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UNDERSTANDING THE RELATIONSHIP BETWEEN SOIL SURFACE AREA AND AGRICULTURAL PEST POPULATION

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Abstract

Soil surface area plays an important role in supporting agricultural insect pests, influencing factors like reproduction, body temperature and survival. Larger surface areas improve moisture retention, nutrient availability and habitat for pests, which can increase pest populations. However, this can also make pest management more challenging. Soil structure impacts pest dynamics, insect behaviour and reproduction. Understanding these relationships is important for developing better pest management strategies.

Introduction

Soil is far more than just the dirt beneath our feet-it's a living, breathing ecosystem that plays a vital role in supporting agriculture. Beneath the surface, soil serves as a home for a wide variety of organisms, including plants, microorganisms and insects. The way soil is structured: its texture, composition and surface area greatly influence how these organisms interact with each other and the environment around them. When we talk about soil surface area, we're referring to the total exposed area of soil particles, which includes both the tiny pores called micro-pores and the larger spaces macropores between them. These spaces are critical because they determine how much room there is for soil-dwelling creatures to thrive, and how well water, air and nutrients can move through the soil to support plant growth and insect activity. Micro-pores are typically smaller than 0.08 millimetres in diameter, while macropores range from 0.08 millimetres to several centimetres (Bengtson and Lundström, 2006).

The surface area of soil also has a big impact on the resources available to insects and other soil organisms. For example, when soil has a larger surface area, it can provide more habitat for beneficial organisms like earthworms, which improve soil health by enhancing aeration and helping nutrients cycle more effectively (Jones *et al*., 2017). The increased availability of organic matter and moisture in soils with greater surface areas supports not only plants but also herbivores like root-feeding insects. These insects can have a direct impact on crop yields, especially when their populations grow too large (Gómez-Moracho *et al*., 2018). In fact, the structure of the soil is so important that it has been shown to influence

the population dynamics of certain pests, such as nematodes, which rely on very specific soil conditions for survival (Wardle *et al*., 2004).

Soil's physical properties also play a major role in how insects interact with the ecosystem, especially with regard to the microbial communities within the soil. A soil with a greater surface area tends to support a higher density of microbes, which helps break down organic matter and recycle nutrients, benefiting both plants and the insects that depend on them. However, an overabundance of certain microbial species can lead to soil-borne diseases that harm insect populations, suggesting that soil surface area might also help regulate pest outbreaks through microbial competition (Lamb *et al.*, 2009). Additionally, the structure and surface area of the soil can affect how easily soil-dwelling pests can move through their environment. Insects have to navigate through various microhabitats in search of food, mates and shelter, so the physical characteristics of the soil can directly impact their survival and movement (Snyder and Wise, 2001).

Finally, soil surface area plays a crucial role in regulating the soil's physical properties like moisture retention, temperature and aeration. These factors, in turn, affect both plant growth and the behaviour of insects. Soils with a larger surface area are better at retaining moisture, which creates a more stable environment for pests that thrive in humid conditions, such as termites and ants. Conversely, soils that are compacted or have insufficient surface area may not provide enough resources for insect populations to thrive, leading to shifts in pest behaviour and distribution over time. These changes can have significant implications for agriculture, as pest populations may adapt to new conditions, affecting crop yields and pest management strategies (Lamb *et al*., 2009). In this way, the surface area of soil is a key factor in the health of both the soil ecosystem and the agricultural systems that depend on it. The relationship between soil surface area and the dynamics of insect pests is complex, involving interactions with soil temperature, moisture, nutrient content and microbial communities (Jones *et al*., 2017). An in-depth understanding of this relationship can inform sustainable pest management strategies, aiming to minimise the impact of insect pests on crop yields.

The relationship between soil surface area and insect pests

The surface area of soil is directly related to the density and diversity of insect pests in agricultural fields. Insects that inhabit the soil, such as root-feeding pests (e.g., wireworms, root maggots), rely heavily on the soil's texture and surface area for survival and feeding. A larger soil surface area can provide more space and resources for these pests, increasing their population density in fields. For instance, soil particles with higher surface areas can retain more moisture and organic matter, offering a favourable environment for soil-dwelling pests like nematodes and soil aphids in contrast, finer soils, such as clays, might support a different suite of pests than coarser soils like sands or loams.

In addition to physical space, the soil's surface area can affect the microbial communities that influence pest presence. Soil-borne pathogens

that affect insect pests are influenced by the quantity and nature of available surfaces for microbial attachment (Bengtson & Lundström, 2006). A greater soil surface area might encourage a higher density of beneficial microbes, which could act as natural pest control agents by competing with or preying on pest insects. Furthermore, soil surface area can also affect the feeding behaviour of soil-dwelling insects. For example, ants, termites, and other soil-inhabiting insects might alter their behaviour or abundance in response to changes in the soil surface area (Wardle *et al*., 2004). The presence of organic matter, which increases the surface area, can also attract pests such as beetles, which feed on decomposing material.

Effect of Soil Surface Area on Insect Fecundity

Insect fecundity or reproductive output is one of the most significant factors determining population growth. The surface area of the soil can have both direct and indirect effects on insect fecundity. Insects that require specific soil conditions for oviposition, such as certain species of moths, flies and beetles are strongly influenced by the surface texture and area. Larger surface areas can provide more sites for eggs to be laid and may improve the survival of larvae, depending on the moisture and organic content of the soil. Soil with a larger surface area tends to retain more moisture, which is beneficial for insect larvae during their development stages. Additionally, soils with increased organic matter or finer particles might offer better protection against desiccation, enabling insects to invest more energy into reproduction. In agricultural fields, the presence of organic mulch or soil amendments that increase surface area may, therefore, lead to an increase in the fecundity of pest species.

Soils with higher surface area typically have better aeration and drainage, providing a more favourable environment for insect larvae to hatch and grow. This can lead to higher rates of fecundity, as larvae require optimal conditions such as adequate moisture and oxygen availability to develop successfully (Broughton *et al.*, 2014). Research has shown that soil with greater surface area tends to retain more organic matter, which can support higher larval survival rates by providing both nutrition and a stable microenvironment (Heijden *et al*., 2008).

Effect of Soil Surface Area on Insect Body Temperature

The body temperature of soil-dwelling insects is a critical factor influencing their behaviour, development and overall fitness. As ectothermic organisms, insects rely on external environmental conditions to regulate their body temperature. The surface area of the soil plays an important role in shaping the thermal environment in which these insects live. Soils with larger surface areas typically have a greater heat retention capacity, as the increased presence of micropores allows for better moisture retention and less temperature fluctuation, creating a more stable microclimate (Wiggins *et al.*, 2011).

Warmer soil temperatures can accelerate the metabolic rates and development of insect pests. For instance, soil-dwelling creatures such as root-feeding nematodes, beetles and larvae

of certain pest species thrive in warmer soil conditions, often reproducing more rapidly when exposed to soils with a larger surface area that retains heat effectively (Glynne and Doulgeridou, 2008).

Studies have shown that warmer soils promote faster insect development and higher fecundity, which can lead to more significant pest populations under favourable conditions (Stewart *et al.*, 2014). However, excessive heat retention can also stress the insects, leading to reduced survival rates, lower reproduction and even mortality if soil temperatures exceed their tolerance limits (Hodda and Nicholas, 2008). This creates a delicate balance where moderate heat retention is beneficial, but extreme temperature fluctuations can negatively impact pest populations.

Furthermore, soil surface area influences the microclimate by affecting moisture retention, evaporation rates and humidity levels, all of which are essential for insect survival. Higher humidity levels, which are often linked to larger soil surface areas, are especially important for insects like termites, ants and some species of beetles that depend on moisture for both thermal regulation and feeding (Jones and Sutherland, 2007). These pests are more likely to thrive in environments where the soil retains moisture, providing a stable and humid microhabitat that supports their metabolic and reproductive processes. For example, termites are particularly sensitive to moisture levels and are more abundant in soils that can maintain higher humidity, allowing them to carry out their complex social behaviours and feeding activities (Liu *et al.*, 2011). Similarly, ants that forage and nest in soil benefit from the microclimates provided by higher surface area soils, which help maintain the humidity levels required for their survival and colony success (Winston and Johnson, 2009).

Effect of Soil Surface Area on Insect Reproduction

The reproductive success of soil-dwelling insects is linked to the conditions provided by the soil environment, including its surface area. Insect reproductive behaviours, such as mating, oviposition and larval development, can all be influenced by the soil's physical properties. For example, insects like soil-dwelling moths or root maggots require specific soil types with adequate surface area for successful egg-laying (Snyder and Wise, 2001). Soil surface area also affects the availability of food resources, which in turn influences reproductive success. Soils with high surface areas provide more opportunities for nutrient uptake by plants, which may lead to higher availability of food sources for herbivorous insects (Wardle *et al.*, 2004). For example, root-feeding insects that depend on plant roots may benefit from soil surfaces that allow greater root growth, thus providing more food for larvae. The availability of organic matter, which increases soil surface area, can also support a greater diversity of soil organisms.

This diversity can create a more stable environment for insect populations, increasing reproductive success by ensuring a constant availability of resources (Lamb *et al.*, 2009). Conversely, changes in surface area, such as soil compaction due to farming practices, might

reduce the availability of food and shelter for pests, leading to decreased reproduction rates.

Conclusion

The surface area of soil plays a crucial role in shaping the environment for agricultural insect pests, influencing many aspects of their biology. When the soil has a larger surface area, it tends to create a more favourable habitat for soil-dwelling insects. This is because the increased surface area helps retain moisture, makes nutrients more accessible, and supports a variety of microbial communities that can either serve as food sources or help control pest populations. Essentially, it creates a richer, more stable environment where insects can thrive. However, there's a flip side. While a larger surface area offers these benefits, it can also contribute to higher pest densities. More surface area can lead to more insects, which may accelerate the spread of pest populations and make pest management more challenging. In this way, the surface area of the soil becomes a balancing act providing an ideal environment for insects to grow and reproduce, but also potentially contributing to an increase in pest numbers that could harm crops. By managing soil physical condition, particularly in agricultural settings, farmers can create environments that reduce pest abundance while enhancing soil health. Further research into the specific mechanisms linking soil surface area to insect pest behaviour, survival, and reproduction is essential for developing more sustainable agricultural practices.

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