Bioresources Use in Organic Farming

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Over the years, the practice of agriculture has transformed from the era of traditional to that of intensive agriculture in the bid to boost the production index that will satisfy the food needs of the globally growing population. However, the continuous and exaggerated use of chemical fertilizers and pesticides has resulted in major adverse impacts on food and environmental safety, whereas most traditional techniques for the reclamation of natural soil nutrients, including shifting cultivation and polyculture, are no longer attractive measures of land rejuvenation. There is, therefore, the need for urgent evaluation and adoption of innovative methods of replenishing the agricultural soils that conform to the current agricultural systems without exerting undesirable effects on the ecosystem. We elucidated the use of key bioresources, such as organic fertilizers, biofertilizers, and biopesticides, as alternatives to chemical-based products in attaining a safe and sustainable agricultural system. Bioresources are naturally available, safe, and easily accessible products. The potential of these biological products in fostering soil microbial growth, plants' productivity, and induced host immunity to diseases, alongside the promotion of healthy soil–microbe–plant relationships and preservation of the ecosystem processes without disruption, are aspects that were also explored. Therefore, the productive use of bioresources is considered strategic as it pertains to attaining safe and sustainable food production.

Keywords: soil–microbe–plant relationship ; food security ; soil health ; biofertilizers ; biopesticides

1. Introduction

Continuous land cultivation without commensurate nutrient replacement leads to declining soil performance as a result of the depletion of essential nutrients that support crop growth. This also causes an imbalance in the ecosystem, leading to reduced land productivity and eventually impairing both the quantity and quality of the farm produce obtained at harvest [1]. This becomes critical where non-eco-friendly sources of nutrient additives are applied to make up for the soil nutrient requirements as the natural rejuvenation processes of the farmland are altered. Hence, the importance of healthy soil to the attainment of efficient food production that would support the ever-increasing human population cannot be over-emphasized.

Considering the current global shrinking of agricultural land as a result of urbanization [1], and the trend of large-scale monocropping [1], adequate soil fertility replenishment during or before crop cultivation is highly essential if a successful cropping season is attained. Some of the traditional farming practices, such as shifting cultivation and mixed cropping, may no longer be methods of choice. In recent times, agriculture has depended mainly on using chemical fertilizers and pesticides to enhance crop yield and quality. Generally, fertilizer and pesticide use has been categorized into chemical, organic, or biofertilizers, with each category possessing distinct characteristics and effects on soil fertility and crop management [2].

Synthetic fertilizers are classified based on their mode of action and their chemical nature. The commonly available types are categorized into nitrate (e.g., sodium nitrate), ammonium (e.g., ammonium nitrate), nitrate and ammonium (e.g., ammonium sulfate), and amide (e.g., urea) fertilizers [3]. They improve soil fertility and provide essential nutrients to plants, which results in noticeable improvements in plants' growth within a short period. Despite their benefits, the use of chemical fertilizers comes with several drawbacks, as inappropriate or prolonged use could result in water and environmental pollution, which occurs through leaching, runoff, or volatilization [4].

The recently advocated measures for soil nutrient replenishment with better crop productivity include the use of biological resources, which are naturally available products that could be productively harnessed in sustainable farming [5][6]. Bioresources are natural materials that are degradable and renewable; some of these substances include plant biomass and wastes from some industries and municipalities, agriculture, grasses, weeds, forest, and/or marine resources, such as fishes and aquatic crustaceans [7]. All these bioresources are valuable and may be utilized as raw materials or feedstocks for the manufacturing of a variety of valued goods that are strategically significant both economically and industrially. Hence, bioresources are considered to be a major center of the bioeconomy [8].

On the other hand, over-exploitation and improper use of bioresources have been reported to have detrimental impacts on the environment [9][10]. Most of the associated adverse effects are prevented by applying bioresources, such as human-modified plant- and/or animal-based products to aid soil health and plant performance. Since bioresources are organic materials, they are often used in agriculture as organic fertilizers, biofertilizers, and biopesticides because they hold enormous potential in nurturing plant–soil–microbe relationships by creating a favorable soil environment in which valuable macro- and microflora and fauna thrive. Furthermore, products of bioresources enhance soil's inherent buffer capacity without causing heavy metal contamination in the soil [11][12]. They are, therefore, a suitable alternative to chemical use in agricultural practices. Although an initial agricultural boost could be experienced by the chemical-based formulations, the consequences of their use over a prolonged period could be detrimental to both the soil and the human environment.

2. Roles of Bioresources as Biofertilizers and Biopesticides

As a result of their continuous and incessant application, chemical fertilizers alter the soil characteristics to either become more acidic or alkaline [13], a condition that results in a reduction in the naturally occurring soil microbes, and it also affects the availability of plant nutrients for uptake and use, which in turn decreases yield production. However, the application of beneficial microorganisms as biofertilizers and biopesticides, which is currently gaining attention, serves as an effective alternative to the use of chemical-based products in enhancing soil fertility and managing the associated pest and diseases. Biofertilizers and biopesticides are eco-friendly products and suitable candidates for integrated nutrient, pest, and disease management techniques [14].

Unlike organic fertilizers, which are constituents of various agricultural wastes that require the intervention of microorganisms for their degradation from a solid state into decomposed and soluble material for easier absorption by plants, biofertilizers and biopesticides are made up of beneficial microorganisms. They are microbial inoculants that consist of living cells of microorganisms, such as bacteria, fungi, alga, or the consortium of the inoculants. They colonize the plant endosphere or the rhizosphere when applied either to seeds, plant surfaces, or soil [15]. Biofertilizers, unlike organic fertilizers, employ natural processes of solubilizing phosphorus and nitrogen fixation to increase the available primary nutrients to the host plant. They also stimulate plant growth through the synthesis of growth-promoting substances. On the other hand, biopesticides describe a variety of substances from preparations containing live microorganisms to botanical compounds, plant-incorporated protectants, and semiochemicals, such as pheromones [16] (**Figure 1**). Hence, the use of biopesticides is not restricted to the applications of microbial pest control agents, i.e., fungi, bacteria, viruses, nematodes, and protozoa.

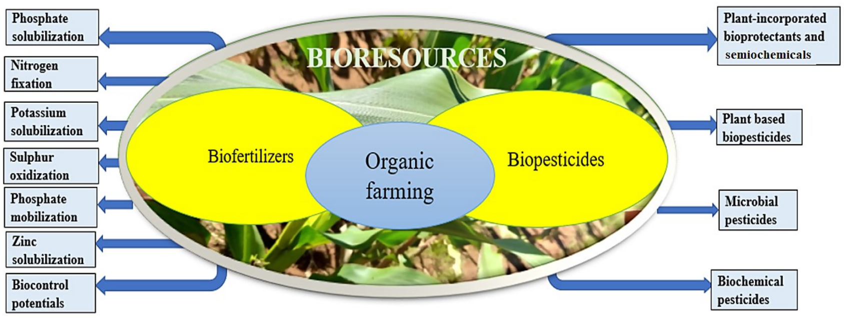

Figure 1. Role of bioresources in organic agriculture.

A further consideration includes using bioactive compounds, such as metabolites produced directly from the microbes that suppress the pest populations, including pathogens, insects, and weeds [17]. Thus, biopesticides are becoming more important in pest management, biological control, cultural techniques, newer synthetics, and the genetics of plants and animals. They are characterized by their beneficial roles, such as eco-friendliness, being less harmful, specificity in targets, effectiveness at low dosage, biodegradability, and non-persistent nature [17].

Many microorganisms have been characterized as of now; they are commonly referred to as plant-growth-promoting rhizobacteria (PGPR) or plant-growth-promoting fungi (PGPF) [18][19]. Their plant growth and disease management deployment have been widely encouraged by soil scientists [20][21][22]. Thus, the natural soil microflora contains a variety of PGPR or PGPF [23], and they constitute a key element of integrated nutrient management with their application as biofertilizers that could be employed in sustainable agriculture. They can be suitably formulated for application through the seed or soil. These preparations, which include living or latent cells of effective microorganism strains, aid in the nutrient absorption of agricultural plants by interacting with the rhizosphere. They accelerate several microbial activities in the soil that increase the amount of nutrients available in an easy-to-assimilate state for plants. These potential biofertilizers have been classified based on their roles as nitrogen fixers (*Rhizobium, Azospirillum, Azobacter,*blue–green algae, and *Azolla*), phosphate solubilizers (*Pseudomonas*, *Rhizobium, Bacillus, Achromobacter, Burkholderia, Aereobacter, Microccocus, Flavobacterium, Agrobacterium,* and *Erwinia*), phosphate absorbers (Mycorrhiza), and zinc solubilizers (*Bacillus subtilis*, *Thiobacillus thioxidans,* and *Saccharomyces* sp.) [24][25][26].

Many of these bioagents are now available in commercial quantities [5][22]. Furthermore, botanical pesticides obtained naturally from plant-based products have also been demonstrated as effective alternatives to synthetic pesticides [27]. For instance, neem-based pesticides, pyrethrum, and eucalyptus oil have been widely explored for agricultural pest management [28][29][30]. However, the use of biofertilizers and biopesticides, unlike classical biological control, requires repeated applications to the desired field or pest-infested areas because they are not capable of spreading beyond the applied region, and, more importantly, their population is not self-sustaining beyond one or a few growing seasons [31], except for endophytes, which are delivered in seed or other propagation material, typically through inundate release as a spray, drench, granules, or seed coating. They often need to be registered with the appropriate authorities to affirm that they are safe for the environment and the community when mass-produced, manufactured, packed, and sold as a bioprotection product [32][33].

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