Superabsorbent Polymers

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Contributor: Ippolito Camele

Natural strategies for protecting the environment as well as plant, animal and human health is considered one of the main goals of developed countries. Recently, the use of absorbent polymers and hydrogel in agriculture has demonstrated several benefits for soil amendments, saving water content, reducing the consumption of soil nutrients, minimizing the negative impacts of dehydration and moisture stress in crops and controlling several phytopathogens.

biological control | sustainable production | phytopathogens | hydrogel

1. Introduction

Recently, due to the growing world population, there is a necessity for increasing crop production [1]. Traditional agriculture in different countries, especially the developing ones, depends on mineral fertilizers and chemical/synthetic pesticides, which have several side effects on human, animal and plant health [2]. Hence, there is a need to introduce innovative strategies, such as crop rotation, new plant varieties and vertical increase of crop/land productivity, for raising crop yield without the use of pesticides and other conventional chemical substances.

In the same context, the increase of global population leads to the search for innovative solutions to increase crop production through vertical farming approaches as well as maximizing the crop/land productivity in order to provide a greater crop yield per square meter of land [3]. However, the erosion of surrounding areas, global warming, increase in urbanization and desertification phenomenon lead to the loss of agricultural lands [4][5]. For these reasons, there has become an urgent necessity to find innovative ways to increase agricultural production, as well as to protect plants and soil from diseases that may affect crops and reduce the productivity of the land in a related and parallel way.

In a similar way, it is worth noting the urgent importance of introducing appropriate agricultural management that would reduce water consumption by improving the soil's ability to retain water, increase the efficiency of the use of agrochemicals and effectively control several phytopathogens [6]. The use of absorbent polymers, especially the superabsorbent ones, has several benefits, such as conservation of water, lowering surface runoff, avoiding soil erosion and improving the performance of different soil fertilizers [7]. The protection of seeds and their main biochemical properties can positively enhance plant performance and make them more resistant towards more unfavorable surrounding conditions, such as climatic changes and severe phytopathogens. For those reasons, the seed-coating technique is one of the most interesting and recent strategies for achieving the above goals by using natural agents, such as fertilizers, hydrophilic substances, growth regulators, plant essential oils, microorganisms and biopesticides in different adhesive substances like absorbent polymers and hydrogels [8].

2. Superabsorbent Polymers

Superabsorbent polymers (SAPs) can also be identified as absorbent polymers, absorbent gels, water gels or hydrogels [9]. They are synthetic macromolecular materials having a water-hyper accumulation capacity of up to 100% of their own weights through osmosis property [9]. In addition, SAPs are used mainly to improve soil properties, and they are composed generally of sugar-like hygroscopic materials, which transform into a transparent gel when added to water [9].

2.1. Soil Amendments

The application of suitable soil conditioners to enhance soil properties has become a progressively common solution [10]. SAPs are characterized by hydrophilic, three-dimensional and crosslinked functional polymers [6][11][12], which enable them to hyper-accumulate the excess volumes of water in the soil a hundred times their own weight [13][14][15].

The application of absorbent polymers in agriculture is very important because they can absorb water and make it available to plants over time [16]. Recently, SAPs have been used in agriculture as soil additives for their amendments in order to save water loss and nutrients in the soil and minimize the negative impact of dehydration and moisture stress in crops [17][18].

Particularly, there are several advantages of using SAPs in the soil, such as (i) it can absorb and keep the water hundreds of times more than its own weight and become similar to long-lasting gels [15]; (ii) it can also protect the soil from runoff reduction; (iii) it can further improve the performance of different soil fertilizers [7] and (iv) finally it can enhance the activities of soil microorganisms [18][19].

Barakat et al. [20] reported that the problems associated with conventional irrigation techniques could be avoided by the application of some polymers. There are several recent studies, which reported the importance of using some SAPs in order to help in absorbing and retaining water. Consequently, SAPs can prevent/reduce water loss by percolation and act as a water reservoir in the root zone [6][15][21].

There are some other basic points concerning the importance of using SAPs for improving the performance of soil fertilizers and also to enhance the activities of soil microorganisms. The application of SAPs can alter the physicochemical properties of soil as well as improving the fertilizer-retaining capacity [22][23]. Other studies have focused on the potential effect of SAPs in saving soil water content, conserving fertilizers and reducing their losses [22][24]. At the same time, the use of SAPs plays an essential role in enhancing soil microbial community [25][26].

A recent study was conducted by Yin et al. [27] to investigate the biological effect of an innovative SAP, poly-γ-glutamic acid, for maize growth and enhancing beneficial soil microorganisms. In that study, the utilization of this biological polymer proved that it could improve soil saving water, increase maize seedling growth and enhance the relative abundance of plant growth-promoting bacteria, such as *Bacillus*, *Pseudomonas* and *Burkholderia* [27].

2.2. Plant Growth

The application of some absorbent polymers has significantly increased the yield of *Citrus limon* by improving the water holding capacity of the soil, which maintains the soil moisture for a longer period, thus enhancing the microbial activity of the soil and preventing fruit loss [28].

Similarly, Pieve et al. [29] studied the effect of polymers on plant growth of coffee plants in the open field and found that the application of polymer solution at the time of new planting can reduce the mortality of coffee plants. The coating with highly absorbent polymers can potentially improve the water availability for the early growth of seeds under dry conditions and, therefore, prevent associated delays in the emergence and reduce crop standing [30][31][32].

Several studies have also been conducted to evaluate the application of different doses of SAPs to help soil remediation and plant growth and concluded that the use of SAPs, especially in the soil surface of (0–20 cm), has explicated promising effects on soil temperature and increasing photosynthetic rate and crop yield [23][33].

2.3. Challenges of Absorbent Polymers

In addition to the beneficial uses of SAPs in soil amendments, there are some other changes in soil physical properties, such as soil porosity, bulk density and structure [34]. The use of SAPs is often restricted by the water application rate; hence their performance may not properly be determined [6].

There are some disadvantages, especially for the synthetic SAPs; they are not biodegradable substances being nonrenewable materials and possibly toxic [35][36][37][38].

Several studies have reported the effect of commercially available SAPs on seed and plant growth where they do not decompose in the environment and their raw materials are nonrenewable [39]. Therefore, the excess use of these polymers in agriculture, either for seed-coating or soil amendments, can lead to a great risk for plant health, soil fertility and environmental pollution [39][40].

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