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ENST422 Term Paper

Dung Beetles and Microbial Decomposition of Dung

Introduction

Dung beetles belong to the superfamily *Scarabaeoidea*, and are mostly within the subfamilies of *Scarabaeinae* and *Aphodiinae.* They are given their name because they feed partially or exclusively on feces. Each species of dung beetles can be classified as one of several types: rollers, tunnelers and dwellers. Rollers roll the dung into round balls, which are then used for brooding chambers or as a food source. Tunnelers bury the dung ball and create vast tunnels that can be several meters deep. These tunnels are used to create brooding chambers that are backfilled with soil. Dwellers do not move the dung; they simply live inside of it (Nichols et al. 2008).

Dung beetles play an active role in agriculture by rolling and burying the feces of herbivores that are raised as livestock, which mostly includes cattle raised on pastures. They are also seen as a way to improve nutrient recycling by changing the way carbon and nitrogen are decomposed. This paper will focus on dung beetles and their effect on the microbial decomposition of dung and the underlying soil as well as the difference between decomposition of dung above ground and decomposition after the beetle has buried the feces.

The Chemistry and Biochemistry of the Process

The movement of manure by the dung beetle changes the way nutrients cycle from the dung to the surrounding soil. Tunneler and roller dung beetle species are especially important because they bury fresh manure below the soil surface, which places the nutrient rich dung directly in the soil and activates microbial activity that begins to break down the dung (Nichols et al. 2008). Because cows are ruminants and only eat plants, they had to evolve a special set of stomachs and microorganisms that can break down plant fibers. Therefore, most of their feces is comprised of plant matter that their rumen and other stomachs could not metabolize, and metabolic excretions. The undigested plant material includes cellulose, hemicellulose and lignin (Van Soest 1982).

Cellulose is the most common structural polysaccharide in plant matter. Its size and insolubility in soil make digestion harder for microbial organisms. Extracellular enzymes called cellulase must first break the cellulose down into smaller pieces that can be used inside the cell wall to create energy. Hemicellulose has polymers consisting of hexoses, pentoses, and uronic acids. Its decomposition is more rapid than cellulose. Lignin has the slowest decomposition because of its large molecular nature and its complexity (Sylvia et al. 2005). All of these components exist in cow dung, but they can greatly vary in density according to the diet of the cow.

Another component of cow dung is metabolic excretions, which include microbial debris and endogenous secretions. Microbial debris is comprised of dead microorganisms that digested plant matter in the cow's stomachs. It can also contain nitrogenous matter left over from digestion. Endogenous secretions consist of salts, dead animals cells and mucus, all excreted during digestion (Van Soest 1982). Cow dung contains nutrients, especially carbon and nitrogen compounds, and has been used as a fertilizer as well as a fuel supply in some countries. The cow dung not only provides food for the dung beetle, but also gives a rich food supply to the microorganisms within the soil.

The cycling of nitrogen and carbon under the influence of dung beetles has been studied several times. Gillard (1967) reported that dung burial by dung beetles reduced the amount of N lost through ammonia (NH_3) volatilization, while Yokoyama et al. (1991a) observed that dung beetles increase mineralization rates. Specifically, Yokoyama et al. (1991a) determined that in the first five days of the experiment, the readily-decomposable organic nitrogen inside the cow manure mineralized quickly without any effect from the dung beetles. 15 days later, another ammonification process began in the dung balls, which was attributed to the dung beetles. The conversion of organic nitrogen to ammonium is carried out by enzymes produced by microbes. The microbes use extracellular enzymes to convert organic-nitrogen polymers to monomers. After the monomers are metabolized more, ammonium is released into the surrounding soil (Sylvia et al. 2005). The nitrogen in the cow dung would not be accessible to plants if it was not first converted to ammonium by soil microbes, which is made easier by dung beetles and their impact on dung and the soil under the dung.

Yamada et al. (2007) studied the effect of tunneler dung beetles on soil nutrients and the decomposition of the cow dung. The greater density of the dung beetle population, the higher the decomposition of the dung. There was also a greater movement of nutrients, especially nitrogen, from the dung into the soil when dung beetles were present. Yokoyama et al. (1991a) also saw an increase of inorganic N in the soil below the buried cow dung that had dung beetles compared to the control, which did not. Owen et al. (2006) found similar results; total nitrogen and carbon decreased in the dung pads, but increased in the soil beneath the pads. Manure with dung beetles, *A. fossor,* had significantly less total N in the pads than pads without beetles, as well as total C amounts that were significantly lower in the crust. It can also be hypothesized that by making tunnels, the tunneler beetle carries dung with it to the surrounding soil. The dung beetle is important in moving the nitrogen and carbon from the dung to adjacent soil, where it can then be more easily decomposed by soil microorganisms.

Yokoyama et al. (1991a) also observed nitrification differences between the uncolonized dung balls and the colonized dung balls. The dung balls with dung beetles present were more aerated than the dung without dung beetles. The soil must be aerated in order for nitrification to occur because nitrifiers are almost always aerobic microorganisms. In addition, inside and around the dung there is plenty of ammonium available from the increased rate of ammonification because of dung beetle action, and therefore nitrification easily happens. Another important factor for nitrification is soil pH. Nitrification will most likely not take place below a pH of 4.5 and will most readily occur in neutral soils (Sylvia et al. 2005). In another experiment, it was shown that dung beetles lowered the pH of the soil, allowing for more nitrification and a decrease of ammonia volatilization (Yokoyama et al. 1991b). The movement of dung beetles within the dung and the surrounding soil greatly help to increase nitrification, which is essential for plant growth. Especially in agricultural use, the dung beetle promoting nitrification would be benefit in pastures where the cow dung can be used as fertilizer for the pastures themselves.

The Microbial Ecology and Diversity

Dung beetles have a significant impact on the microbial community composition. The presence of dung beetles creates a new environment for microbes. Yokoyama et al. (1991a) observed a difference in aeration between the colonized and uncolonized dung balls. The dung balls colonized by dung beetles were rolled into balls and tunneled into, which decreased the amount of moisture in the dung. This created aerobic conditions and allowed aerobic microorganisms to thrive, unlike the uncolonized dung which remained wetter and had more anaerobic conditions. The aerobic microorganisms were able to break down the dung and carry out nitrification thereby additionally helping plant growth.

Owen et al. (2006) compared the weight of dung pads that were inoculated with dung beetles to those that were not. The weight of the dung pads containing beetles increased over the length of the study, and it was thought that the adult *A. fossor* could have increased microbial growth, which explained the increase in weight. In an earlier study, it was hypothesized that a tunneler dung beetle, *Aphodius*, encouraged microbial growth by exposing bacteria to fresh substrate (Hotler 1977). The hypothesis could be explored more by performing further experimentation. Counts of microbes could be done comparing the number of bacteria on the surface and at different depths within cow dung that had not been buried by dung beetles compared to ones that had been. These counts could be performed at various time intervals. Counts could additionally be carried out on the lining of the tunnels created by tunneler beetles and on the beetles themselves. These experiments would lead to a better conclusion as to exactly how much the beetles affect microbial growth.

In the same experiment by Owen et al. (2006), it was observed that *A. fossor* activity caused movement of microbes from the cow pads to the surrounding soil. Soil levels of minimum bactericidal concentration (MBC) were significantly different between different dung beetle dung pads and the treated pads and control pads. There was a higher MBC in the soil beneath the pads with the dung beetles, compared to pads without dung beetles. This most likely occurred because dung beetles moved microbes from the dung into the soil beneath. More research could be executed to see exactly what type of microbe was being moved by the beetle. Examinations of cow dung and its composition, the kinds of microbes that were living in it, could be compared the composition of the surrounding soil. Microbes attached to the beetles themselves could also be analyzed. Certain microbes would be more likely to attach to the beetle than other microorganisms. The microbes that were found could provide more insight into the specific type of microbes the beetle was helping to spread.

Large Scale Implications

Dung beetles are essential to many ecosystems, especially grasslands. Many studies have shown an increase in herbage growth in relation to the density of dung beetles. Fincher et al. (1981) studied how dung beetles affected the yield and quality of coastal Bermuda grass. It was found that, with the dung beetles present, the yield was 7,791 kg/ha, compared to 6,364 kg/ha for feces-only treatment, and 8,305 kg/ha for the 224 kg nitrogen fertilizer treatment. In a second experiment, the yield of the grass with the dung beetle exceeded the yield from the fertilizer. In a third experiment, it was shown that there was a link between the dung beetle density and the highest yield and crude protein of Bermuda grass (Fincher et al. 1981).

Yamanda et al. (2007) found that plants were able to uptake more nutrients when dung beetles were present. The dung beetles increased the decomposition of the dung and the amount of nutrients transferred from the dung to the soil. Studies have also shown that dung beetles decrease the amount of nitrogen lost to volatilization, which helps to keep more of the nitrogen in the soil (Gillard 1967) and promote plant growth. Dung beetles could be a valuable tool in recycling dung into the soil if there is a need to remove large amounts of dung from herbivores.

Another important role for dung beetles is in agriculture. They add nitrogen to the soil, help soil aggregation, and bury the dung underneath the soil fast enough that flies cannot lay their eggs in it. It is for the last reason that the Australian Dung Beetle Project began in 1965 and ended around 1985. Dr. George Bornemissza started the project with the observation that the dung beetles that were native to Australia were not equipped to deal with cow dung and were only used to using dung from native animals. Originally dung beetles were brought in to control the buffalo fly, a large pest of cattle in tropical Australia (Hughes 1975). Results of many experiments show that the introduction of the dung beetle did not help with the buffalo fly, but did help with many other fly pests including the bush fly, whose population was reduced by 80 percent (Dadour and Allen 2001). Along with the pest control, the beetles have been recognized for their value in nutrient cycling, another main reason why the Dung Beetle Project was carried out.

Other countries have acknowledged the importance of the dung beetle. It is estimated that the United States saves 380 million dollars through the use of dung beetles to bury livestock manure (Losey and Vaughan 2006). New Zealand is attempting to begin a dung beetle program to import beetles to increase the fertility of their pastures and reduce their emissions of nitrous oxide (Ihaka 2010). As agriculture continues to grow, dung beetles will continue to provide an important ecological function in burying and increasing the decomposition of feces.

Conclusion

Much of the research done on the relationship between dung beetles and dung decomposition has shown positive connections. The beetles increase cow dung decomposition, while moving the dung and its nutrients to surrounding soils. The microbial communities within and adjacent to the dung are expanded through beetle action in the dung and tunnels outside of the dung. Further research could be done to explore the particular microbial community that the dung beetles foster. The microbes within the beetles' digestive system could also be examined; they themselves eat the dung and must possess the proper microbes for doing so. Their larvae use the dung as a food source as well, and studies into their digestive tract could also show how the dung is decomposed.

Another aspect to consider in relation to microbial communities is the kind of diet eaten by the dung-producing animals and its relation to the microbes found in the dung. For example, Dadour and Cook (1996) studied the effect of pasture-fed cattle versus grain-fed cattle on the reproduction of the scarabaeine dung beetle. The dung beetle made more brood masses when presented with pasture-fed cattle dung. Most cattle are now raised in feedlots and fed grain, rather than eating grass. Feeding cows grain negatively changes their rumen, while changing the microbes and pH within the rumen. The results of the experiment might suggest that the dung produced by grain fed cows is not as nutritional as grass fed cows. The microbial communities cultivated from the cow dung could be less beneficial than feces from grain-fed cows and should be explored further.

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