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Millipede- A Review

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Abstract: Diplopods are called millipede, one of the largest arthropods that are known throughout the world as inhabitants of moist areas with a prevalence of organic material. Millipede occurs in most of the globe except cold and deserts zones. It can be encountered nearly everywhere in places supporting plant debris, the maximum number of millipede lives in the forest. Millipedes are ecological engineers, the vertical movement of millipedes through the soil system causes the spread of microorganisms. They are fragmented by detritus to allow more surface exposure for fungi and bacteria to act upon and to stimulate the growth of these mineralizers. Millipedes, the saprophagus diplopods play an important mechanical role in breaking up the plant litter into smaller particles in the form of feacal pellets. Generally, millipedes are detritus feeders apparently affect the nutrient cycling through the redistribution of organic materials and consequently release the chemical elements in the soil.

Key words: Diplopoda · Arthropoda · Millipedes · Saprophagus · Detritus · Nutrient Cycling

INTRODUCTION

Millipedes, the ancient arthropods which belong to class Diplopoda, are the third most diverse class of terrestrial arthropods, following Insecta and Arachnida. Millipedes have a long and recognized history on our planet, crossing more than 400 million years. These arthropods existed on earth in excess of multiple times longer than man and their fossils records show their overall dispersion [1, 2]. An estimated total of more than 80, 000 extant species, only about 12, 000 millipede species have been formally described [3, 4]. In most languages, the millipedes are called by names, which are derived from the (large) number of legs, for example: Miljoenpoot (Dutch), millipede (French), quilopodo (Portuguese), Tausendfussler (German), jongvoo (Swahili), Songololo (Zulu), Kaki seribu (Indonesia) and Maravattai in Tamilnadu, India. They occur in most of the globe's natural zones or belts except the icy zones (Arctic and Antarctic desert) as well as the driest deserts [5].

Millipedes are significant parts of invertebrate variety evaluations and other biodiversity considers. The wellbeing and endurance of each deciduous woodland relies upon them, since they are one of the prime mechanical decomposers of wood and leaf litter, particularly in the jungles. They additionally establish one of the significant gatherings of soil and litter fauna in mild and tropical conditions. Diplopods assume a significant part in energy stream just as in the humification of soil and course of minerals in earthly environments. Millipedes end up being the significant individual from the waste food web in the leaf litter rich biological system [6]. Wilson and Anderson [7] reported that millipedes are abundant detritus feeders and occasional herbivores and played a major role in soil formation and nutrient cycling.

Despite their large availability and ecological importance, millipedes remain one of the poorly studied animal groups on the planet, more so in India. Hence, this review paper describes the millipede systematics, morphology, nutrients and digestion, locomotion, reproduction, ecology.

Millipede Systematics: Millipedes belong to the class Diplopoda (double-footed) of Phylum Arthropoda. The class Diplopoda is collected with Chilopoda (centipede), Paurapoda and Symphyla as Myriapoda [8, 9]. The earthbound millipedes were the principal land creatures, emerging during the Ordovician time frame in excess of 450 million years prior [7]. As indicated by the fossil record, diplopods turned out to be extremely different and

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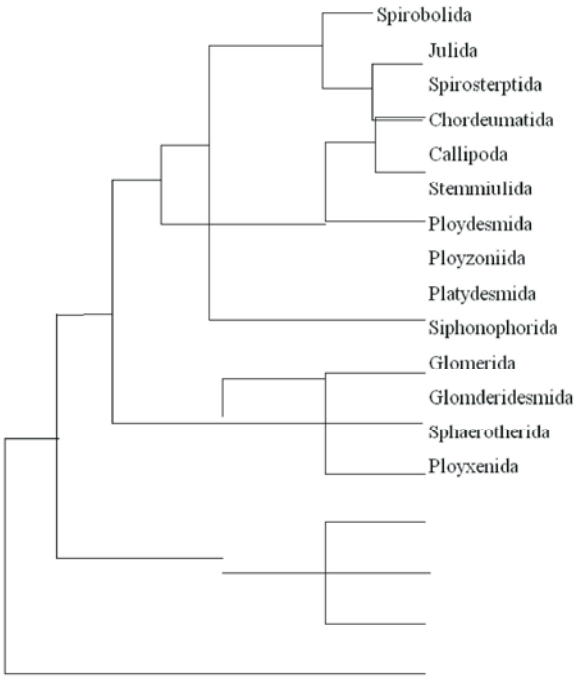
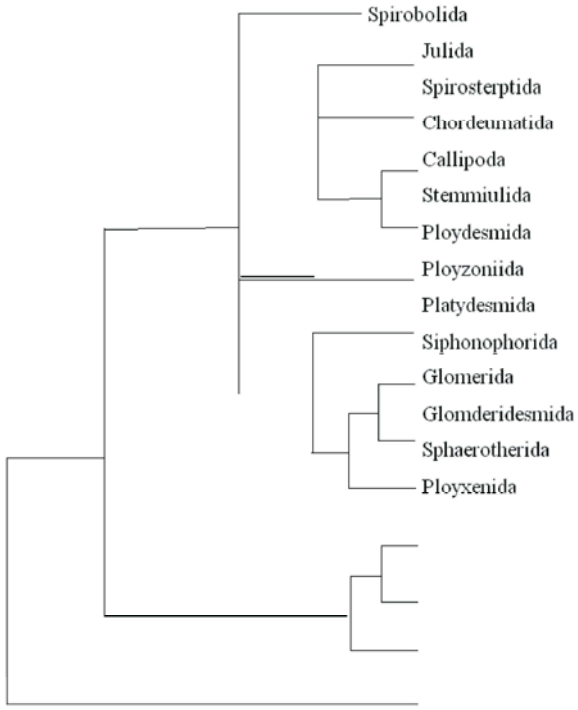
Cladogram 1.1: Phylogeny of millipede orders based on morphological characteristics, with exception of the Siphoniulida [13]



Cladogram 1.2: Phylogeny of millipede orders based on nuclear protein – coding [13]



really normal in the timberlands during Devonian and Carboniferous periods [10]. Millipedes are the significant segments in the developmental systematics of the phylum Arthropoda. Taxonomists generally place the class Diplopoda inside the Super class Myriapoda (Cladogram. 1.1).

In addition to the fact that fossil evidences, the consequences of ongoing sub-atomic, hereditary and neuro embryological examines support that the pancrustacean model in which millipedes separated from the shellfish bug clade [11]. For instance, hemocyanin proteins (Hc's) in creepy crawlies and shellfish are more comparative in amino corrosive groupings to each other than they are to millipede Hc's [12]. In like manner, phylogenetic examination utilizing the construction of three atomic protein-coding qualities puts the bug/hexapod clade profound inside the scavangers, far off from the Myriapods [13]. Morphological data on neurogensis in euarthropod group does not support the atelocerate model but it is consistent with the pancrustacean model of arthropod phylogeny [14-16].

The phylogeny of the class Diplopoda at the ordinal level was well established by [17]. Extant millipedes are classified into fifteen taxonomic orders [18] (Chart.1.2). The orders are combined into two subclasses (Penicillate and Chilognatha) based on the presence or absence of a hard, calcified exoskeleton. Larger part of millipedes have a place with the subclass Chilognatha, which has a calcified exoskeleton, thus the orders in this subclass are additionally gathered into two infraclasses specifically Pentazonia and Helminthomorpha. Pentazonia are somewhat short, wide millipedes, while Helminthomorpha are prolonged, worm-like millipedes. Using morphological characteristics and cladistic analyses, all the orders of millipedes, with the exception of the enigmatic Siphoniulida, are organized into a preferred cladogram (Cladogram. 1.1). The revised phylogenetic analysis using nuclear protein-coding, yields a cladogram (Cladogram. 1.2), which largely agrees with the morphological tree. The discrepancies between the two approaches are considered minor and easily explained by Regier *et al.* [13].

Morphology and Growth: One of the most notable characteristics of millipedes is that they have two pairs of legs on most body segments, hence, the name "Diplopoda". The characteristic feature of a millipede is the exoskeleton, an almost rigid armoured covering, which is impregnated largely with calcium salts, making the millipede incompressible. The animal is often round and cylindrical or hemispherical in cross section [8]. They have a generally unbendable body made out of three units: the head, a variable number of trunk fragments

and a pygidial portion that contains the rear-end. The head is followed by the trunk, consisting of a column or first trunk unit, three segments sharing three pairs of legs and many (more than four) similar leg-bearing ring segments, with two pairs of legs on each segments [9]. Each ring segments or diplosomite actually consists of two fused segments. The body segments bear a number of hairs, sensitive to touch 81]. The last leg-bearing segments are called telson contain one or two apodous rings. The terminal telson consists of a pre-anal ring, a pair of anal valves and a sub-anal scale [9]. The telson often plays a key role in the identification of millipede species. The short antennae are composed of eight segments. They carry sense organs, which palpate the substrate immediately in front of the head [9]. Lawrence [8] reported that, when the millipede walks along, the tips of the antennae are constantly tapping against the ground. The mouth-parts of millipedes consist of a pair of mandibles, of which, with a few exceptions, the biting portion is armed with blunt and rather clumsy 'teeth', which are used to break up and grind the bigger particles into smaller particles for swallowing [19]. The gnathochilarium, which forms the floor of the buccal cavity, is hardly involved in chewing. As the food passes into the mouth, these organs come first into direct contact with the food. The detailed shape of the gnathochilarium varies from order to order and hence, it is also used for identification.

As millipedes live in dark places sight, is not well developed and not much significant to the animal in finding food [8]. The members of *Polydesmida* possess no 'eye' at all [9], while in the majority of the super order a cluster of ocelli, just above the antennae, is found [8]. The millipede leg has *Juliformia,* a basic number of seven podomeres, in contrast to most insects, which have only five podomeres. Besides the trochanter, prefemur and femur, there is an extra postfemur, followed by the tibia, tarsus and tarsal claw. The position of the post femur corresponds with the position of the 'knee', which gives an S-shaped bending to the leg. The legs of the *Juliformia* are positioned ventrally through the coxae to the sternite, although those of the *Polydesmida* are inserted more laterally [9]. Most millipedes have the ability to burrow below ground. In fact, some millipedes spend majority of their lives below ground. On the other hand, there are some millipedes that have lost the ability to burrow and they live entirely above-ground leaf litter, in cracks in the soil substrate, or up in trees [20, 21]. Interestingly, the millipede, *Xenoboluscarnifex* lives and infests the organic thatched roof of the huts and drastically decreased the durability of the thatch [22].

Millipedes exhibit a wide range of body lengths. The littlest millipede, *Polyxenuslagurus* has a place with the family Polydesmidae, is 3-6 mm though the biggest millipede, *Archispirostreptusgigas* is 275 mm when completely developed. At last, contrasted with bugs and arachnids, millipedes as a taxon are extensive. The pill millipede, *Glomerismarginata*, requires quite a while to develop physically and can satisfy 11 years. In this case, adults moult annually and continue to increase in body size and mass [23].

Nutrition and Digestion: Millipedes play an important mechanical role in breaking up the plant litter into smaller particles. Further, apparently millipedes absorb a tiny piece of the material they ingest [9]. Some millipedes routinely consume their own exuvia after moulting to obtain calcium and other nutrients [19]. The requirement for diplopods to aggregate calcium implies that, hence alone, they are a significant part in the cycling of calcium in some earthly biological systems. The vast majority of millipedes are detritivores that feed opportunistically on decaying leaves or wood on the ground [21]. Mundel [24] noted that few species eat living plant tissue or decaying animal tissue.

Blower [9] reported that millipedes do not have specific digestive enzymes in order to digest the leaf material itself and it is therefore assumed that the digestive system accommodates micro-organisms, which induce this process. Millipedes deal with food in two stages. At first, after the mechanical break up by the mandibles, nutrients pass through the mid-gut epithelium and are quickly assimilated across the microvilli. Secondly, enzymes from the secretion of the salivary glands [25] and the mid-gut epithelium and probably from the present micro-organisms mixed with the food in the mid-gut lumen, ensure that the products of digestion are assimilated by the body. The rectum in forms the faecal pellets. It can re-retain water from a damp substrate [19].

Locomotion and Burrowing: In the event that a moving millipede is seen from its side, it shows up as a little skimming train, for which the co-activity of the various legs is required. Numerous millipedes need to discover normal safe houses, like stones, trunks of fallen trees and once in a while abandoned termite hills. Overall they stay in the shallow dirt layer, however during the hot dry season they can tunnel to more noteworthy profundities. However millipedes come up short on the vital burrowing structure for tunneling, they are found overwintering in tunnels [26]. Hopkin and Read [19] announced that, the

head capsular is normally vigorously calcified to work with tunneling. Also, the ventral beginning of the legs is viewed as a transformation for tunneling [27].

Reproduction and Life Cycle: Millipedes have separate sexes and are typically sexual. They have the openings of the genital channels of both genders on the seventh section ring of the storage compartment [8]. In millipedes of request Julida, a couple of testicles opens however gonopores on a twofold lobed penis simply behind the second pair of legs and in Polydesmida, the outside male organs, the purported gonopods, open through gonopores on the coxae of the second pair of legs, or through a penis on them In all sets of Diplopoda, the female millipedes have matched oviducts, which independently open through the vulvae, back to the second pair of legs [9, 28]. Berns [29] showed that in the request Spirobolida following the shed to the fifth arena, the utilitarian strolling legs of the seventh ring fragment are supplanted ventrally by little knocks. In the next stadium, these bumps will undergo morphological changes and will develop into gonopods at maturity. Hopkin and Read [19] presumed that gonopods go through reformist development and separation of their own and don't create as a slow alteration of the strolling legs. At development, every female species has a remarkable itemized construction of the vulvae and this might be of significance in distinguishing proof [30]. Lawrence [8] noticed that the external male sex organs are often a helpful means to identify the species whereas the females do not have these pads.

After the cycle of insemination, the female stores the sperm in the alleged spermathecae. The eggs will only be fertilized when they leave the body at oviposition [9]. As egg is energetically a closed biological system, embryogenesis is largely dependent on the egg's nutritive reserve, the yolk. Yolk is a product accumulated in the egg by vitellogenesis [31]. Browder [32] reported that yolk is the most prominent cytoplasmic component of the egg, consisting of lipids, carbohydrates and protein in many species. It is a special kind of reserve substance containing almost the entire spectrum of nutrients to ensure the normal development of the embryo. Millipede laid eggs in various forms and shapes. They are usually laid in the soil. Generally the eggs of millipedes are typically very yolky and are nutritious to nurture the offspring until after emergence following the second moult because many immature millipedes remain in an egg capsule and do not feed till then [19]. The quantity of eggs laid by a female millipede changes generally: from not many as 3 or 4 up to 2, 000 eggs in a single grip.

Eggs with moderate yolk are usually deposited at a time, often in specially constructed 'nests' made out of moistened soil. The outside of the 'nests' is often camouflaged with fragments of soil and dirt [8]. A resistant capsule, camouflaged with saliva moistened earth, is prepared around the egg [19]. Hatchings are regularly legless. They develop legs and add segments at each moult post eclosion. After hatching, the embryo feed on the walls of the capsule; which serve as its first nourishment until after the second moult. The larva is born with only three pairs of legs and four fully developed ring segments. Posterior to these podous ring segments there are one to three apodous ring segments. It soon sheds its skin and after each moult it initiates more ring segments and more legs, which appear in the proliferation zone, near the posterior end of the trunk. This mode of embryonic development is called as anamorphosis. The youthful hatchlings are a lot lighter in shading than the developed ones and it takes over a year to arrive at full size of the developed millipede [9].

Most millipedes undergo a pure anamorphic development. Generally there are 7 or 8 moults after the 6 first legged stadia. However, there are also species, which undergo even 6 to 14 or 15 moults. For example, the Polydesmida has either 7 or 8 moults. The number of moults in Julida is even more variable i.e., from 6 to 15. The shedding of the skin also continues from time to time during the life of the adult [8, 9]. The entire interaction of shedding, keeps going roughly for three 3 weeks, during which the millipedes are even stable. The shed skin is frequently eaten, as the fingernail skin contains important calcium salts, which can be utilized for solidifying the enhanced one as announced by Lawrence [8].

Natural Enemies and Defense: Diplopods are attacked by a lot of organisms, including vertebrates. The stomach of various South African birds contained millipedes, demonstrating that they can conquer the debilitating impacts of the protective organs. In South Africa, professional killer bugs (Hemiptera; Reduviidae) burn-through for the most part bigger types of the family Spirostreptidae, while some more modest species, like Chersastus (Spirobolids), are not under any condition assaulted. Similar record for parasitic vermin, which assault in huge numbers on Doratogonus (Spirosteptidae), yet are infrequently discovered benefiting from Chersastus [8]. A few millipedes of the Julida are regularly influenced by ectoparasitic organisms of the Laboulbeniales [33]. The branched hyphae infect the first three pairs of legs of females and the first seven pairs of legs of males and ultimately result in the

restriction of their mobility. It very well may be because of the way that the millipede is as of now not ready to prep productively, or to the shortfall of guarded organs in the initial five ring portions [9].

Millipedes ordinarily are sluggish and non-forceful animals. Notwithstanding the way that they may appear helpless, the majority of millipedes show three kinds of defensive frameworks against different trackers. In the first place, the greater part of the millipede species have a thick, hard exoskeleton that gives some security; Second, most millipedes can twist into a winding or ball that ensures the delicate top of the creatures. For instance, Eisner and Davis [34] clarified that an African pill millipede, *Sphareotheriium sp*. can get away from predation from various foes due to its exceptionally hard exoskeleton and the capacity to shape in a tight ball. Be that as it may, this millipede can't get away from predation from the grouped mongoose, which heaves the millipede through its rear legs and crushes the millipedes against a stone or another hard surface and afterward eats them. Third, various millipedes use a watched release that can cause stinging, troubling, or sedation to likely trackers. In many cases the exudates contain hydrogen cyanide or quinones, however others release uncommon particles. Carrel and Eisner [35] found that hunters like wolf arachnids, *Lycosa sp*. which endeavored to go after quinazolinone-discharging millipedes, *Glomerismarginata* were immediately deflected by the radiated liquid; those not many that continued and devoured some emission were quieted for quite a long time regardless of whether they had ingested short of what one bead of the discharge. Then again, Polyzoniidae millipedes, for example, *Polyzoniumrosalbum* discharge ployzonimine and nitro-polyzonamine when upset. Polyzonimine is a notable insect obstacle. It has been shown that when insects assault this millipedes they will quickly withdraw when the millipede discharge its poisons. Consequently, the millipede gets away from the assault safe.

Pest Status: Though earlier studies on the biology and ecophysiology of millipedes have considered them mainly as saprophytes, some are treated as indoor nuisance pests, as they crawl into basements, rooms of first floor, living room outside walls and ceilings of houses. Johns [36] exhibited that the millipede, *Ommatoiulusmoreletti* caused huge aggravation in New Zealand. Urban invasions by the millipedes, Oxidus have been reported in Tennessee, U.S.A [37]. Niijima and Shinohara [38] emphasized that the outbreaks of the train millipede, *Parafontarialaminata* led to suspension of the train service in central Japan. Boccardo *et al.* [39] recorded a notorious millipede pest, *PlusioporusSetiger* invading houses besides causing damage to vegetable gardens, orchards and small plantations in Brazil. Alagesan and Muthukrishanan [40] recorded that millipede, *Xenoboluscarnifex* as family bug making extreme harm the covered top of the hovels. By and large millipedes are innocuous to man. But, Lavaund *et al*. [41] observed a 43 years old man developed prutitus, fever, edema and arthralgia, after 48 hours he was bitten by the millipede, *Lithobiusforficatus* in France. Norris [42] has attributed medical importance to the irritating defensive secretion of millipedes which contains benzaquinones, aldehydes, hydrocyanic acid and other substances: the secretion causes irritation in the skin and eye, mild edema, local erythema etc., in man.

Alagesan and Ganga [43] announced that the grown-ups and adolescents of *Harpurostreptus sp*. feed on delicate buds and foundations of recently planted custard and cause hindered development or demise of the plant. Millipedes for the most part ingest the delicate and effectively absorbable parts, like delicate shoots or fine roots [19]. Studies showed that yam ranchers from North-eastern Uganda considered the millipedes as the second hugest arthropod bother after yam weevils [44, 45]. Besides, it created the impression that other significant yields, like groundnut, maize, cassava, beans (kidney beans and other grain vegetables), sesame, cotton, cabbage, sunflower and banana pseudostems were additionally influenced by millipede species [45-47].

Ecology of Millipedes: Millipedes are ecologically important organism and play a crucial role in the decomposition of leaf litter and in the nutrient cycling within the soil. Millipedes destruct dead plant material into small pieces thus increasing the surface area. This is important because the surface is the only part the microbes such as bacteria and microfungi can reach and they are the main agents of recycling in the soil. An American biologist estimated that millipedes in an unnamed forest in USA contributed 2 tons of manure per acre per year to the forest. Mild types of millipedes will in general eat leaf litter around multiple times of their weight. Some temperate species of millipedes tend to eat leaf litter about five times of their weight.

Millipedes are functionally important in enabling nutrient cycling and decomposition of dead plant tissues, perhaps much more so than is envisioned [48]. In addition, millipedes can be bio-indicators for environmental changes in ecosystem. They are primary

consumers. McBrayer and Reichle [49] reported millipedes are litter fragmenters. The contribution of the millipedes to the ecosystem is significant as they transfer energy through their feces and produce animal biomass for consumption by members in the next trophic level which are called as secondary consumers. Mostly the primary consumers are heterogenous in their contributions to the ecosystem. Thus the exploitation of food by each group is distinct. The degree of alteration of food processed by these animals varies so widely according to the morphology and physiology of their digestive tract that the feces produced by one group plays a different role in the food web of the ecosystem from that produced by other groups.

The animal groups vary greatly in their ratio of known and described species to yet to be discovered species diversity. The recorded predisposition against spineless creatures and among them the millipedes, is absolutely to some extent because of specialized hardships and the measure of exertion needed to survey their morphological characters, undertakings that draw in couple of scientists, in the past just as in the present. The examination work on diplopods is extremely restricted and has gotten next to no consideration from systematists and the scholars. Maybe their dark nature probably won't have displayed interest among the zoologists and entomologists and along these lines there is an absence of aptitude regarding the matter. The taxonomy of this group remains at the alpha stage and the biology is at an infant stage in India. Millipedes are important parts of invertebrate variety appraisals and other biodiversity examines. The health and survival of deciduous forests depend on millipedes as they are one of the primary mechanical decomposers of wood and leaf litter, especially in the tropics.

The success of a species is judged by the rate at which it establishes its population and by its ability to maintain it in a stable condition in the long run. Millipede populations are not stable and they exhibit a gradient and cyclic pattern of growth. Considerable information is available on diplopod population structure [40]. The millipede's activity above-ground is usually correlated with seasonal climatic variations. Most species of millipedes are active when it is warm, especially during the rainy season or after a single rain event [19]. For instance, Barlow [50] showed that calm millipede, *Cylindroiulusfrisius* is generally dynamic in wet, warm conditions. Generally millipedes are found in habitats containing much leaf litter in order to feed, remain hidden and stay moist, all at the same time. They are more powerless to parching than other earthly arthropods in light of the fact that many clearly do not have a waterproofing epicuticular lipid layer [51].

Millipedes are not exceptional with particular compounds to empower them to process the plant litter itself. It is thought that miniature organic entities in the nutritious trench assume a vital part in the processing of food [9] and in a roundabout way impact the transitions of supplements [52]. Leaf-litter taking care of by millipedes influences decomposer soil microorganisms, which improve the action of the last mentioned and frequently builds biomass after litter entry through the millipede gut [53, 54]. The digestive system of most millipedes is rich in enzymes. Diplopods likewise seem to help brief microbial symbionts that obliterate cellulose, gelatin and many plant items like protein and carbohydates [55].

Millipedes as a huge detritivores, obviously influence supplement pushing through the reallocation of natural material and, thus, the arrival of compound components like nitrogen in the dirt [56]. The job of millipedes in woodland environment is critical and they go about as tractors or rammers, wedge type or litter-splitters, drills, epitomized rollers and bark occupants [19, 57]. Through this cycle, the millipedes further develop the dirt ripeness and improve the development of bacterial and parasitic species in soil. The conditions of millipedes gut like high humidity and low oxygen are creating a suitable habitat for the anaerobic bacteria to grow [58]. Millipede gut-adjusted microorganisms achieved to corrupt complex natural make a difference to give basic wanted substrate to the millipede, thus millipedes continually supply natural make a difference to gut organisms with appropriate condition [59].

The specific food consumption strategy adopted by each group determines its nutritional relationship with other groups and thus not only influences the flow of energy and matter through the ecosystem but also individualizes its structure [60]. Diplopods feed mainly on decomposing vegetation, but some species eat animal substances. In some tropical regions these animals are more important than earthworms in when it concerns soil recycling since they feed on decomposing plant material eating fungi, bacteria and the material they have already torn in pieces [61]. The faeces of millipedes are composed of undigested dead plant tissues, mineral particles and soil microflora but they have higher pH values, water holding capacity and surface/volume ratio than structured waste [62, 63]. Karthigeyan and Alagesan [64] affirmed that millipede manure got from different natural substances showed critical upgrade in the physiochemical

and biochemical constituents. Millipedes play a significant role in the composting of plant residues, should be considered as economically significance producers of compost in organic farming, besides enriching the soil in terms of nutrition and soil microflora [65].

CONCLUSION

Millipedes are the highly diverse arthropod groups present on the earth having 12000 described species. They are classifies into 16 orders and 145 families. Millipedes are economically important to human beings through directly or indirectly. Millipedes mean thousand legers, sluggish limed and secretive creature. It is move slowly because of its short legs, these help to push soil. Millipede is a biological indicators because the environmental changes commonly affect millipede population. Millipede influence the soil edaphic factor includes: texture, water content, temperature, minerals, humidity and type of humus. Decomposition of detritus is one of the important ecological role in soil ecosystem. Millipedes are known to ingest plant detritus and convert in to mineral rich feacal pellets. They are one of the vital macro fauna in organic matter recycling in a variety of habitats by fragmentation and deposition of feacal pellets, which enhance the surface area for bacterial and fungal colonization. The climatic desiccation by human interference is one of the major threats for millipedes. Hence, an intensive survey, documentation and monitoring of different millipedes species, especially in different unique habitats is extremely needed to conserve these species and also ecosystem.

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