quantified; sporadic but economically significant	Ontario, Canada	Retallack, 2019

3. Using Grass Heaps as Biological Traps

Heaps of grass gathered during field clearing activities, sweet potatoes vines or any other plant remains can serve as cheap biological traps. The damp and decomposing matter is where the millipedes are found in greater numbers and hence, they are easier to concentrate and capture. The resource-poor environment is especially amenable to this technique when local material is favoured over synthetic materials.

4. Roof Tiles as Shelter Traps

Field experiments have shown in the United Kingdom that roof tiles provide the millipedes with daytime terrestrial hiding spots. When these tiles were turned over, lurking millipedes were often exposed and these could be easily gathered in. They do not however work so well on hot sunny days where the millipedes move deeper in the soil and also availability of roof tiles in some rural setting may be a limitation to their mass adoption.

5. Application of Botanical Extracts

Plant products such as neem (*Azadirachta indica*), goat weed (*Ageratum conyzoides*), African marigold (*Tagetes* spp.), tobacco (*Nicotiana tabacum*) and chili (*Capsicum* spp.) have been tested as repellents or insecticide of millipedes. Other conventional materials such as ash and goat droppings that have been marinated in urine have been used as well.

6. Use of Biocontrol Agents

Millipedes produce very repulsive chemicals in their defensive glands that most predatory arthropods and the birds will not eat; it makes up to millipede largely indigestible. Nevertheless, there are some predators who have been found to feed on black Portuguese millipedes including *Iridomyrmex* sp. (meat ants), but most of the spiders and beetles that feed on millipedes do not cause significant depletion in large populations. One approach that shows a lot of potential as a biological control mechanism is the introduction of parasitic nematodes, *Rhabditis necromena* to be exact, which are in fact commercially available and can be spread through baiting stations (Retallack, 2019).

B. Chemical Control

Chemical control of millipedes in plantations is usually through the use of insecticides such as organophosphates and pyrethroids, *e.g.*, carbaryl, bendiocarb and cyfluthrin have been used for many years. Since the chemicals must touch the pests, the best control comes from treating where millipedes congregate or where they are active at, preferably under mulch or organic debris (Nieradko-Iwanicka and Jung, 2020).

Hand picking, use of baited pitfall, grass piles, roof tile trap and plant extracts are environmentally safe and cost-effective to suppress millipedes in the perspective of Integrated Pest Management (IPM) systems. The best thing you can do is to remove them manually, but only on a small scale and various types of insect traps that the habits of millipedes can be used to reduce their population. Chemical control is not the preferred method of control, other than as a last resort method in exceptionally severe infestations, where other techniques have proved ineffective and must otherwise be employed selectively, given the risks of environmental contamination and risk to untargeted organisms. Natural pesticides, which are less hazardous than the chemical, fit the policy of attack and prevention of IPM and restrict the pollution of the environment and the reduction of the ecological footprint of the globe. In combination these methods share the basics of the task of IPM to partial, yet choosy pest management. However, some more ecological approvals through case studies are needed to determine the potential and efficacy under various cropping scenarios.

Conclusion

Even though millipedes play a crucial role in nutrient cycling and organic matter breakdown, they may turn to major crop pests when proper environments promote their growth, especially in wet, organically rich soils. Most of the contemporary management strategies such as hand removal, trapping and botanical repellent are promising strategies but will have to undergo some refinement and field standards to facilitate their use in the field. Considering both the positive and negative ecological effects of millipedes as decomposers and potential pests, pest control will have to tread very fine waters in the future between minimizing crop damage and conserving millipede ecosystem services. With the ongoing change in the environment due to climate change and intensification in agriculture, the need to create adaptive measures that are ecologically sensitive in their management will become more significant to protect crop production yields and soil quality.

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