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ASSOCIATION FOR AGRICULTURE ENVIRONMENT AND BIOTECHNOLOGY

Review paper

Development of Novel Biofertilizer by Combining the Banana Waste and Cyanobacteria in Sustainable Agriculture

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ABSTRACT

This review article discusses the technologies for mass producing cyanobacterial biofertilizers as well as their applications in industrial and agricultural contexts. The agriculture sector is always looking for novel approaches to boost crop yields without sacrificing environmental sustainability. In this review paper, it is suggested that banana trash and cyanobacteria that have been isolated from banana plantations be combined to create a unique biofertilizer. This review paper's objective is to use agricultural waste and naturally occurring microorganisms to create a sustainable alternative for crop fertilisation. Banana waste, which is plentiful in banana-growing areas, a supply of nutrients that the cyanobacteria can use, which will then give the soil nitrogen fixation and other advantageous qualities. The soil from a banana plantation will be used to separate the cyanobacteria, which will then be examined for their capacity to stimulate plant development. A suitable substrate for the cyanobacteria to grow and reproduce will be created from the processing of the banana trash. The efficacy of the resultant biofertilizer in enhancing plant development and yield will be evaluated on a range of crops. The goal of the study is to show how this strategy might support sustainable agricultural practises while also offering an economically viable method for handling banana trash. Overall, this work gives a viable plan for creating a unique biofertilizer that may completely transform the agricultural sector.

Keywords: Cyanobacterial biofertilizers, Banana waste, crop, yields

Modern agricultural crops heavily rely on chemical-based fertilizers to increase crop productivity, but excessive use of these fertilizers can now seriously harm human health and have a bad influence on the environment. Therefore, research on fertilizer is focused on developing more environmentally friendly agricultural practices that take advantage of microbes like cyanobacteria. These cyanobacteria promote agricultural output and soil fertility. Cyanobacteria, tiny algae, rhizobacteria, ecto- and endo-mycorrhizal fungi, and any microbe capable of coexisting with higher plants like banana plantains are all included in the biotechnological toolbox. The research accomplishments on cyanobacteria and banana peel-based biofertilizer for agricultural applications are the main topic of this review study. Biofertilizers are the living microorganisms that enrich the soil and enhance plant growth by fixing atmospheric nitrogen, solubilizing soil minerals, and producing phytohormones. Micro and macro nutrients are present in biofertilizers. Plant growth

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enhancing substances, antibiotics and organic matter are present in soil with the help of nitrogen fixation, mineralization of potassium and phosphate solubilization. Cyanobacteria, also known as blue-green algae, are photosynthetic bacteria that have a significant role in maintaining the health of aquatic and terrestrial ecosystems. Cyanobacteria are the primary producers that fix atmospheric nitrogen and convert it into ammonia, nitrate, and other organic forms, which serve as a nutrient source for plants. In heavy metal-contaminated effluents, nitrogen is frequently the limiting nutrient for algal development; as a result, nitrogen fertilizers must be supplied externally to support the process, which can be expensive. This is crucial given the number of fertilizers presently needed for food production, which could cause synthetic fertilizers to become more and more costly if alternative strategies are not taken to reduce their use.

Importance of sustainable agriculture practices and biofertilizers

Traditional agricultural methods have contributed to soil erosion, water pollution, and environmental damage, making them no longer viable in the long run. The authors argue that sustainable agriculture practices, which focus on minimizing the negative impact of agriculture on the environment, are essential for the future of agriculture.

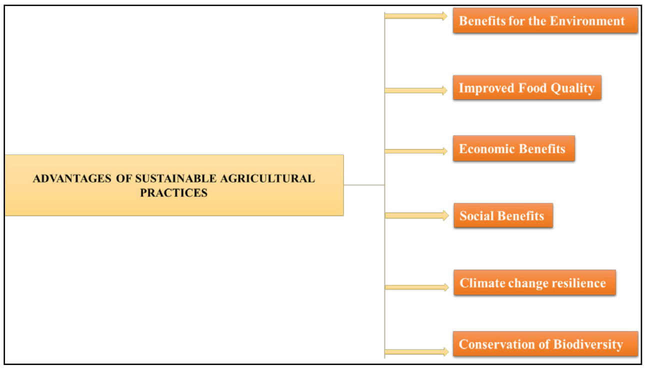

Fig. 1

The authors point out that using sustainable farming methods may enhance soil health, boost yields, and cut back on the usage of artificial fertilizers and pesticides. They emphasise how farmers may maintain their way of life while adapting to changing climatic conditions by engaging in sustainable farming practises. According to the authors, using biofertilizers has a positive impact on the ecology. The environmental challenges that traditional chemical fertilisers, which can result in pollution and other problems, have are not present with biofertilizers. Farmers may reduce pollution and preserve the health of their soil by employing biofertilizers rather than synthetic fertilisers.

(a) Benefits of sustainable farming methods

Sustainable agricultural practises seek to improve social justice and economic viability while reducing the environmental impact of farming. By ensuring that agricultural practises are ethically and economically sound, this method hopes to protect natural resources and increase food security. Numerous methods, such as crop rotation, integrated pest management, and conservation tillage, are used to achieve this. By reducing soil erosion, saving water, and guarding against pollution, these methods help maintain a healthy environment. Farmers may earn from using sustainable farming practises when output rises and input costs fall. Crop rotation is one strategy that can help improve soil health and eventually boost crop production. Additionally, conservation tillage can reduce the need for expensive equipment and fuel, saving farmers money. Sustainable agricultural practises may promote social justice by ensuring that farmers have access to the resources they need to produce food. Access to markets, to water, and to land are all included. By bolstering local food systems, sustainable agriculture practises can contribute to the establishment of jobs and economic growth in rural areas. Sustainable agricultural practises can raise the quality of the food produced by reducing the use of dangerous chemicals and promoting the use of natural pesticides and fertilisers. Customers' food may become healthier and more nutritional as a result. By encouraging techniques like crop diversification and soil conservation, sustainable agricultural practices can aid in the development of climate change resistance. By using these techniques, it may be possible to lessen the effects of extreme weather conditions on agricultural production, such as floods and droughts. Sustainable agricultural practices can aid in biodiversity preservation by encouraging the use of agroforestry and other techniques that combine crops and trees. This can give animals a home and aid in preserving biodiversity in agricultural environments.

(b) Biofertilizer role in sustainable agriculture

The use of cyanobacterial biofertilizers can improve soil fertility and plant growth, reduce the use of chemical fertilizers, and promote sustainable agriculture. Biofertilizers are living organisms that fix nitrogen, solubilize phosphorus, and mobilize other nutrients to improve the fertility and productivity of the soil. When added to soil or plants, these microorganisms can assist in lowering the need for artificial fertilisers and pesticides, which may have detrimental effects on the environment. Because they may assist improve soil fertility, plant development and output, and the negative environmental consequences of chemical fertilizers and pesticides, biofertilizers are a crucial part of sustainable agriculture.

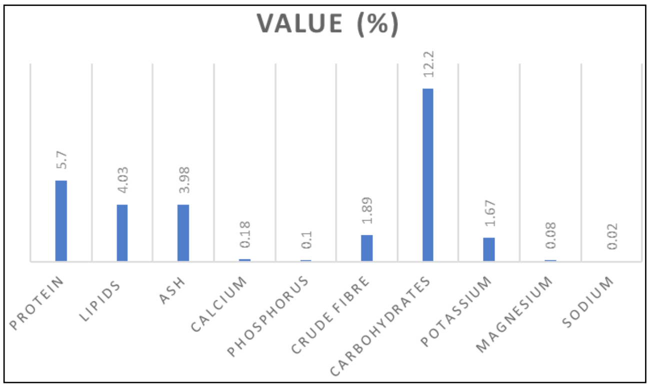

Fig. 2

The two primary categories of biofertilizers are those that fix nitrogen and those that solubilize phosphorus. Rhizobia, Azospirillum, and Azotobacter are examples of nitrogen-fixing biofertilizers that can transform atmospheric nitrogen into a form that plants can utilise. Biofertilizers that help liberate phosphorus from soil minerals so that it is accessible to plants include phosphate-solubilizing bacteria and mycorrhizal fungus. The potential of biofertilizers to enhance soil structure, water-holding capacity, and nutrient availability is another benefit. This is accomplished by soil microbes, which work to decompose organic matter and release nutrients in a way that plants may easily absorb. Additionally, by encouraging the growth of advantageous microorganisms that can outcompete dangerous pathogens, biofertilizers can aid in the reduction of soil-borne illnesses.

(c) Benefits of biofertilizer from banana peels

With an annual production of 40 million tonnes, or roughly 35% of the weight of all bananas, banana peel is a significant agricultural waste product. The sustainability and viability of using banana by-products are the untapped opportunities and challenges for transforming these by-products, such as peels, leaves, mock stems, stalks, and inflorescence, into vibrant food and non-food operations, serving as thickening agents, colourants, and flavours, essential sources of macronutrients and micronutrients, natural cuticles, animal feed, natural filaments, and sources of naturally occurring bioactive composites and bio-fertilizers. Anti-cancerous property is also found in banana. Banana peel is a commonly found organic waste material, which contains a wide range of nutrients and organic compounds that make it an effective biofertilizer. In recent years, the use of banana skin as a biofertilizer has grown in popularity due to its ability to increase crop output and soil health while lowering the need for artificial fertilisers. Numerous minerals, including nitrogen, phosphorus, and potassium, which are necessary for plant growth and development, may be found in banana peel.

Banana Peel Composition

Additionally, according to table given above banana peel is also rich in other micronutrients such as calcium, magnesium, and Sodium with values such as 0.18%, 0.08%, 0.02, 5.7% respectively, which are crucial for plant health. The 1.67 % of potassium content in banana peel makes it an excellent source of fertilizer for crops like tomatoes, peppers, and bananas, which require high levels of potassium. Potassium deficiencies in vegetation can result from several things aging of plant is shown by potassium deficiency which is shown by older leaves having brown veins on it. Potassium is a crucial nutrient for plant growth and development, so when the earth is deficient in it, plants will exhibit signs of a shortage. pH of the soil increases that makes potassium less available to plants, which can cause shortage signs. Imbalanced of fertilisation causes by excessive use of some fertilizers, especially nitrogen, can prevent plants from properly absorbing potassium, which can result in a shortage. Stressful environmental circumstances, such as drought or extremely high temps, can cause vegetation to exhibit signs of potassium deficiency. Stunted development, yellowing of the foliage, scorching of the leaf edges, and lowered resilience to pests and illnesses are all signs of potassium shortage in plants. Banana skins have potassium concentration of about 200 mg per fruit. When used in fields, banana leaves not only serve as a pest deterrent but also provide nutrients to the plants. The use of banana peel as a biofertilizer has several advantages.

Firstly, it is an eco-friendly option, as it uses an organic waste product that would otherwise be discarded. This reduces the amount of waste going into landfills and reduces the environmental impact of chemical fertilizers.

Secondly, it is an affordable and easily accessible option for farmers, as banana peel is readily available in many regions. The use of banana peel as a biofertilizer can also strengthen the soil's structure and increase its organic content, which can enhance soil health and lessen soil erosion. After analysing various studies, it has been found that banana peel contains maximum amount of potassium in comparison to other elements. Banana peel is high in potassium yet has low salt contain. From papers shown that Banana peel contains many minerals and nutrients which can be actively used in farming as biofertilizer. Several studies have demonstrated the effectiveness of banana peel as a biofertilizer. In one study, banana peel extract was shown to increase the growth and yield of tomato plants. Another study found that banana peel compost improved the soil structure and nutrient availability, leading to increased crop yield and quality. The use of banana peel as a biofertilizer has several potential benefits, including its eco-friendliness, affordability, and ability to improve soil health. Banana peel is a promising option for sustainable agriculture, studies shows that banana peel have antimicrobial and antifungal properties which is good for agriculture sector.

Table 1: Banana peel decomposition content

Feedstock's total solid	31%
Moisture Content	47%
Ash	67%
Volatile Matter	69%

A major challenge in the manufacture of biofertilizers is the proper NPK allocation. According to author Yunus research study, galvanised steel sheet was used to construct a 30 litres bench-scale anaerobic biodigester for the creation of biofertilizer from solid refuse. A total of 12kg of substrate 4kg of poultry manure, 7.5 kg of wastewater treatment sludge, and 0.5 kg of banana peel is then blended with water in a 1:1 ratio. The sludge is delivered 24 kg (w/w) into the biodigester. 37 days are given for the mixture to remain at mesophilic temperature. The temperature during absorption is between 25 and 34 degrees Celsius, and the pH is between 6-7. After decomposition, the feedstock's total solid, moisture content, ash, and volatile matter all drop by roughly 31%, 47%, 67%, and 69%. Additionally, it was noted that the nitrogen level increased from 0.3783% to 0.6420%, phosphorus level increased from 0.1903% to 0.2983%, and potassium level increased from 0.1876% to 0.3153%. After digestion, a 2:1:1 quantity of biofertilizer is generated, which is suitable.

Methods of preparation of banana peel biofertilizer

Composting is a natural process that transforms organic waste products, such discarded food and yard trash, into a nutrient-rich soil amendment that may be utilised to increase the fertility of the soil and the development of plants. Banana peels can be composted along with other organic waste, such as food scraps, leaves, and grass clippings, to form a nutrient-rich soil supplement. During the composting process, temperature is crucial. Higher temperatures in the thermophilic range help to destroy pathogens and clean the organic waste. Simply layer the organic waste with soil or other compost to create a compost pile and keep it moist and well-aerated. The waste will eventually decompose into compost, which may be used to fertilise plants. A study discovered that composting banana peels along with other organic waste produced a nutrient-rich mixture that enhanced soil fertility and plant development. The compost has high quantities of organic matter, nitrogen, phosphorous, and potassium, which are vital elements for plant development, according to the researchers.

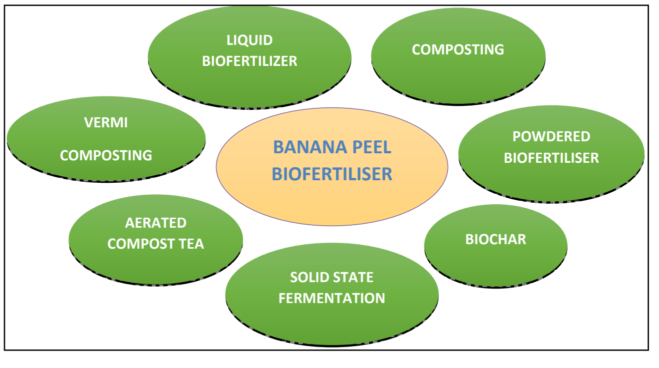

Fig. 3

Solid-state fermentation (SSF) is a method for transforming organic waste into usable goods by utilising microorganisms. Banana peels are an abundant supply of organic matter, and in recent years, SSF has been used to create biofertilizer from them. Large amounts of banana peels are produced as trash in both homes and the businesses that handle bananas. Consequently, the use of banana leaves as a substrate for the creation of biofertilizer presents a chance to minimise pollution and advance sustainable agriculture. Banana peel preparation, inoculation, moisture correction, incubation, drying, and packing are all stages in the SSF technique for making biofertilizer out of banana peels. Banana peels are gathered in the first stage, washed, and then sliced into tiny bits. The components are then thoroughly dried, either outside in the sun or inside a dryer. Following drying, bacteria, fungus, and yeast are injected into the dried banana peel pieces. A 1:10 ratio of inoculum is introduced to the banana peels, and water is then added to get the moisture content down to around 60%.

This guarantees that the bacteria have access to adequate moisture to develop and proliferate. Banana peels that have been vaccinated are then incubated for 7–14 days in sealed containers. During this time, the microorganisms break down the organic matter in the banana peels and convert it into nutrients that can be used by plants. After incubation, the biofertilizer is removed from the containers and dried in the sun or using a dryer until it is completely dry. The dried biofertilizer is then packaged in airtight containers or bags and stored in a cool, dry place until it is ready for use. According to studies, banana skin SSF used to make biofertilizer is an abundant source of potassium, phosphorus, and nitrogen, all of which are vital for plant development. The biofertilizer also includes advantageous microbes that support healthy soil and plant development. The SSF technique has several benefits over other processes for making biofertilizer from banana peels. It is a straightforward and economical procedure that is simple to build up for industrial output. 0.5 kg of the banana peels were thoroughly cleaned with water to get rid of any contaminants and dust that had been attached to the outside of the fruit. With the use of a high-speed mechanical blender, the gutted peels were torn into little bits and combined with regular water. To create a homogeneous slurry, the thick slurry was combined with the specified amount of potassium hydroxide and agitated for 1 minute. The alkaline amalgamated peel slurry was subjected to a 30-minute boil while being stirred. After boiling, the slurry was allowed to cool at room temperature so that it could be processed further. Vacuum filtering was used to separate the cold slurry into thick, dark brown sludge and clear, brown filtrate. As a result, the clear filtrate was heated to around 70 °C while being continuously rotated at 300 rpm. Urea and citric acid were then added gradually until the pH value reached about 5. At 105 °C, the obtained sludge was dried and ground into fine greasepaint.

Earthworms are used in the vermicomposting process to decompose organic waste and produce a nutrient-rich soil supplement. Banana peels may be composted by chopping them into little pieces and placing them in a worm bin with other organic waste, such as newspaper and food scraps. The trash will be consumed by the worms, who will then create nutrient-rich compost that may be used as plant fertiliser. Because they have a significant amount of vital nutrients like nitrogen, phosphorus, and potassium, banana peels are a great source of organic matter for vermicomposting. These minerals, which are crucial for plant development and growth, are frequently present in commercial fertilisers.

Banana peels vermicomposted using a small vermicomposting bin or worm farm, and the procedure is rather straightforward. To hasten decomposition and make them simpler for worms to ingest, the banana peels are first chopped into little pieces. The shredded newspaper, cardboard, or dry leaves are then placed to the worm bin together with the diced banana peels. The bedding materials serve to absorb moisture and reduce odours while also acting as a habitat for worms and other microbes. The worms are then introduced to the worm bin once the banana peels and bedding items have been added. African nightcrawlers (*Eudrilus eugeniae*) and red wigglers (*Eisenia fetida*) are the two types of worms most frequently employed in vermicomposting. Because they are voracious eaters, these worms will eat the banana peels and other organic material, breaking them down into a compost that is rich in nutrients. Banana peels and other organic materials are broken down by the worms during the vermicomposting process, resulting in castings or worm faeces that is nutrient-rich. These castings are a concentrated supply of nutrients and beneficial bacteria that can aid to enhance the health of the soil and plant development. The resultant vermicompost can be utilised in a range of applications, such as gardening, landscaping, and agriculture, as a soil supplement or fertiliser. Vermicompost formed from banana peels is an efficient soil amendment that may increase soil fertility, promote the growth and development of plants, and lessen the need for artificial fertilisers, according to studies. Vermicomposting banana peels yields a great resource for plant development while being an efficient and ecological method of handling organic waste. Vermicomposting banana peels is a crucial instrument for accomplishing the aims of sustainable agriculture and the production of organic food considering the rising demand for these practises. Another technique to use this organic waste product is to make banana peel powdered biofertilizer. Banana peels may be used to make powdered biofertilizer, which is an easy procedure that can be completed using common home tools. Drying the banana peels is the first step. They may be dried in the sun or by using a dehydrator. The shelf-life is extended, and the moisture content is decreased by drying the banana peels. The banana peels can be processed or blended into a fine powder after they are totally dry. To ensure that nutrients are distributed evenly, it is crucial to make sure the powder is finely crushed.

Table 3

Content of banana peel powder biofertilizer	% Value	References
Nitrogen	14	(Zone *et al.* 2021)
Calcium	40	(Zone *et al.* 2021)
Phosphorus	37	(Zone *et al.* 2021)
Magnesium	2	(Zone *et al.* 2021)
Potassium	7	(Zone *et al.* 2021)

The final biofertilizer in powder form can then be used as a soil amendment or combined with compost. The biofertilizer is a superior source of organic matter for plant development due to the high nutritional content of banana peels. The biofertilizer is abundant in vital nutrients including nitrogen, phosphorus, and potassium, which are crucial for plant development and growth. According to research, utilising banana peel-derived powdered biofertilizer can increase soil fertility and promote plant development. For instance, research carried out in India discovered that utilising banana peel biofertilizer enhanced wheat and rice crop productivity by 11–18% compared to conventional chemical fertilisers. Research discovered that utilising banana peel biofertilizer boosted tomato plant growth and production. Banana peels may be used to make powdered biofertilizer, which is an efficient approach to use this organic waste product and produce a useful resource for plant development. Since the procedure is straightforward and can be completed with common household items, a variety of practitioners can use it. By utilising banana peel biofertilizer, you may increase soil fertility, lessen the need for artificial fertilisers, and promote plant growth and development.

An organic substance, such as agricultural waste, forestry by products, or other plant materials, can be burned in the absence of oxygen to create biochar, a form of charcoal. This procedure, known as pyrolysis, creates a highly porous and stable form of carbon that may be added to soil to enhance its structure, ability to retain water, and nutrient availability. A sustainable technique to utilise this organic waste product is to make biochar from banana peels. Drying the banana peels to remove moisture is the first step in creating banana peel biochar. When the peels are dry, they can be burned at 350°C to 700°C in a pit or kiln. This process transforms the organic material in the banana peels into a stable form of carbon that may last in the soil for hundreds or even thousands of years and is resistant to breakdown. The resultant biochar can then be used to increase the fertility of compost or soil. It has been demonstrated that biochar enhances soil structure by enhancing water retention and porosity while also encouraging the development of advantageous microbes. By gradually absorbing and releasing nutrients like potassium, phosphate, and nitrogen, it can also boost the availability of nutrients. By storing carbon in the soil, biochar can also aid in lowering greenhouse gas emissions. According to research, adding biochar made from banana peels to the soil can increase plant output and development. For instance, research revealed that utilising banana peel biochar enhanced tomato plants' growth and yield when compared to untreated soil also, use of banana peel biochar boosted the soil's availability of nutrients including phosphate and potassium. Biochar made from banana peels is a sustainable method of using this organic waste product and enhancing soil fertility. Banana peels may be used to make biochar, which is a useful resource for farming while reducing waste. Biochar is a desirable alternative for sustainable agriculture since it offers several advantages for healthy soil and plant growth.

Aerated compost tea is a liquid fertiliser that contains a variety of beneficial bacteria, fungus, and other microorganisms that can enhance soil health and plant development. Banana peels may be used to prepare aerated compost tea by first chopping them into little bits and adding them to a container of water with compost and a sugar source, such as molasses or honey. The bacteria may eat from the sugar supply, which also aids in promoting their growth. The mixture is then stirred and oxygenated water is added using an air pump. As a result, aerobic microbes flourish, which are crucial for decomposing organic waste and releasing nutrients into the soil. For a few days, the mixture is allowed to steep, during which time the microorganisms grow and concentrate. Before using the liquid to fertilise plants, it can be filtered to remove any particles and then diluted with water once the liquid is teeming with bacteria. Aerated compost tea is an efficient technique to give plants a boost of nutrients and healthy microbes. It may be applied as a foliar spray or soil drench. Aerated compost tea has been found in studies to enhance soil health and plant growth, resulting in larger yields and healthier plants. Research discovered that utilising aerated compost tea enhanced maize plants' growth and production when compared to untreated soil. Another study discovered that employing aerated compost tea improved tomato plant growth and yield while decreasing the occurrence of plant illnesses. Using banana peels as a source of organic fertiliser is made simple and effective when done using aerated compost tea. Banana peels may be used to make a nutrient-rich liquid fertiliser that can enhance soil by adding them to compost and letting them sit in water with a sugar source and oxygen.

Banana peels can also be used to make a liquid biofertilizer in addition to vermicomposting. A type of fertiliser known as liquid biofertilizer delivers vital nutrients to plants in liquid form to assist their growth and development. The procedures described in the study report to make liquid banana peel biofertilizer. Banana peels should first be chopped into tiny pieces. The rate of decomposition increases with the size of the fragments. Add water and a sugar source, like molasses or brown sugar, after that. The bacteria that aid in the breakdown of the banana peels are fed by the sugar supply. Depending on the size of the container we are using, and the number of banana peels we have, decide how much sugar and water to add. Next, put a lid or piece of cloth on the container. This will aid in deterring pests like flies that could be drawn to the combination. Allow the mixture to ferment for a few weeks, stirring every so often to make sure the banana peels are distributed evenly and the microorganisms are healthy. The liquid is prepared for usage when it has become brown and has a sour scent. To get rid of any solid particles, strain the liquid using a cheesecloth or fine mesh strainer. Because it is so concentrated, the resulting liquid biofertilizer needs to be diluted with water before use. The sort of plants you are fertilising, and their nutritional needs will determine the liquid biofertilizer to water ratio. In order to encourage the growth of banana plants, the study report provided an example of the usage of liquid banana peel biofertilizer. Banana peels were cut up and combined with molasses and water in the study. After three weeks of fermentation, they strained the mixture and added water to diluted it. Banana plants received the resultant liquid biofertilizer once every week for six weeks. In comparison to the control group that did not get the liquid biofertilizer, the plants that got it exhibited a considerable increase in leaf area, stem diameter, and root length.

Biofertilizer potential of cyanobacteria

In addition to freshwater and marine areas, cyanobacteria also live in terrestrial ecosystems. They are a varied group of photosynthetic bacteria. As an organic source of nutrients for plants, cyanobacteria have the ability to fix atmospheric nitrogen. Blue-green algae, often known as cyanobacteria, are common photosynthetic microorganisms in both aquatic and arid habitats. Due to their distinctive biological characteristics, they have been exploited in many different industries including agriculture, aquaculture, environmental restoration, and biotechnology. Cyanobacteria are essential for the nitrogen cycle because they fix atmospheric nitrogen, which may then be utilised in agriculture as a biofertilizer. Additionally, cyanobacteria create phytohormones that aid in the growth and development of plants, including as gibberellins and indole acetic acid (IAA). By secreting organic acids, enzymes, and siderophores, cyanobacteria also help to solubilize soil minerals like phosphorus. As a result, cyanobacteria have the potential to be employed as biofertilizers in agriculture.

(a) Benefits of biofertilizer from cyanobacteria

Banana peel biofertilizer production and use are characterised as affordable, renewable sources that might potentially supplement inorganic fertilisers.

Nitrogen is a crucial ingredient for plant growth and development. Plants cannot use nitrogen gas while it is gaseous, despite the fact that it makes up around 78% of the atmosphere. The conversion of nitrogen gas into ammonia, which plants may use, is a process known as nitrogen fixation. Cyanobacteria, some of which can fix up to 50 kg of nitrogen per acre per year, are among the most efficient nitrogen-fixing organisms. They have a unique mechanism that allows them to convert atmospheric nitrogen into useable nitrogen without the help of other inputs like fertilisers. Cyanobacteria can fix atmospheric nitrogen and convert it into organic forms, such as ammonia and nitrate, which can be utilized by plants. The use of cyanobacterial biofertilizers can reduce the need for chemical nitrogen fertilizers, which are expensive and have negative impacts on the environment. Living microorganisms that enhance soil fertility and plant development are referred to as biofertilizers. A good source of biofertilizers, cyanobacteria are known for their capacity to fix atmospheric nitrogen. A variety of growth-promoting chemicals are also produced by them, including phytohormones, vitamins, and amino acids, which are helpful for plant growth. Cyanobacterial biofertilizers can boost plant growth and reduce the need for synthetic phosphorus fertilisers. Utilising cyanobacterial biofertilizers can increase crop quality, output, and plant growth.

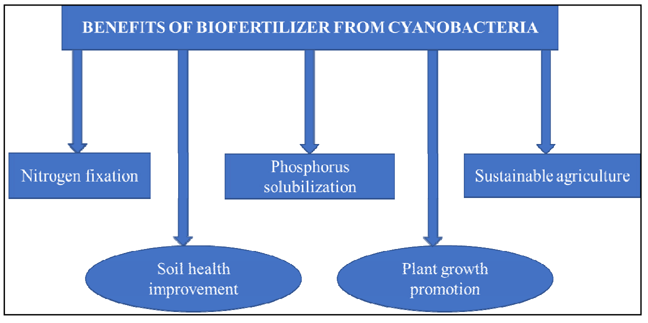

Fig. 4

A farming technique called sustainable agriculture aims to produce food in a way that is morally righteous, financially successful, and ecologically friendly. The use of cyanobacteria as biofertilizers adheres to the ideals of sustainable agriculture by reducing the usage of artificial fertilisers and improving soil health. Cyanobacteria can be used in conjunction with other environmentally friendly agricultural practises including crop rotation and cover crops in order to further enhance soil health and crop yield. By utilising less chemical fertilisers, enhancing soil health, and boosting crop yields, cyanobacterial biofertilizers can help advance sustainable agriculture. Through the use of sustainable farming methods, agriculture may improve its long-term sustainability and lessen its negative effects on the environment. Increases in soil organic matter, better soil structure, and a decrease in soil erosion are all ways that cyanobacteria can enhance soil health. In order to improve soil fertility, cyanobacterial biofertilizers can reduce the need for chemical fertilisers.

Banana processing waste and cyanobacteria from banana plantations were combined to make a biofertilizer for sustainable farming.

Biofertilizers are microorganisms that are added to the soil to increase soil fertility and plant growth. They provide a secure alternative to chemical fertilisers, which could be risky for both the environment and human health. A possible biofertilizer substitute is created by mixing banana waste with cyanobacteria isolated from banana farms. Potassium, nitrogen, and phosphate are just a few of the minerals found in banana waste that are important for plant growth. Cyanobacteria are notified as photosynthetic germs which have the capacity to convert atmospheric nitrogen into a form that is advantageous to plants. These cyanobacteria are when combined with a slurry of water and banana waste then they produces the biofertilizer. As the bacteria multiply and consume the nutrients in the banana waste, the mixture ferments for a few days.

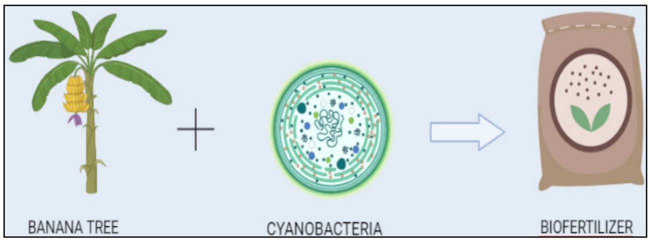

Fig. 5

Once the fermentation process is finished, the final biofertilizer can be applied to soil as a liquid or a solid fertilizer. This biofertilizer has the potential to improve soil fertility, encourage the plant growth, and reduces the need for artificial fertilizers. Utilising cyanobacteria and banana waste can also encourage sustainable agriculture practises and the decrease of garbage. The use of cyanobacteria and banana waste as a biofertilizer is one possible tactic for sustainable agriculture. It is a cheap, environmentally friendly option for boosting soil fertility and promoting healthy plant growth. A restricting factor for biofertilizers might potentially be manufacturing. According to reports, these biofertilizers can be used in place of inorganic fertilisers since they are reportedly made from cheap, renewable resources.

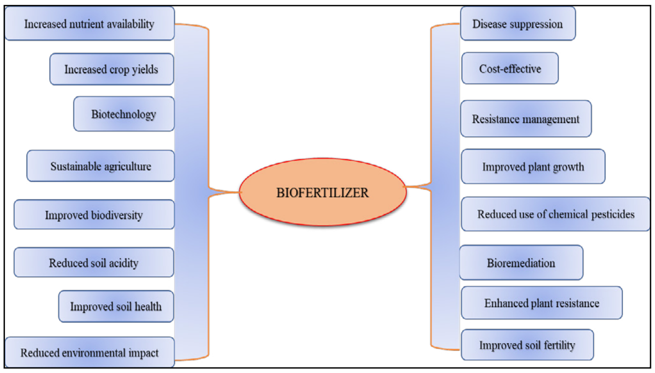

Fig. 6

Limitations of biofertilizer

Biofertilizers are a potential substitute for chemical fertilisers as a sustainable and environmentally responsible technique to increase soil fertility and promote plant growth. Like any other technology, biofertilizers have their limits, therefore it's necessary to be aware of them before employing them. One of the main issues with biofertilizers is their effectiveness. Although biofertilizers include the nutrients that plants require to grow, they may not provide as much nutrition as traditional fertilisers, especially in locations with high nutritional requirements or poor soil conditions.

Furthermore, biofertilizers might not be as effective as conventional fertilisers at hastening plant development, which could be problematic in some situations. Biofertilizers may require adequate storage and temperature management to retain their effectiveness. To promote plant development, they might also need to be given at precise times and in particular methods. This might increase the cost and make their use more difficult. Due to their compatibility issues with particular crops, soil types, or other agricultural inputs, some biofertilizers may have limitations in their usage in various situations. Due of the wide variances in crops and inputs, this can be particularly challenging in industrial agriculture. For small-scale farmers or those in underdeveloped nations, producing biofertilizer may need specialised tools and knowledge. When utilising biofertilizers, longevity is another aspect to take into account. While certain biofertilizers can boost soil fertility and plant development over the long term, others can have a shorter shelf life and need to be used more often to be effective. This may increase their use's expense and complexity. The dependability and efficacy of biofertilizers can be increased via research and development. There is still much to learn about the use of biofertilizers in various locations and for various crops, despite the fact that they have numerous advantages. These issues may be resolved and the usage of biofertilizers in sustainable agriculture can be improved with the aid of ongoing research and development. The delayed and perhaps lengthy nutrient release from banana waste might delay the nutrients' availability to plants.

An example of an organic material with nutrients that can be helpful to plants is banana trash. The size of the material, the degree of decomposition, the soil, and the weather are just a few of the factors that might affect how quickly these nutrients become available. When nutrients from banana waste release slowly over many months, it may not be the best choice for plants that require more immediate nutrient availability. It can be challenging to precisely quantify and use bananas as a fertiliser since the nutritional content might vary based on the type, level of ripeness, and processing technique. Nutrients like potassium, phosphorus, magnesium, and nitrogen are crucial for plant growth, and bananas are regarded as a rich supplier of these nutrients. Banana variety, ripeness stage, and fertiliser preparation technique are just a few examples of the variables that might affect a banana's nutritional value. In contrast to ripe bananas, which have a high sugar content and a low starch and potassium content, green bananas are heavy in starch. It can be difficult to precisely quantify and apply the right amount of nutrients to plants due to the nutritional variability of bananas as a fertiliser. As a result, it is advised to either use other fertilisers with predictable nutritional compositions or have the bananas examined for their nutrient content prior to use.

(a) Limitations of banana as a biofertilizer

The high moisture content of bananas can interfere with microbial development and breakdown during storage and transit, decreasing the efficiency of bananas as a biofertilizer. The availability of bananas as a biofertilizer is constrained since banana trash isn't always easily available in significant amounts. A temporary nutritional shortage for plants may emerge from the high carbon to nitrogen ratio in banana peels, which can cause nitrogen to get immobilised in the soil. The sluggish release of nutrients in bananas is one of its main drawbacks as a biofertilizer. The availability of nutrients for crops may be delayed since it might take plants several months to absorb nutrients from banana trash.

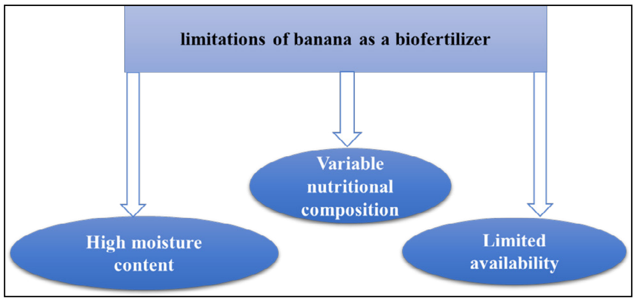

Fig. 7

This suggests that for crops that need quick nutrient availability, bananas might not be the ideal choice. The variable nutritious makeup of bananas is another drawback. The kind, level of ripeness, and manner of processing of bananas may all affect the amount of nutrients they contain. Because of this variety, it can be challenging to measure and apply bananas as fertiliser precisely, which might result in over- or under-fertilization. Bananas have high moisture content which prevents them from being used as a biofertilizer. Since bananas contain a lot of water, microbial development and breakdown during storage and transit may be a problem. Because of this, bananas may be less effective as biofertilizers and may be more difficult to handle and transport. Bananas have a high water content and are vulnerable to microbial growth and deterioration, making them a particularly perishable fruit. In turn, there can be a variety of post-harvest losses, such a shortened shelf life, a lower nutritional value, and more spoilage. The employment of various chemical and biological agents, controlled atmosphere storage, modified atmosphere packing, and other post-harvest procedures have all been developed to address these problems.

The limited availability of banana waste is another significant disadvantage. Despite the fact that bananas are extensively consumed and farmed all over the world, the availability of banana waste for use as a biofertilizer may be limited in some areas. Additionally, compared to conventional fertilisers, banana waste may not be as cost-effective due to the expense of collection, transportation, and processing. Last but not least, not all crops or soil types may respond well to the usage of bananas as a biofertilizer. The nutritional makeup of bananas could not fit the particular requirements of some crops, and the soil might not be conducive to using banana waste as fertiliser. Due to their high nutritional content, bananas have the potential to be used as a biofertilizer; nevertheless, there are a number of restrictions that must be taken into account.

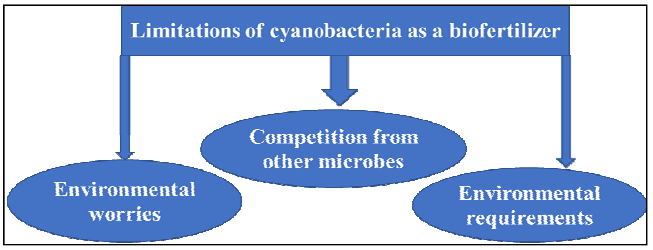

Fig. 8

These restrictions include the uneven distribution of nutrients, the sluggish release of nutrients, the high moisture content, the restricted availability, and the appropriateness for particular crops and soil types. Despite these drawbacks, using bananas properly may still make them a valuable complement to a sustainable farming system. Overall, bananas can be a beneficial biofertilizer, but because to their limits, they are not likely to completely replace conventional fertilisers. The best ways to use bananas as a biofertilizer should also be carefully considered in order to maximise their advantages and minimise any potential negatives.

(b) Limitations of cyanobacteria as a biofertilizer

Cyanobacteria have the potential to be used as biofertilizers since they can fix atmospheric nitrogen, make substances that promote plant growth, and improve soil structure. The ecology has to offer sufficient amounts of heat, moisture, and sunlight for cyanobacteria to thrive. Limited nitrogen fixation and lowered growth may be the effects of unfavourable circumstances. Cyanobacteria can only thrive in specific types of soils and plants, which restricts their use as a biofertilizer for all types of crops and soils. Cyanobacteria may face competition from other soil microbes, which might limit their capacity to colonise and grow. The economic feasibility of cyanobacteria as a biofertilizer may be constrained by the fact that they can be expensive and challenging to harvest and treat. The cyanobacteria in the environment emit toxins that can harm other creatures and have an impact on the cleanliness of the water. Cyanobacteria should not be used as biofertilizers on a large scale without first thoroughly evaluating any potential environmental consequences. Cyanobacteria might be employed as biofertilizers overall, but this must be done with careful consideration of their disadvantages.

Preparation of Biofertilizer

(a) Cyanobacterial selection standards

Water quality is a crucial factor to take into account while selecting a study site for cyanobacteria. The water should be somewhat clean and free of pollutants since cyanobacteria are sensitive to changes in water chemistry. Sites with low concentrations of nutrients like phosphorus and nitrogen are preferred to stop the growth of cyanobacteria. Since cyanobacteria require sunshine for photosynthesis, the research site should get an adequate amount of sunlight. It is not advisable to study cyanobacteria in locations with little or no access to sunlight. The development of cyanobacteria might vary based on the water depth. Cyanobacteria are typically observed in shallow waters because sunlight may penetrate the water's bottom there. Because sunlight cannot reach the water's bottom at locations with deeper waters, those locations might not be ideal for cyanobacteria study. When selecting a study site, it may be useful to take historical cyanobacterial occurrence into account. At locations where they have previously been found, cyanobacteria could be more likely to be present throughout the research period. The study site should be easily accessible and minimally disruptive to the environment. Sites that are challenging to reach would not be good candidates for sampling, and disruptions might affect how the cyanobacteria grow and spread.

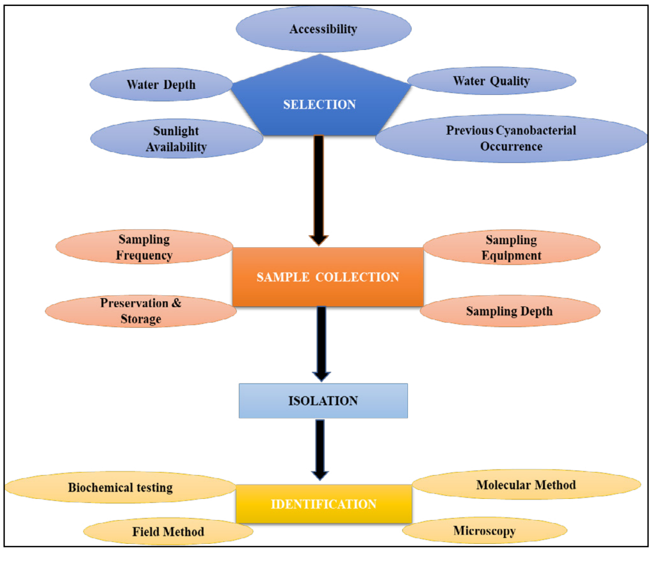

Fig. 9

(b) Collection techniques for cyanobacteria

The tools used to gather the samples must be spotless and uncontaminated. Equipment that is often used includes water samplers and plankton nets, for instance. Equipment that is clean and free of contaminants must be used for collecting cyanobacterial samples. Data accuracy can be affected by equipment contamination, which could lead to erroneous judgements. Examples of regularly used sampling instruments designed to collect samples at certain depths or locations are plankton nets and water samplers. The kinds and quantity of cyanobacteria in the sample might vary depending on the depth of sampling. To provide a representative sample of the water column, sampling should be done at different depths. The types and quantity of cyanobacteria present in the sample might vary depending on the depth of sampling. Sampling depth is important because it can affect the kind and quantity of cyanobacteria in a given body of water. This can happen depending on the depth at which the sample is obtained.

Since cyanobacteria are photosynthetic organisms that need on sunlight to thrive, it's probable that the area where the most of them are found is near the water's surface. Since certain cyanobacterial species may also grow in deeper water, it is essential to gather samples from a variety of depths in order to get a representative sample of the water column. The frequency of sampling might change based on the goals of the investigation. Depending on the temporal dynamics of cyanobacteria at the research location, sampling might be done daily, weekly, or monthly. The sample frequency is determined by the objectives of the study and the temporal dynamics of the cyanobacteria at the study site. For some cyanobacterial species that bloom irregularly, repeated sampling may be necessary in order to document these occurrences. However, some species could be rarer and just require sporadic sampling. When selecting the sampling frequency, the particular research project objectives should be taken into account.

In order to halt any changes in the cyanobacterial composition, the obtained samples should be promptly maintained and kept in a cold, dark environment. The sample can be preserved by adding formalin or Lugol's iodine, or by freezing it at a low temperature. The preservation technique chosen may be influenced by the downstream analysis that will be conducted since various preservation methods may affect the sample's suitability for a particular type of analysis. Microscopy or DNA sequencing are frequently used in the examination of cyanobacteria samples. While DNA sequencing can offer more precise information on the sample's taxonomic makeup, microscopy can be utilised to identify and quantify the cyanobacteria that are present in the sample.

(c) Cyanobacteria isolation and identification

Cyanobacteria are grown using the enrichment culture technique on media that closely resembles their natural habitat. To encourage the growth of cyanobacteria, the culture media is often supplied with nutrients like nitrogen and phosphorus. Cyanobacteria may be recognised after incubation based on their morphology, which includes cell shape and pigment concentration. This technique works well for separating several cyanobacterial strains that have evolved to a certain environment. Filtration is a typical method for removing cyanobacteria from water samples. Depending on the size of the target cyanobacteria, a membrane filter with holes ranging from 0.2 to 3 micrometres is used to treat the water sample. To promote the growth of cyanobacteria, the filtered material is then put on agar plates or immersed in culture medium. Cyanobacteria can be recognised by their form after incubation. This approach is frequently used with other methods, including as microscopy and DNA analysis, to identify the isolated cyanobacteria more precisely. Use of magnetic beads coated with antibodies that only bind to cyanobacteria in the immunomagnetic separation process. The cyanobacteria are isolated from other organisms in the water sample using a magnetic field after being combined with the water and magnetic beads. After that, the isolated cyanobacteria can be identified using DNA testing or by examining their form. Small amounts of cyanobacteria may be isolated with this technique from difficult environmental samples, including those present in natural water bodies.

(d) Techniques for recognizing cyanobacteria

Cyanobacterial identification is most usually done by microscopy. To identify morphological characteristics of cyanobacteria, such as size, shape, and colour, a microscope is used to examine the sample. We can more easily see cyanobacteria by staining with iodine or methylene blue. Based on the sample's quality and the observer's degree of competence, there can be limitations to microscopic inspection. It's still a useful technique for detecting cyanobacteria and learning about their physical traits. Cyanobacteria may be recognised using DNA sequencing and PCR (Polymerase Chain Reaction), two molecular techniques. These techniques look at the cyanobacteria's DNA sequences, providing extensive information on their genetic makeup. It can discriminate between several cyanobacterial species and monitor long-term population fluctuations by amplifying specific DNA sequences using PCR. Although DNA sequencing can be more time- and money-consuming than PCR, it provides more precise genetic information. The availability of reference DNA sequences for comparison might also place restrictions on molecular approaches. Another method for detecting cyanobacteria based on their metabolic activity is biochemical testing. Based on their ability to fix nitrogen or their ability to produce enzymes, certain cyanobacterial species can be identified using this approach. Scientists can learn more about cyanobacteria's ecological functions and possible effects by studying their metabolic processes.

However, this technique needs specialized tools and knowledge, which restricts its application in particular circumstances. There are various approaches that may be used in the field to identify cyanobacteria. Utilizing field kits with test strips that change color when cyanobacterial toxins are present is one such technique. These tests can deliver quick, accurate findings on the spot, enabling immediate evaluation of potential health issues. Using portable fluorometers, which gauge chlorophyll-a fluorescence, is another field-based method for detecting cyanobacteria. This technique can be helpful for differentiating cyanobacterial blooms from other forms of algae since cyanobacteria often have greater chlorophyll-a concentrations than other kinds of algae.

Preparation of banana waste extraction

Banana waste can be collected from homes, supermarkets, and processing facilities. Peels, stems, or leaves are examples of waste. The garbage that has been gathered has to be cleaned and sorted to get rid of anything that isn't a banana, including plastic or other impurities. The trash should next be properly cleansed to get rid of any dirt or debris. Banana waste may be dried using a dehydrator or by placing it in the sun. The trash can then be blended or processed in a food processor to create a fine powder. A solvent, such as ethanol or methanol, is used in the solvent extraction process to dissolve the necessary components from the waste material. The solvent is combined with the dry waste and left to stand for a certain amount of time. The solvent is released after sifting the mixture to make the extract visible.

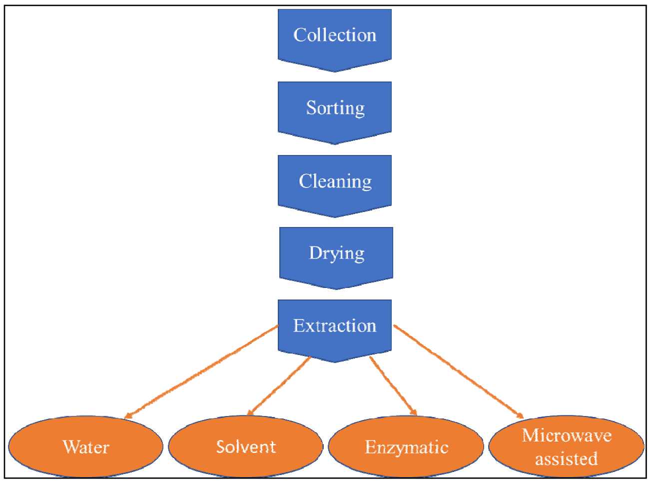

Fig. 10

Studies show that solvent extraction is a practical method for extracting bioactive elements from banana waste. As part of the easy and low-cost process of water extraction, the dried waste is cooked in water for a specific amount of time. The residual solids are then removed from the extract using filtering. Often, pectin is extracted from banana waste using this method. The bioactive components are extracted from banana waste using water in this method. The extract is made by mixing water and dry waste, bringing them to a boil for a predetermined period of time, and then filtering them. Enzymes like pectinase and cellulase are used in the enzymatic extraction process to break down the cell walls of the banana waste and release the beneficial chemicals. The waste material and the enzymes are joined, given time to react, and then filtered to produce the extract. Pectin may be extracted from banana waste via enzyme extraction, which has been demonstrated to be efficient. The enzymes and banana waste are combined, given time to react, and then the combination is filtered to produce the extract.turbid, and low juice recovery. Sapodilla processing for juice requires liquefying enzyme that leads to rectifying flow of juice.

This study was conducted to optimize the enzymatic pectolytic conditions of sapodilla fruit processing to extract maximum juice using a central composite design (CCD in microwave-assisted extraction, the bioactive substances from the banana waste are extracted using microwave radiation. The dried waste is combined with a solvent and heated in a microwave oven for a certain amount of time. The resulting combination is then filtered to produce the extract.

CONCLUSION

Biofertilizer prepared from combination of both cyanobacteria and banana peel are eco-friendly and economical. Application of combined biofertilizer have been used in agricultural lands to reduce global warming in atmosphere by decreasing the amount of greenhouse gases. The banana waste is known to be enriched in potassium which makes them a high-quality Potassic bio-fertilizer for farmers. Cyanobacteria being natural biofertilizers have currently been explored to combat many kinds of stress conditions in agricultural fields and farms too. Combining the banana waste along with the cyanobacteria will not only help in enhancing the quality of the crop but will also as resist the crop from many environmental stresses (drought stress, alkaline stress, acidic stress, and heavy metal stress).

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