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Use of Cost-Effective Biofertilizers Interventions for Enhanced food Security and Soil Management Amidst Covid-19 Crisis. Review

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Abstract— *Current soil management strategies are mainly dependent on inorganic chemical-based fertilizers, which are expensive and have led to a serious threat to human health and environment. Moreover, COVID-19 pandemic caused economic recession coupling with the effects of climate change. The effect of the pandemic has led to increased prices of inputs particularly chemical fertilizers, resulting in a reduction in crop production. Soil fertility which is a function of agricultural production has declined overtime due to nutrient depletion. The exploitation of cost effective and beneficial microbes as a biofertilizer has become paramount importance in agriculture sector for their potential role in food safety, sustainable crop production and soil fertility improvement. The eco-friendly approaches inspire a wide range of application of plant growth promoting rhizobacteria (PGPRs), endo- and ectomycorrhizal fungi, cyanobacteria and many other useful microscopic organisms that have led to improved nutrient uptake, plant growth and plant tolerance to abiotic and biotic stress. The present review highlights; biofertilizers relevance and plant tolerance to environmental stress, biofertilizer exploitation and nutrient profile of crops, potential significance of beneficial microbes in sustainable agriculture. The knowledge gained from the literature appraised herein will help in understand the benefits of biofertilizers towards sustainable agriculture in reducing problems associated with the use of chemicals fertilizers.*

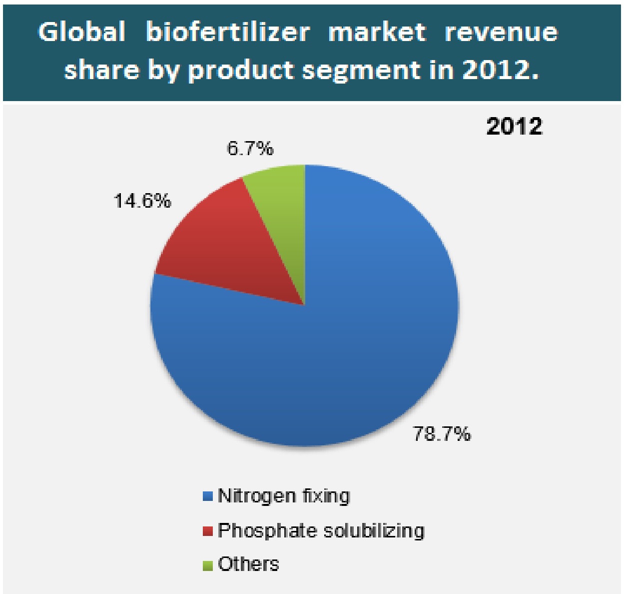
Keywords— Biofertilizer, Crop improvement, Food security, Soil fertility management, Covid-19 pandemic, Sustainable agriculture

I. INTRODUCTION

The world population is estimated to reach about 9 billion by 2050 and Africa, especially sub-Saharan Africa, has been predicted to contribute to bulk of the increase (Godfray et al., 2010; United Nations, Department of Economics and Social Affairs, (UN DESA, 2015). In this context, sub-Saharan Africa needs to increase food production to feed her growing population adequately. This growing population has triggered competition in all forms of resources required for human survival such as land, water, energy and food. Perhaps, the most essential is the food resources that have become insufficient, and consequently, its increased production cannot be compromised (Asenso and Jemaneh, 2012).

Sadly, many African countries lack political will that can drive agricultural policies, and this has caused low agricultural productivity. Lack of attention for improving agricultural productivity has degenerated to a more complex situation of food insecurity, which has caused economic, environmental and financial losses in sub-Saharan Africa (Rosegrant et al., 2015). Therefore, sub-Saharan African nations need to combat food security situation with a scientific, economic and technologically based approach which will increasing agricultural productivity at a rate higher than the population growth rate, which will in turn trigger economic growth and development (Muzari and Muvhunzi, 2016). Many economic, scientific and technological measures have been designed to support farmers and increase food production in developed countries.

Biofertilizers are considered as strong alternative for minimizing the use of various types of synthetic fertilizers which are not only costly but also cause adverse effects on soil health. In general, biofertilizers include living microorganisms which provide nutrients and promote growth and development of plants via the natural processes such as nitrogen fixation, phosphate solubilization, production of hormones, and other plant growth-promoting substances (Rai, 2006; Kumar et al., 2017). Biofertilizers are ecofriendly, inexpensive, important source of essential nutrients for plants, and increase soil fertility as well as play a vital role in improving soil nutrient status and, thus, crop productivity. Biofertilizers are living formulations consisting of advantageous microorganisms, including fungi, bacteria, and actinomycetes, that can be applied successfully to seeds, seedlings, plant roots, or soil and which help in the mobilization as well as the accessibility of nutrients due to their inherent biological activities (Pal et al., 2015).


Global biofertilizer market revenue share by product segment in 2012.

Source: Novozymes, Agri Life, Primary Interviews, Transparency Market Research

1.2 OBJECTIVE OF THE REVIEW

This review was aimed at highlighting the huge economic importance associated with the use of biofertilizers in improving crop productivity and soil fertility management sustainably among in sub-Saharan Africa.

II. METHODOLOGY

The search strategy was designed by the author to identify articles that address the effects of biofertilizers with regard to sustainability in soil management and agricultural production. A filter of subject-related key words was used to obtain relevant articles. The filter for defining biofertilizers was comprised of the following phrase and words; as major types of biofertilizers in soil fertility management, including nitrogen fixation, mycorrhizal Fungi, plant growth promoting rhizobacteria, potassium solubilizing bacteria, contribution of biofertilizers in agriculture such as increased yield and nutrient availability, prevention of plant pests and diseases, water stress resistance. Some of the parameters of concern were obtained from individual researchers' publications that outlined in-depth the use of biofertilizers in agriculture.

2.1 SELECTION OF ARTICLES

The study undertook the article selection process following two steps; i) Preliminary review of titles using the key words. (ii) Review of article abstracts. The selected abstracts had to address the contributions of biofertilizers in soil management and agricultural production. Thus the articles were eliminated based on inconsistency with the search strategy and criteria, this followed the article review form to classify and describe the characteristics of each article including study aims, parameters discussed and the mentioned effects of biofertilizers in agriculture. However, the effects and results of the different biofertilizers varied slightly across the articles reviewed.

III. RESULTS AND DISCUSSIONS

3.1: MICROBES-SOIL-PLANT INTERACTIONS

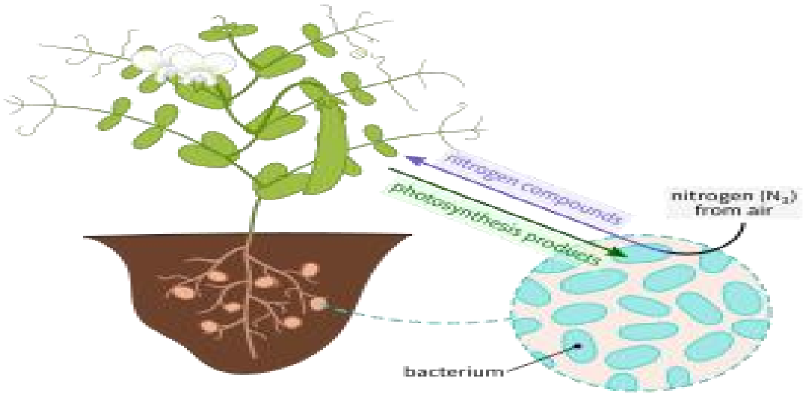
Soil is a complex mixture of minerals, water, air, organic matter, billions of organisms, and the changes taking place in its composition (biogeochemical transformations). Soil fertility refers to the capacity of the soil to supply essential plant nutrients such as N, P, K and micronutrients, which are often not available in free form or are in limited quantities in the soil. This is where root-associated beneficial microbes are important partners. It is known that microorganisms can make nutrients available to plant by different mechanisms (Ahemad & Kibret 2014). In the soil, it is possible to find various types of microorganisms such as bacteria, fungi, actinomycetes, protozoa, and algae which bacteria are by far the most common (i.e., ~ 95%).

There is an estimated 60,000 different type of bacteria that reside in the soil, most of which have yet to be even named, and each has its own particular roles and capabilities. The number and diversity of bacteria are influenced by the soil conditions such as organic carbon, temperature, moisture, electrical conductivity and other chemicals as well as by the number and types of plants found in those soils. Therefore, soil-grown plants are immersed in a sea of microorganisms especially bacteria (Chianu et. Al., 2010). Recent studies show that most plant species require microbial associations for survival (Balestrini, 2015). In addition, plants possess the ability to select their own root microflora from the surrounding soil. In other words, each particular plant species has a characteristic group of associated microbes. The establishment of beneficial plant–microbial interactions needs a mutual recognition and a considerable orchestration of the responses at both the plant and the microbial side (Beneduzi et al., 2012). By exuding chemicals or signals, plants can effectively communicate with the rhizosphere microorganisms, while their associated microbes may establish an efficient associative symbiosis with plants by triggering host functional signals (e.g., microbial chemotaxis and colonization). The interactions established between bacteria and plant may be beneficial (e.g., plant growth promoting rhizobacteria, PGPRs), harmful (e.g. pathogens), or neutral for the plant, and sometimes the impact of a bacterium may vary as the soil conditions change (Han, 2006). The microbes that provide some benefits to plants are: (i) those that form nodules on host plant roots (symbiotic relationship) and fix nitrogen; (ii) those that are endophytic and colonize the internal plant tissues without pathogenic effects in host; (iii) those that have ability to competitively colonize the rhizosphere and plant root surface; and (iv) those that are free living in the soil (Gupta et al., 2007). In agriculture, beneficial bacteria are defined as any bacteria that colonize the roots of plants following inoculation onto seed and improve plant growth by increasing seed emergence, plant weight, and crop yields.

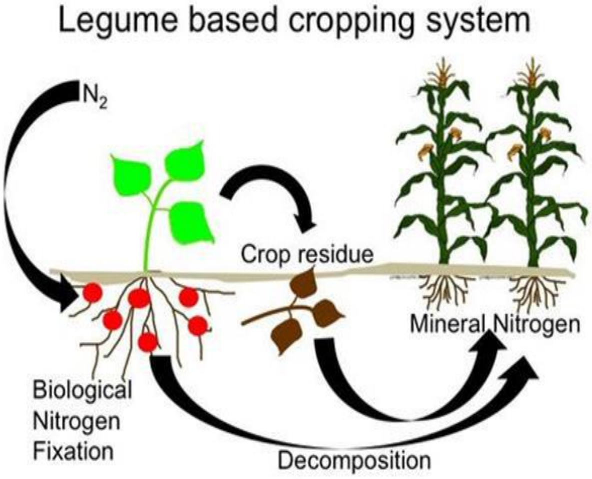
3.2: MAJOR TYPES OF BIOFERTILIZERS AND THEIR EFFECT ON SOIL FERTILITY MANAGEMENT

3.2.1 Biological Nitrogen Fixation (BNF)

Bacterial symbionts are well-recognized natural donor of fixed nitrogen as they enrich soil fertility by fixing atmospheric dinitrogen (N_2) resulting in increased growth and yield of rice. Besides N_2 fixation, they produce various types of growth hormones, vitamins, bioactive compounds, organic acids, antagonistic compounds, and play an important role in nutrient cycling (Singh et al., 2016). Cyanobacteria also increase the soil fertility by increasing soil pore size and water holding capacity due to excess mucilage production and can tolerate high dose of pesticides over the recommended levels applied in the field (Kaushik, 2013; Cohen, 2008). In addition, BNF form symbiotic associations with a number of eukaryotic hosts including plants, and cyanobiont present therein fixes N_2, the fixed nitrogen is utilized by the respective hosts (Adams, 2013). The fixed nitrogen may be excreted in the form of ammonia, amino acids, short nitrogenous polypeptides, certain vitamins, and hormones as well as other bioactive compounds.

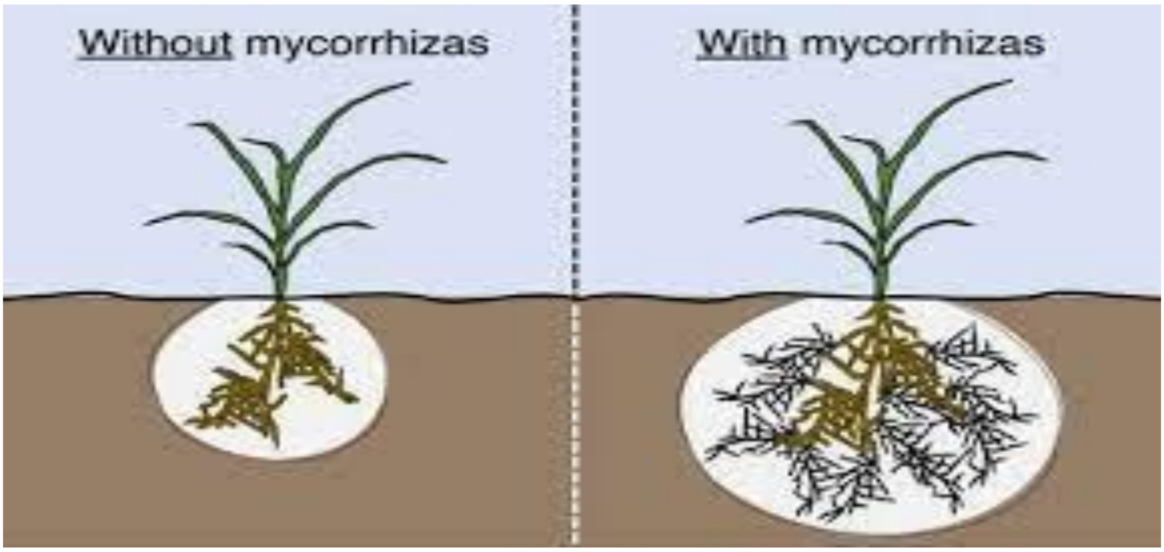


However, bulk of the fixed nitrogen is released after death and decay (autolysis) of cultures followed by decomposition. Potentials of a number of free-living species of cyanobacteria as biofertilizer have been tested in different crops, the results are encouraging (Karthikeyan et al., 2007; Singh et al., 2016). Studies based on $^{15}N_2$ experiments and N-balance suggested that cyanobacteria can fix up to 20-40 kg N ha^{-1} crop^{-1} and the fixed nitrogen is readily available for plants especially the rice plant. $^{15}N_2$ experiments carried out in the field have demonstrated the exchange and bulk accumulation of fixed $^{15}N_2$ in rice plants (Ladha and Reddy, 2011). It has been proposed that BNF especially cyanobacteria can solubilize and mobilize the insoluble P by the enzyme phosphatase. In addition, Ca^{2+} bound P may be dissociated either by the formation of a Ca-specific chelator or by the formation of organic acids (Cameron and Julian, 2010). Subsequently, solubilized P may be directly used by the plants or indirectly after death and decay of cyanobacteria which had utilized the solubilized P for their own metabolism. Recently, Teikari et al. (2015) have reported the upregulation of phosphorous.

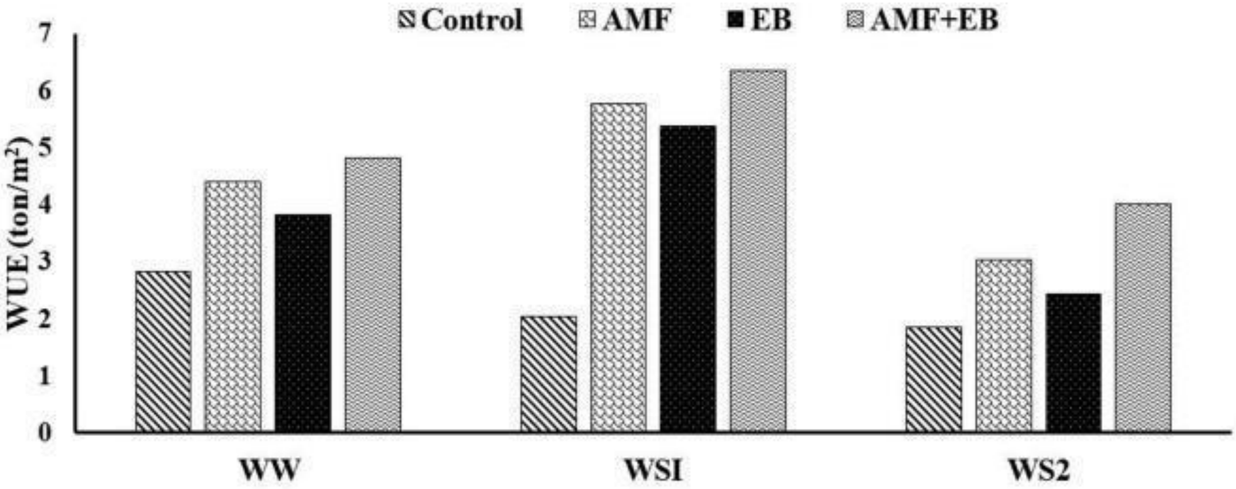


3.2.2: Mycorrhizal Fungi as a Biofertilizer

Fungal biofertilizers, when applied in a natural field system either alone or in combination, are known to cause a direct or indirect beneficial impact on plant development, growth, and yield through several methods (Rai et al., 2013). The roots of different plant groups, such as herbs, shrubs, trees, aquatics, xerophytes, epiphytes, hydrophytes, and terrestrial plants, growing in natural conditions, have been reported to develop mycorrhizal associations when grown in conditions with a low bioavailability of essential elements, including phosphorus, nitrogen, zinc, copper, iron, sulfur, and boron (Zhu et al., 2008).Phosphate solubilizing fungal biofertilizers are one of the most commonly employed biological agents for improving plant growth and development by facilitating phosphorus uptake in plants. Fungi possessing a phosphate solubilizing property contribute significantly to the availability of soil phosphates to plants.



The amendment of yeasts (either live or dead) to soil has been demonstrated to substantially enhance the nitrogen and phosphorus availability to the roots and shoots of *Solanum lycopersicum* L. and sugarcane plants (Mohammadi, 2012. Moreover, yeast amendment to soil was also reported to enhance the root to shoot ratio in both plants and the induction of species-specific morphological alterations leading to enhanced tillering in sugarcane and higher shoot biomass in *S. lycopersicum* L. Brewer's yeast is an inexpensive biofertilizer that enhances plant nutrient status and plant potential, thus, aiding plant growth and nutrient uptake (Lonhienne et al., 2014). Approximately 80% of plant species are reported to have mutualistic association with arbuscular mycorrhizal fungi (AMF). Partial or complete degeneration of AMF activity in soil can lead to significant changes in soil properties, that directly or indirectly helped in the enhancement of agriculture production.



Effect of arbuscular mycorrhizal fungi(AMF) alone, endophytic bacteria(EB) in combination on seed yield of common bean plants grown under different levels of water stress (WW, WS1, WS2)

3.2.3: Plant Growth Promoting Rhizobacteria as Biofertilizer

Various species of beneficial microorganisms grow in the rhizosphere, participating in nutrient cycling and the production of plant growth promoting substances. Hence, are called plant growth promoting rhizobacteria (PGPR) (Ahemad and Kibret, 2014). Similarly, bacteria such Bacillus and Paenibacillus have been found to cause an increase in plant-mycorrhizal colonization, therefore, are referred to as mycorrhizal helper bacteria (MHB) (Adeleke and Dames, 2014). Some biofertilizing-PGPRs produce phytohormones such as indole acetic acid, gibberellins and cytokinins that cause an increase in plant foliage, root elongation, fruit yield and plant-microbe symbiosis (Hassen et al., 2016; Vacheron et al., 2013). Indole acetic acid (IAA) affects plant root architecture; leading to increased root surface area and root tip elongation (Ahmad, Ahmad, & Khan, 2005; Lu et al., 2015) while gibberellic acid induces increased flowering, stem and internode elongation, fruit setting and growth in plants (Zalewska and Antkowiak, 2013). Therefore, beneficial microbes that promote root development have an immense impact on nutrient uptake ability.

3.2.4: Potassium Solubilizing Biofertilizer (KSB)

Potassium solubilizes aids in solubilizing potassium from compounds such as mica, illite, orthoclase and biotite by producing organic ligands, hydroxyl anions, enzymes and biofilms (Bahadur et al., 2014; Shanware et al., 2014). The ability to solubilize potassium effectively depends on the soil type and microbial strain, as well as the form of K compounds (Bhai and Srinivasan, 2012). Potassium solubilizing biofertilizer include; Pseudomonas, Burkholderia, Bacillus, and Paenibacillus genera (Ahmed and El-Araby, 2012; Liu et al., 2010; Yasin et al., 2016)

IV. ONTRIBUTION OF BIOFERTILISER IN AGRICULTURE

4.1 Increased Yield and Nutrient Availability

Legume yield among smallholder farmers can be increased by using N-fixing biofertilizers such as Rhizobium and Bradyrhizobium (Hassen et al., 2016). For example, inoculation of soybean causes an increase in yield, improves soil organic matter while also fixing about 80% of soybean N need (Giller et al., 2011). Rose et al. (2014) reported that biofertiliser could replace about 52% of N-fertiliser and cause an increase in rice yield over the control. Rhizobium biofertiliser alone can supplement about 50% of the fertilizer need of crops in most arid and semiarid marginal lands of Zimbabwe, Tanzania, and Kenya, which are deficient in N (Chianu et al., 2014). Ronner et al. (2016) also found that crop yield increased by 447 kg/ha over the control due to inoculation in northern Nigeria. Azolla soaked in 50 ppm of superphosphate when inoculated in a paddy field fixed about 40–55 kg N/ha, 15–20 kg P/ha and 20–25 kg K/ha in a month per 1 kg of Azolla applied, bringing the yield of flooded paddy to about 10–20% over the control (Wagner, 2012).

The use of biofertilizers leads to separate accumulation of N, P and K in the soil, thereby maintaining soil nutrient balance (Adesemoye et al., 2008; Egamberdiyeva, 2007). Sundara et al. (2002) observed an increased sugarcane and sugar yield when the plant was inoculated with PSB, Bacillus magisterium var. Phosphaticum. Similarly, the use of biofertilisers with cheap rock phosphate increased crop yield by 74% over the control, while peanut and sunflower plants inoculated with PSB recorded a significant yield over the control (Ahmed & El-Araby, 2012). According to Bambara and Ndakidemi (2010), the concentrations of Fe, Cu and Zn in the rhizosphere of Phaseolus Vulgaris when inoculated with Rhizobium increased by 28, 20 and 67% respectively compared to the control. This could be due to the role of biofertiliser in improving soil nutrient content and nutrient uptake of the plant (Guimarães et al., 2016).

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4.2 Prevention of Plant Pests and Diseases

Some biofertilizers prevent plant diseases by directly inhibiting pathogens through their metabolic activities or indirect competition (García et al., 2015; Rudrappa et al., 2008). The nodule-forming symbiotic association of legumes with Rhizobium has been established to enhance the synthesis of cyanogenic defense substances, which increases plant resistance to herbivore attack (Mazid et al., 2011; Megali et al., 2015; Thamer et al., 2018). Bacterial and fungal attacks are major factors affecting smallholder productivity, especially in sub-Saharan Africa (Strange & Scott, 2005). Fusarium wilt of pigeon pea and soft rot of potato caused by Fusarium and Erwinia Carotovora can be controlled by Pseudomonas fluorescent and sinorhizobium, both producing chitinase and β-glucanases (Guo, et al., 2013; Kumar et al., 2017).

Bacillus sp. inhibit important pathogens such as Rhizoctonia solani in tomatoes and Phytophthora capsici in pepper (Solanki et al., 2012). Some biofertilizers produce siderophore, a Fe-chelating agent, which limits the available Fe in the soil. This indirect competition for nutrients suppresses the pathogen's ability to cause diseases (Arora, Khare, & Maheshwari, 2010; Solanki et al., 2014). Siderophores produced by Pseudomonas and Bacillus attack the popular fusarium wilt of potato and maize, thereby increasing potato and maize yield of smallholder farmers (Beneduzi et al., 2012). Similarly, Pseudomonas aeruginosa is used against bacterial blight caused by Xanthomonas oryzae and Rhizoctonia solani, which are major rice diseases in West Africa (Mali, Senegal, Nigeria, Niger etc.) (Nga et al., 2013)

4.3 Water Stress Resistance

Many African countries, especially the arid and semi-arid areas, have long drought season and this has caused limitation to plant growth (Falkenmark & Rockström, 2008). In this situation, biofertilizers, which enhance plant water-stress tolerance, is of immeasurable importance (Dimkpa, Weinand, and Asch, 2009; Hassen et al., 2016). The production of auxins, cytokinins, gibberellins and 1-aminocyclopropane-1-carboxylate (ACC) deaminase by some biofertilizers has been reported to improve plant water stress tolerance (Khalil and El-Noemani, 2015; Mayak, Tirosh, and Glick, 2009). Similarly, Aroca and Ruiz-Lozano (2009) and Mayak et al. (2004) reported an increase in water resistance of pepper and tomato plant grown on water deficient soil when inoculated with PGPRs. Essentially, under water-stressed conditions, AMF with their hyphae make available substantial amounts of ammonium and nitrate to the host plant (Wu & Xia, 2006). Therefore, biofertiliser has a great economic importance in improving the productivity of smallholder farmers in seasons of drought, especially in drought-prone sub-Saharan African countries such as South Africa, Kenya, Uganda, Ethiopia and Somalia (Kaushal andWani, 2016).

V. CHALLENGES FACING UTILIZATION OF BIOFERTILIZERS

- Lack of awareness amongst farmers
- Lack of government support on the production of biofertilizers
- Lack of trained staff in the production of biofertilizers
- Low acceptance on the use of biofertilizers by most of the large scale farmers
- In availability of commercial biofertilizers

VI. CONCLUSION

From the different literature reviewed, the use of biofertilizer has been established to increase plant growth and yield, as well as improve soil quality. In addition, biofertilizer could also protect the natural environment and soil biodiversity. Certain biofertilizers produce metabolites that protect plants from pest and disease attack. The environmentally friendly property of biofertiliser, as well as its great potential in sustainable agriculture, have accentuated the need to reduce, if not replace, the use of agrochemical inputs with biofertilizers. The resource-poor farmers who cultivate on nutrient-poor sub-Saharan African soil need a costeffective and efficient technology to increase yield and profitability. It is uninteresting that the intensification in the use of chemical fertilizers has mainly focused on productivity with little or no concern about the increasing cost and ecological damage. This review revealed that the cost-benefit ratio in using biofertiliser is higher than any other nutrient management practice especially the inorganic fertilizers.

In conclusion, there is an urgent need to improve the awareness and use of biofertiliser among sub-Saharan smallholder farmers. Research studies on efficient microbial strain production, optimization of product design and biofertiliser business management as well as extension programs and product-marketing strategies are essential to achieving these objectives. It is pertinent to emphasize that sub-Saharan African government have crucial roles to play in ensuring biofertiliser technology is fully adopted as the first choice in our quest to address soil fertility challenges. Their support can be in the form of subsidy or materials to farmers. Apart from training the smallholder farmers, the accessibility of the product is also essential

AUTHORS' CONTRIBUTIONS

This review work was carried out in collaboration among all authors. Author FKM come up with the review gap, designed the study and wrote the first draft of the manuscript. Author HON and GOOA managed the literature searches and editing of the manuscript. All authors read and approved the final review manuscript

CONFLICT OF INTEREST STATEMENT

The authors declare that the review was conducted in absence of any commercial or financial relationships that could lead to a potential conflict of interest.

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