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REVIEW ARTICLE **OPEN ACCESS**

A Bibliometric Study on Potassium Solubilizing Bacteria

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ABSTRACT
In all living cells, potassium (K) is an important component and a necessary nutrient. Soils naturally have the highest concentrations of K of any nutrient, however, this K is inaccessible to plants for absorption. Environmental sustainability is severely harmed by the use of chemical fertilisers. K-bearing minerals may be solubilized by potassium solubilizing bacteria (KSB), which then transforms the insoluble K into forms that plants can absorb. The ability to solubilize K minerals is shared by a wide variety of bacteria, including Acidothiobacillus ferrooxidans, several Paenibacillus species, Bacillus mucilaginosus species, B. edaphicus species, and B. circulans (e.g., biotite, feldspar, illite, muscovite, orthoclase, and mica). All soils contain KSB, although its abundance, variety, and capacity to solubilize K are all dependent on soil and climate. Acidolysis, polysaccharides, complexolysis, chelation, and exchange reactions are only some of the methods KSB uses to dissolve silicate minerals and liberate K. This means that biological fertilisers containing KSB may be an efficient substitute for chemical fertilisers. KSB is discussed in this article, along with their significance in plant growth promotion, as well as some potential directions for future KS studies.
Keywords: *Biofertilizer, Non-legume, Mineral solubilization, Nitrogen fixation, potassium solubilizing bacteria.*

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INTRODUCTION

The potato (Solanum tuber sum L.) is one of the most significantcrops in the world. Potato is the best source of vitamins and carbohydrates.(1) Its water content ranges from 70–82 percent and its dry matter from 17–29 percent to 11–23 percent to 0.8–3 percent protein to 0.1–3 percent fat .(2) Roughly 365 million tonnes of potatoes were grown on a total area of about 9 million hectares (3). In 2015, Egypt's potato crop planted area was around 183 thousand hectares, which produced over 5 million tonnes of potatoes (4). It is necessary to increase the quality of the soil in order to promote plant development and production (2,4). Increase crop output by using bio-fertilizers that deliver nutrients, promote plant development via the generation of plant hormones and prevent the action of plant diseases, enhance soil structure, and bioaccumulate or microbially leach inorganics (5). Silicate forms of Pseudomonas and Bacillus are known as KSB (6) play a significant function when it comes to potassium (6,7). Enhancing plant nutrition; enzyme activation, maintaining cell turgor; transporting sugars and starches; improving crop quality; increasing resistance to stress conditions such as pests and diseases; reducing nitrate and nitrite contents of potato tubers are some of the benefits of using this solution (8). Increasing soil fertility, productivity, and reducing the use of chemical fertilisers are all made possible in large part by KSB (9). Reduce the need of chemical fertilisers by using bio-fertilizers insoil or plant (5,10). Aside from health and environmental risks, over usage of chemical fertilisers may lead to crop shortages because of degradation in soil qualities. The use of bio-fertilizers alone or in combination with organic and inorganic amendments resulted in a rise in plant weight, the number of big tubers, and the overall number of tubers (11). In addition, the use of bio-fertilizer improves the plant's root development circumstances, increasing the plant's growth, and ultimately improving the plant's biological functions.Chemical and physical properties of soil were improved by the use of bio fertilisers. (10). Bio-fertilizers like KSB may be used as an alternative for chemical fertilisation, although little is known about their usage in potato cultivation. Therefore, the present research intends to explore the impact of bio-fertilization on plant development and production as well as a soil containing potassium like seen in potato plant.

POTASSIUM SOLUBILIZING BACTERIA

Some of the primary difficulties facing agriculture in the twenty-first century are food security, climate change, and adaptation to drought conditions in emerging nations.

To feed an ever-increasing global population, agriculture will have to become more productive and long-term sustainable. A well-known fact, however, is that agriculture's ability to provide food cannot be maintained unless the nutrients lost to greater crop output are replenished. Due to deficiencies in one or more nutrients, agricultural soils sometimes provide unsatisfactory crop yields. The use of artificial fertilizers by farmers has increased as a means of mitigating this issue and boosting crop yields (12). Chemical fertilizers aided plant growth, but they had little effect on soil quality.

Chemical fertilizers, particularly those containing phosphorus, nitrogen, and potassium, have long been known to have detrimental environmental consequences (13).Microbial soil communities have been shown to have an impact on fertile soil via decomposition, mineralization, and nutrient storage/release mechanisms (14). There is a broad variety of helpful soil microorganisms, including a wide range of saprophytic bacteria as well as diverse fungal strains and actinomycetes, that may be used to solubilize inorganic and organic acids, polysaccharides and complexolysis to chelate and exchange the insoluble forms of K.

K solubilizing bacteria (KSB) are among the microorganisms that have drawn the attention of agriculturists as a soil inoculum to increase plant development and productivity. Inorganic and insoluble pools of total soil K may be released by the KSB by solubilization (8,14,15). Inoculation with KSB has previously been shown to have a positive impact on the development of several plants (5,16).

Phosphorus and nitrogen are essential to plant growth and development, but potassium (K) is the most critical of the three. In addition to boosting plant resistance to diseases, pests, and environmental challenges, K is required by over 80 distinct enzymes involved in plant and animal functions such as energy metabolism, starch synthesis, nitrate reduction, photosynthesis, and sugar breakdown (17, 18).The fifth-highest concentration of K is found in the Earth's crust.The use of various microbial strains as biofertilizers has thereby reduced the usage of chemical fertilisers and offered high-quality commodities free of dangerous agrochemicals and safe to consume for humans [19].

Between 0.04% and 3% of soil's total K concentration is K. Only 1% to 2% of the soil's K is accessible to plants, despite the fact that this element is there in plenty (20). Most of the remainder are inaccessible to plants because they are bonded to other minerals.

K is found in the soil in a variety of forms: as a mineral, as a non-exchangeable, as an exchangeable, and as a solution.Soil K content ranges from 90 to 98 percent mineral K, with the vast majority of this K being inaccessible to plants for absorption (20). In addition to orthoclase and microcline feldspars, mica also contains K. (biotite and muscovite). Between 1% and 10% of soil K is non-exchangeable K, which is trapped between layers or sheets of specific clay minerals.

This kind of K is easily absorbed by plants and microorganisms in the soil. As an added bonus, this form is the most easily broken down by soil bacteria. Normal agricultural soils have a K content of between 2 and 5 mg l–1 in the soil solution (20). Because soil K is mostly in a fixed form (not available to plants indirectly), fertiliser use is uneven, crop yields are rising rapidly (depleting soil K), and farmers aren't adding crop residue to the soil, a K deficiency has been observed in many crop plants (7). Due to the rising costs of K-fertilizers (potash $470 per tonne since 2011) and the detrimental environmental consequences they cause, it is imperative that an indigenous source of K be found that the K level in soils is maintained for sustainable crop production.

K may be made accessible to plants via KSB, as shown by the aforementioned experiments. To maintain our current resources and reduce environmental contamination threats, it is important to identify effective bacterial strains capable of solubilizing K minerals. Thus, in this review, we summarised the investigations of KSB, including the isolation and methods of solubilizing K-bearing minerals, in order to produce effective bacterial inoculants for the solubilization of K in soil, which is one of the goals of attaining sustainable agriculture.

Bacteria-soil-plant interactions

Minerals, water, air, organic matter and billions of species make up soil, which changes constantly (biogeochemical transformations). This term describes how well the soil can give nutrients like nitrogen, phosphorus, and potassium to plants, as well as the micronutrients that are typically

unavailable in free form or in restricted amounts in the soil. It's here that root-associated beneficial bacteria play a crucial role (21).
Microorganisms are known to be able to provide plants with nutrients in a variety of ways. Bacteria, fungus, actinomycetes, protozoa, and algae are all microorganisms that may be found in soil, although bacteria are by far the most frequent (95 percent). Bacteria are found in soil in an estimated 60,000 varieties that have yet to be identified, and each has a specific function and ability. There are several factors that affect the quantity and variety of bacteria in soil, including the amount of organic carbon, temperature, moisture, electrical conductivity, and other substances. Consequently, plants growing in soil are surrounded by a sea of microorganisms, particularly bacteria (12).
For the majority of plant species, microbial interactions are essential to their long-term survival (21). It's also worth noting that plants have the power to choose their own root microbiota from the surrounding soil. As a result, each plant species is connected with a distinct set of microorganisms. In order to generate positive plant–microbial interactions, both plant and microbial responses must be orchestrated in a mutually advantageous manner. (21). Using chemicals or signals, plants can communicate effectively with the rhizosphere microorganisms, while their associated microbes can establish an efficient associative symbiosis with plants by triggering host functional signals (e.g., microbial Chemotaxis and Colonization) (22).
For example, PGPRs (plant growth promoting rhizobacteria) may be useful to the plant or detrimental (e.g., diseases), and the influence of a bacterium may vary as soil conditions change over time (23). A number of different types of bacteria can benefit plants, including those that can form nodules on the roots of the host plant and fix nitrogen, those that are endophytic (invading the tissues of the host plant without harming it), those that can compete for rhizosphere and root surface colonisation, and those that are free-living in the soil (12).
Bacteria that colonise the roots of plants after seed inoculation are referred to as "beneficial bacteria" in agriculture because they increase seed emergence and plant weight, as well as agricultural yields. A variety of soil bacteria are utilised commercially as agricultural aids despite a lack of knowledge of their interactions with plants (12). These bacteria include *Burkholderia cepacia, Delfitia acidovorans, Paenibacillus macerans, Pantoea agglomerans, Pseudomona spp., P. aureofaciens, P. chlororaphis, P. fluorescens, P. solanacearum, Bacillus spp., B. amyloliquefaciens, B. subtilis, B. amyloliquefaciens, B. fimus, B. licheniformis, B. megaterium, and B. mucilaginous. Radiobacterium, Azospillum, Azotobacter chroococcum, Psyringa syringae, S. lydicus, and S. griseoviridis* are some of the Agrobacterium radiobacter species (12, 24, 25).

DISCUSSION
K may be solubilized by a number of different saprophytic microorganisms. More than one study has shown that soil bacteria are capable of transforming soil K into forms that plants can use. In the soil and around the roots of plants, KSB is concentrated. Most of the KSB in soil is composed of anaerobic and aerobic isolates. KSB concentrations in rhizosphere soil are often substantially higher than in non-rhizosphere soil. When it comes to soil K availability, KSB's ability to dissolve insoluble and fixed forms of the mineral plays a role. Silicate rocks can be solubilized by bacteria such as B. mucilaginosus (Burkholderium circulanscan), Burkholderia edaphicus, Burkholderia edaphica, Burkholderiaceae, Burkholderia burkholderi, and Arthrobacter species (Enterococcus hormaechei), all of which have been shown to be excellent K solubilizers in soil bacteria. Soil-borne pathogen KSB may be found in all types of soil, including rhizosphere and saline soils.
For a number of reasons, results from the laboratory or greenhouse may vary from those from the outdoors. As a result, further research is needed into the potential of these tactics for agricultural production systems and their impact on crop growth and soil behavior. Other nutrients such as P, N, Fe, Zn, and others will also be researched in relation to how KSB affects their availability. Other PGPRs, such as IAA and ACC producers, phosphate solubilizers and N2 fixers, and their interactions with KSB will be studied in order to determine the best conditions for the activity of KSB, such as organic matter, and to evaluate plant species that are effective in K uptake and K-solubilizing microbial populations. KSB is a complex system that must be understood in order to choose the right bacteria to combine with a particular plant. Additional study is required to understand the molecular biology of KSB in comparison to other PGPRs.If KSB application may boost the availability of K and other nutrients, and which K sources are most economically feasible, field tests are required.

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CONFLICT OF INTEREST
The authors declare that they have no conflict of interest.

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