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Progress of Research on Root Secretion under Different Crop Intercropping Systems

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Abstract

Food security has become a global concern with increasing population, declining natural resources, increasing energy costs and environmental changes.Enhancing positive legacy effects requires a deeper understanding of plant-soil-microbiome interactions and innovative crop, input, and soil management, which can help achieve agricultural sustainability.

Keywords

Plant-soil-microbiome; Agricultural; Root Secretion.

1. Introduction

Food security has become a global concern with increasing population, declining natural resources, increasing energy costs and environmental changes [1].Current intensive agriculture, especially crop succession, has had a negative legacy impact on soils, weakening their ability to provide multiple ecosystem functions.Agricultural intensification has had long-term negative impacts, mainly due to excessive inputs of agrochemicals, such as fertilizers; and homogenization of farming systems, such as continuous monocropping [2].Traditional agricultural management has focused on curbing these negative legacy effects. However, there is now an increasing focus on creating positive legacy effects above and below ground by selecting crop varieties/genotypes, optimizing the temporal and spatial mix of crops, improving nutrient inputs, developing smart fertilizers, and applying soil or microbiome inoculation. This can increase yields and reduce pest and disease stress in farming systems, as well as mitigate greenhouse gas emissions and increase carbon sequestration in the soil. Enhancing positive legacy effects requires a deeper understanding of plant-soil-microbiome interactions and innovative crop, input, and soil management, which can help achieve agricultural sustainability [3].

1.1. Root Secretion

Root secretion is an important carrier of material exchange and information transfer between plants and soil, and it is a general term for organic substances released by the plant root system into the inter-root environment, which is an important way for plants to respond to external stress, and it is a key factor constituting different inter-root micro-ecological characteristics of plants, and it plays an important role in the formation of soil structure, soil nutrient transformation, nutrient uptake by plants, soil microbial distribution, and the alleviation of

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environmental stresses. It plays an important role in soil structure formation, soil nutrient transformation, plant nutrient absorption, soil microbial distribution and environmental stress alleviation.Root secretions have important functions in biogeochemical cycling, inter-root ecological process regulation, plant growth and development, especially in regulating the structure and function of inter-root microecosystems, and regulating the complex interactions between plant-plant, plant-microbe and microbe-microbe.Plant chemosensitivity, crop intercropping, bioremediation, and biological invasion are all hot spots in modern agroecology, and they all involve very complex inter-root biological processes. More and more studies have shown that the positive or negative effects of interactions between plants of the same species or different species are the result of the joint action of plants and specific microorganisms mediated by root secretions. Root secretion is an important component of organic matter returned by plants to the soil (about 20% of photosynthetic products), and is an important link between plant-soil-microorganisms, which plays an important role in nutrient cycling, energy flow and organic matter turnover [4].It has been shown that the secretion of the plant root system is an important way of adapting to the stressful environment, through which the plant communicates with the inter-root environment in terms of material, energy and information [1]. Intercropping is an important initiative for green and sustainable development of agriculture in the future, with multiple advantages such as increased yield, efficiency, small environmental costs, low pest and weed infestation rate, etc. There have been many studies on how to improve the yield and resource utilization rate of intercropping, but there are relatively few studies on the intercropping of the below-ground, and the competition and promotion of below-ground interspecies is the key to the intercropping of the advantages of the changes in morphology and distribution of the root system and the root system. Changes in root morphology and distribution and mutual promotion of root physiological functions are the ways to realize the advantages of intercropping [6].Gramineae, legumes and intercropping of gramineae and legumes are frequently adopted as high-yield cropping patterns in northwest China. Some studies have shown that corn-soybean intercropping with reduced nitrogen inputs provides a very useful way to improve land productivity and avoid environmental pollution [7]. Through intercropping technology, light and heat energy resources can be effectively utilized to increase land yield. Maize-soybean intercropping is applicable in areas with two (or three) seasons a year, such as the Yellow Huaihai region and northwestern China [8], while maize-soybean intercropping is practiced in areas with one season (or three seasons in two years), such as southwestern China [9].In set-planting systems, combined crops behave differently than monocultures and have an impact on grain yield and nitrogen efficiency. In a previous study, intercropping with legumes significantly increased nitrogen uptake by the later crop, leading to a 30% increase in grain yield [10]. Nitrogen resource utilization was increased by 30-40% in legume-cereal intercropping compared to the corresponding monocropping [11]. In addition, root distribution plays a key role in below-ground nutrient acquisition. The roots of cereals are distributed in the near-surface and deep soil layers, while the roots of legumes are distributed in the upper soil layers. Currently, academics generally categorize root secretions into primary and secondary metabolites. Primary metabolites include sugars, amino acids, and organic acids, while secondary metabolites include flavonoids, thioglucosides, and growth hormones, and generally primary metabolites are secreted in greater quantities than secondary metabolites. Studies have shown that these metabolites have been identified and quantified in plants such as Arabidopsis, soybean, and rice [12].

1.2. Progress on Root Exudates

Root secretion is mainly released through transmembrane transport, which can be categorized into passive and active transport according to the mode of transport. However, there are many ways to collect root secretion, and the existing research mainly adopts the following methods: solution culture collection method, soil culture collection method, substrate culture collection

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method, continuous collection method, and in-situ collection method, etc. These traditional methods of root secretion collection have certain limitations, and the continuous collection method and in-situ collection method can better reproduce the real situation of plant inter-root, and the new technology can only analyze a small part of the components of root secretion. The continuous collection method and in situ collection method can better restore the real situation of plant inter-root, but the new technology can only analyze a small portion of the root secretion components, and many unknown components need to be studied. Currently, the research on the components of root secretion focuses on the analysis of the total amount, but lacks the analysis of specific substances. In the future, metabolomics, genomics, transcriptomics and proteomics should be comprehensively utilized to understand the response pattern of specific substances in response to various stresses in plants. Root secretion plays an important role in regulating plant growth and development and the structure of inter-root microbial communities. Some studies have shown that it is a short time process for the photosynthetic products of plants to be utilized by microorganisms after entering the soil through root secretion, and it has been concluded from experiments that, through the influence of microorganisms and osmosis, part of root secretion will be transferred to the non-inter-root soil, and then soil organic carbon will be formed, and most of which exists in the inter-root soil and inter-root microorganisms [13]. Zhao et al. (2017) studied the soil of wild grass ephedra in the dryland area of Hebei Province, and the results showed that the total organic carbon (TOC) content of the soil of planted grass ephedra was significantly increased, while the content of active organic carbon (AOC) was decreased compared with that of open field.Li et al. (2020) found that 50% intercutting and understory vegetation culling in Sino-Subtropical moso bamboo plantation forests could reduce soil bioactivity and turnover rate of active organic carbon pools in favor of soil carbon sequestration.

Root secretions can affect the community structure of inter-root microorganisms, and changes in the structure of inter-root microbial communities not only affect the release of plant root secretions, but also have an important impact on soil matter-energy cycling and information transfer, which indirectly or directly affects the growth and development of plants [14].

1.3. The Relationship between Soil Ecology and Root Exudates

In recent years, with the development of biotechnology, significant progress has been made in the methods and techniques of soil ecology research. In particular, breakthroughs in metagenomics technologies, such as environmental macrogenomics, macrotranscriptomics, macroproteomics, and metabolomics, have greatly enriched our understanding of the soil bioworld and the diversity of below-ground organisms and functions. The study of root secretion-mediated plant-soil-microbe interactions is important for elucidating the functions of inter-root microecology and providing practical guidelines.

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