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Sustainable Production of Nano-biofertilizers using Agro-industrial Residues

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Abstract

The present developed a bioprocess to produce nano-biofertilizers from agro-industrial residues by augmentation of microbial agents and vermitechnology. The agroresidues like coir peat, neem cake, pongamia cake, castor cake and polyculture of microorganisms having psuedomonas florescence, microbacterium laevoniformins and pseudomonas putida are added to initiate the degradation of complex biomolecules in the plant biomass into nanosized nutrients line nitrogen (N), phosphorous (P) and potassium (K). The stabilization of produced nano-nutrients are achieved by subjecting to vermitechnology to produce vermicompost aggregates through the associated gut enzymes. The nano-dimension of nutrients are conformed through UV spectrophotometer resulted in higher obsorption compared to control vermicompost. The nano-dimension of nano-nutrients were confirmed by subjecting to dynamic light scattering (DLS) techniques which ranged between 25-50nm. The safety and growth efficiency of nano-fertilizer has been assessed using bioassays like seed germination test on raddish vegetable crop which yielded 100 per cent over vermicompost 90 per cent germination efficiency. The growth indices in the potculutre studies reveals 100 per cent over control vermicompost applied plants showing 90 per cent. This gives scientific support to application of nano-biofertilizer to enhance the growth and yield of the crop and also standardized the process to produce nano-biofertilizers using augmented method of microbial polyculture and vermitechnology.

Keywords : *Agro-industrial residues, microbial polyculture, vermitechnology, Nano-biofertilizers, Raddish crop, bioassays, Enhanced growth and Yield. Nanostructured fertilisers, organic fertilisers, chemical fertilisers, IoT principles, sensor technology, biosensors, wireless networks, smart systems.*

1.0 Introduction

In the present study three types of biofertilizers formulations were prepared to evaluate their quality on plant growth promotion. The formulations comprised agro-industrial wastes like coirpith, castor cake, neemcake and microbial consortia are added in varied composition to optimize the process of nano-fertilizer production. After the completion of the process the product is evaluated for its plant growth promotion activity and nano-dimensional parameters of the nutrients. The results reveal that the formulation with coir pith, neemcake, castor cake, pongami cake in ration (3.5:0.5:0.5:0.5) added with 1 per cent microbial innoculum followed by vermi technology treatment found to be more effective. The process leads to bioreduction of biomolecules into nano-dimenstional fertilizers with desired stability. It also gives good plant promotion activity when pot culture studies carried out using Phaseolus vulgaris resulted in per cent enhancement over normal vermicompost applied plants. The Scanning Electron Microscopic analysis of extracted

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nutrients revaealed the nano-dimension of the molecules which supported the bioreduction of nutrients of the agricultural material. The prepared nano-biofertilizers are found to be biodegrading mocrobes with various concentration of the total mass of 5kg. After composting period of 30 days involves biodegradation of substrates to nutrients, the growth promotion acitivty of produced biofertilizers are screened on Phalceoulus plant in port cultures. The reveals the following findings. Among the formulations tested, effective formulation with compostion coirpith 3.5kg+neem cake 0.5kg+castur cake 0.5+ vermicompost 0.5+polyculture of microbes 50ml given good growth which is supported by higher vigour index compare other formulations and contorls. The statistical analysis proven the above findings. The presnt study developmed a effective biofertilizer formulation in labortaroty scale and validated its potential by taking phaselons as target crop. The mcrobes, vermicompost synnertically acted on agricultural residues to produce biofertilizer of rich content of nutrients for crop cultivation.

2.0 Nano-particles

Single-unit devices between 1 and 100 nm in size on at least one side are referred to as NPs. Similar to conventional fertilisers, NP fertilisers can either directly supply one or more nutrients to plants, enhancing their development and yield, or they can help improve the performance of conventional fertiliser. Additionally, there are two subcategories of nano-fertilizers: macronutrient and micronutrient. Nano-fertilizers are predicted to greatly outperform conventional fertilisers in terms of crop growth and production, fertiliser efficiency, nutrient losses, and/or adverse environmental effects[1].

2.1 Macronutrient nano-fertilizers

Many macronutrient elements, such as N, P, K, Mg, and Ca, which are made up of one or more chemical compounds, are able to supply these vital nutrients to plants. To improve the production of food, fibre, and other vital nutrients, a variety of fertilisers containing macronutrients are utilised. Global production of macronutrient fertiliser ($N + P_2O_5 + K_2O$) reached 175.7 million tonnes in 2011 and is projected to rise by 263 tonnes in 2012. This sensitive role of these macronutrient fertilisers in food production across the globe is attributed to an estimated 40% increase in the production of food per capita due to N fertiliser 50 years ago. Poor addition, these macronutrient fertilisers' ineffectiveness and extensive use result in significant amounts of these nutrients (N and P) being carried to surface and groundwater, disrupting the aquatic ecosystem and putting both human and marine life in peril. In order to assure timely food supply and environmental protection, urgent and significant research is needed. This is because macronutrient (N and P) nano-fertilizers will eventually replace traditional N and P fertilizer[2].

2.2 Micronutrient nano-fertilizer

Iron, manganese, zinc, copper, and molybdenum are a few of the plant micronutrients. According to the Hoagland solution's composition, micronutrients are more important for optimal plant growth than macronutrients (N, P, and K). Low doses of micronutrients, such as those from soluble salt plant extraction, are frequently added to N, P, and K fertilisers (Compost fertilisers). These fertilisers often contain micronutrients in the form of chemicals that can dissolve sufficient amounts of nutrients while posing a minor environmental concern. However, in some soils with an alkaline pH, a coarse texture, or low soil organic matter, plant availability of applied micronutrients may also reduce micronutrient deficiency. [Ali etal 2013]. Most likely, even in these harsh conditions, micronutrient nano-fertilizers can enhance the discovery of these nutrients in plants. There are a few, if any, systematic research studies on the results and advantages of employing micronutrient nano-fertilizers under field circumstances because the development and application of nano-fertilizer are still in their early phases[3].

2.3 Mechanism of uptake

According to research, nanomaterials (also known as nano-fertilizers) have more holes in the plant roots than traditional fertilisers do since the roots are the plants main access point to nutrients. The entry of nano-particles into the leaves is also said to be facilitated by abdominal cramps in the leaves.

For their research, scientists used the *faba bean (Vicia faba)* to test how effectively nano-particles permeate plant systems. They discovered that compared to nano-particles larger than 1.0 nm in size, those as small as 43 nm could enter the leaf in greater amounts[4].

It has also been suggested that nutrients are delivered by nano-fertilizers via plasmodesmata. Plasmodesmata are ion-transporting nanoscale channels that range in size from 50 to 60 nm. To move nutrients and other vital biological substances to the target plant, carbon nanotubes and silica nano-particles are helpful instruments. When particle sizes are smaller than the size holes in the cell wall, NPs can enter plant cells directly through a filter, such as a cell wall structure (5 to 20 nm). However, due in part to a dearth of related research, the continuation of NPs through the cell membrane, cytoplasm interaction, and NP-nutrition are very complex and beyond the scope of this review. Similar to how they do with typical melted manure, plants indiscriminately absorb nutrient ions from solvents. The smallest particle sizes and the particular upper particles, however, should cause the rate of dispersion and the level of NPs in water/ soil, The solution, to be higher than those related to a lot of solid objects[3].

Metal elements can enter the cell thanks to the flow of poorly charged compounds via the membranes made possible by negative charging in the plant cell region. Aluminum oxide NPs decreased root extension, according to Yang and Watts' 2005 study on the phytotoxicity of aluminium (Al) oxide-NP in root expansions. However, this inhibitory action was diminished when varying concentrations of phenanthrene (10%, 100%, or 432%) were loaded onto this nano-Al. They contend that NP-coated phenanthrene causes a small reduction in root height. Phytotoxicity is one of Al-NPs' best qualities. However, seed treatment with 0.25 to 4.0% titanium dioxide (TiO_2) nano-particles enhanced the physical characteristics of the spinach there, enhancing the germination rate and vitality of mature spinach seeds. Additionally, there is a large rise in the amounts of chlorophyll, plant mass, photosynthetic rate, and ribulose-bisphosphate carboxylase/oxygenase activity. Yang et al. (2006) also discovered that the presence of nano-anatase TiO_2 improves photosynthesis and the activity of numerous crucial spinach enzymes, such as nitrate reductase, glutamine synthase, glutamate dehydrogenase, and glutamic-pyruvic transaminase[6].

3.0 Natural Resources viable for Nano-fertilizer Production

3.1 Coco Peat

Coir is created from coconut husks, which are byproducts of other industries that use coconut, and is sometimes referred to as coir pith, coir fibre pith, coir dust, or just coir. The primary component of coco peat is coir fibre pith or coir dust, which is made by processing coconut husk and removing the long threads. Like a sponge, the available coco peats can hold a lot of water. It can be used as a soilless substrate for plant cultivation or in soil mixtures in place of regular peat. using coco peat frequently includes: Coco peat is a soil conditioner. use in place of peat since it is stable, free of pathogens, and packed with fungus seeds. generated without causing environmental harm from peat mining. made into high-quality clay soils by blending with fertiliser, compost, and soil. The pH range for coco peat generally ranges from 5.5 to 6.5. Some plants may find it slightly acidic, however many well-known species can survive this pH range. That cellulose-rich material works well as a substrate for growing mushrooms. The cellulose and lignin content of coco peat is high. Three applications of recycled coco peat can be made with little loss of yield. Repeating the use of coco peat from sick plants is not advised. used. The cocofibrion polymer is transformed into a nanofibrion with excellent transport to plant roots when probiotics are used. After being treated with probiotic microorganisms and vermitechnology, it also produces potassium and phosphorus.

3.2 Neem cake

It is a product made from the cold pressing of neem tree fruit and kernels, as well as the solvent extraction from neem oil cake. According to the Bureau of Indian Standards, it is a potential source of biodiversity compost. The power of neem is comparable to fertiliser. Neem cake and neem leaves show great promise for this purpose. Neem Cake has an adequate level of NPK for plant growth in its natural state. The complete botanical product includes 100% natural NPK content in addition to a few other important minerals, including calcium (0.5–3.0%), phosphorus (0.5–1.0%), potassium (1.0–2.0%), and nitrogen (2.0–5.0%). It is also rich in sulphur compounds and bitter limonoids. Neem seed cake causes organic acid decomposition, which lowers soil alkalinity. It ensures soil fertility since it is a perfectly natural habitat that is friendly to soil bacteria, growth, and the rhizosphere microflora. Neem Cake increases the amount of organic matter in the soil, which benefits the soil's water-holding capacity, soil texture, and overall health.

3.3 Pongamia Cake

The pongamia cake is a great organic fertiliser since it contains a lot of NPK, which helps to improve soil fertility. A cake also functions as a pesticide when buried in the ground, particularly in the fight against worms and other diseases of a similar nature. It can be mixed with neem cake pellets to have a synergistic effect, much like natural fertiliser. It has a lot of globulin protein, which helps plants produce sophisticated proteins in nanoscales[9].

3.4 Castor cake

Castor cake is made by crushing castor seeds in an expeller and using steam to extract the oil at a controlled temperature. With a high nitrogen concentration, phosphoric acid, and potash, it is a good fertiliser. It may hold a lot of moisture. It supplies both the large and tiny nutrients required for improved plant growth. It enhances soil quality, increases plant nutrient uptake, and helps protect plants from termites and nematodes[3].

4.0 Analytical Instruments for assessment of nutrient quality in Nano-fertilizers

4.1 pH meter

An electrical device used to measure the activity of hydrogen-ion (acidity or alkalinity) in solution. A pH metre essentially consists of a voltmeter coupled to a reference (non-volatile) electrode and a pH responding electrode. Although a mercury-mercurous chloride (calomel) electrode is occasionally employed, the electrode that responds to pH is typically made of glass, and the reference electrode is a silver chloride electrode. Two electrodes can function as a battery when submerged in a solution. At 59.2 millilitres per unit pH at 25°C (77°F), the solution's hydrogen-ion function creates a power charge on the glass electrode, and the voltmeter measures the potential difference between the glass and reference electrodes.

4.2 Moisture Meters

Moisture metres are used to calculate how much water is present in various materials. The object's readiness for use, sudden wetness or dryness, or the need for more testing can all be ascertained using this information. Because body structures are so sensitive to moisture, prolonged high humidity levels can cause things to deteriorate over time.

4.3 The NPK Soil Sensor

NPK is used to measure the levels of nitrogen, phosphorous, and potassium in the soil and to determine the soil's fertility. The NPK soil sensor with stainless steel probe can withstand continuous electrolysis, salt corrosion, and alkaline corrosion while being buried in the ground for a long time. The shell is totally watertight and vacuum-potted.

5.0 Physical and Chemical Factors Affecting the Analytical Devices

5.1 Impact of Temperature

When measuring pH, temperature is a significant consideration. This is due to the dependence of pH values and chemical reactions on temperature. The temperature affects the electrical signal that the pH metre uses to detect pH. It is advisable to upgrade the pH metre with a temperature sensor when the temperature shifts. The sensor calculates pH using temperature slopes that have been modified[3].

5.2 Effect of Moisture and Pressure

The reference glass object may become damaged by excessive pressure or pressure variations. This problem can be tested by installing a glass membrane with particular inserts and choosing special electrodes. The glass lining may potentially dry out as a result of a lack of moisture[2].

5.3 Mechanical Disruption

The glass pH electrode area may become scratched if there are particles in the middle. This could reduce its lifespan and alter the readout. To lessen the effects of this issue, special or flat portions of glass are used. The lifespan of construction materials can also be shortened by shocks and vibrations that put stress on them. This issue can be resolved with changes to the installation site[2].

5.4 Electrical Disturbances

The pH metre may experience a loss of volume or signal due to electrical errors or short circuits. It is important to examine each electrical component independently both during and after installation, including the flooring, protection, installation, and cables[5].

6.0 Merits of Nano-Fertilizers over Conventional Organic Fertilizers

Nano-particles have special qualities that could be a growth promoter for plants, including high sorption volume, surface elevation to volume ratio, and controlled-release kinetics at specific areas. These qualities make nano-structured fertiliser suitable for use as an intelligent nutrition delivery system. When compared to conventional fertilisers, nano-fertilizers release their nutrients extremely gradually. This strategy enhances nutrient management by enhancing nutrient use effectiveness and decreasing nutrient immersion in groundwater.

Specially created nano-fertilizers are intended to release their active ingredients in response to biological demands and external influences. According to scientists, nano-fertilizers also boost photosynthetic activity, plant growth, seed germination rates, nitrogen metabolism, and carbohydrate and protein synthesis, all of which increase agricultural production[5].

Mineral compounds have the potential to offer several advantages in making plant production sustainable and environmentally benign when utilised in plants as nano-fertilizers. Nano-fertilizers feed the plants gradually and under control, as opposed to the quick and automated release of nutrients provided by conventional fertilisers. Due to extremely little losses in the form of immersion and slippage, nano-fertilizers function very effectively in terms of nutrient uptake and utilisation. Due to the unrestricted flow of nano-sized pores, molecular transporters, and root exudates, nano-particles have a very high appearance. Additionally, different ion channels used by nano-particles cause plant matter to absorb a lot of nutrients. Nano-particles inside the plant travel through the plasmodesmata, effectively delivering nutrients to the submerged parts. Nano-fertilizers can be used in much smaller amounts compared to synthetic fertilisers, which must be employed in much larger amounts due to the significant volume that is lost through immersion and exhaust[6].

The best benefit in terms of minimal losses is that reduces the danger of pollution provided by nano-fertilizers. In comparison with traditional synthetic fertilisers, high solubility delivers a higher level of nano-fertilizers.

Due to the thin coating of nano-particles, intelligent nano-fertilizers, like polymer-based fertilisers, avoid early interaction with soil and water, resulting in a low loss of nutrients.. On the other hand, these are obtained as soon as the plants are in a state of being able to absorb the released nutrients inside[4,6].

7.0 Features of Nano-fertilizer over Chemical Fertilizers in Nutrient Flow and Uptake

Nano-technology is now being used in agricultural fields all over the world as nano-pesticides, nano-herbicides, nano-fertilizers, and nano-sensors. Farmers currently prefer chemical fertilisers because they are effective and more affordable than alternative fertilisers. Chemical fertilisers can be misused or overused, which harms the soil, reduces productivity, and pollutes the environment. Since urea, which is highly water-soluble and prone to loss, provides 80% of the nitrogen fertiliser needs of plants, applying too much nitrogen to a farm can result in denitrification, volatilization, runoff, and liquidation, all of which cause soil leaching[11]. Nitrogen that escapes can contaminate water and air systems, causing eutrophication and hypoxia, which in turn causes a variety of environmental issues, including the death of marine life and a hazard to drinking water supplies. The nanotechnological tool known as “Nano fertiliser” has the ability to meet these requirements in order to increase global agricultural output without having a detrimental effect on the environment and agricultural farmlands[8].

Different fertilisers have employed nano-particles (NPs). Any chemical fertilisers or organic compost that have been loaded with NPs can achieve a delayed release of the nutrients and increase efficiency, lowering the amount needed and the environmental issues brought on by fertiliser runoff. By enhancing soil nutrient management, promoting the development of a nutrient cycle in agriculture, and reducing nutrient resource depletion, NPs improve nutrient absorption. The application of NPs as organic fertilisers and bio-fertilizers involves either introducing them into the system or having them produced biologically from plant and animal organic waste.

The development of clever delivery methods utilising nano-particles has opened up new possibilities for the agro-transition sector’s to sustainability. Smart delivery methods enable organic interactions between the local microbial, plant, and soil ecosystems. These cutting-edge materials make it easier to manage nutrients and regulate nutrient flow, which is necessary for the soil-plant system to meet demands for ions like HPO42-, H2PO4-, and NH4+. The smart delivery agents increase stability and minimise the amount of product required for distribution, allowing for the reduction of excess chemical runoff and the maintenance of an environmental balance.

A growing trend in agriculture is the use of NP formulations with a size between 100 and 250 nm because they improve soil stability and boost nutrient flow activity due to their high water solubility. Because of their ability to integrate with pesticides and herbicides in various distribution media, nano-emulsion NPs with sizes between 200 and 400 nm are often used with them. Furthermore, the pharmaceutical and agro-industrial sectors are researching nano-capsules as a smart delivery mechanism. These structures have polar and lipophilic sides, respectively. They have active substances inside their shells, and when the soil or plants undergo physiological changes, they release nutrients[8].

Although there have been several methods reported for how NPs act as fertiliser to influence plant growth, the fundamental mechanism is the same for all of them and involves reducing particle size to the nanoscale in the fertiliser, which is expected to improve the solubility and dispersion potential of fertiliser nutrients. The capacity of NPs to quickly pass through the membrane barriers of plant cell walls is a result of their small size, which results in altered uptake kinetics. NPs shield fertiliser by encasing it to stop it from evaporating, anchoring it throughout the soil, and limiting leaching losses, all of which increase its effectiveness and lessen environmental harm. Future NPs and Nano fertilisers will efficiently encourage fertiliser absorption and utilisation, enhancing the agronomic characteristics of crops[9].

8.0 Methodologies Involved in Production of Nano-biofertilizers

Agrochemicals and other products based on nano-technology provide a variety of advantages, but they are still in the early stages of development. Even though numerous businesses have applied for patents covering the methods for making and using nano-products, the commercially available nano-technology-based goods still need to be developed and come in relatively small numbers.

8.1 Plants in Nano-particle Synthesis

While the synthesis of metallic nano-particles by microorganisms like bacteria, yeasts, fungus, and actinomycetes is still being researched, the utilisation of plant waste and extracts for a comparable nano-particle biosynthesis is an intriguing option that is yet to mostly unexplored.

According to Thakkar et al. (2010), geranium leaf extract contained aqueous Ag^+ ions that were reduced to form extracellular AgNPs (Pelargonium graveolens). It was shown that employing bacteria or fungi required much longer than using plant extract to reduce Ag^+ ions. In contrast to the process utilising geranium leaf extract, which takes place in about 9 hours, using bacteria and fungus requires between 24 and 124 hours to completely reduce the metal ions. Due to the reduction of the metal ions in solution, a high density of very stable crystalline AgNPs with an average size of about 27 nm were found. Using FTIR analysis, Shankar et al. concluded that the presence of terpenoids in the plant extract contributes to the reduction of Ag^+ ions.

In another study, triangular gold nanoprisms were created using the extract of lemongrass (Cymbopogon flexuosus). The triangular gold nanoprisms were created by reducing aqueous $AuCl_4^-$ ions in a single step at ambient temperature. The nanotriangles were composed of collections of liquid-like, spherical nano-particles. This fluidity was caused by the complexation of aldehydes or ketones found in lemongrass on the surface of nano-particles.

According to Armendariz et al. (2004), the pH of the process affected the size of gold nano-particles (NPs) generated by Avena sativa (Oat) biomass. At pH 2 and 4, smaller NPs were generated in greater quantities while larger NPs (25 to 85 nm) were created in smaller amounts. The authors hypothesised that at low pH, nucleation is less favourable than the aggregation of gold nano-particles to form larger nano-particles. Conversely, at pH 3 and 4, more functional groups are available for gold binding, leading to a greater number of Au (III) complexes binding to the biomass simultaneously. As a result, nucleation is observed.

With Neem cake, insoluble nano fertilisers, and their respective fertilizer-solubilizing Plant Growth Promoting Rhizobacteria, R. Mala et al. (2014) developed an SRFS (Slow-Release Fertilizer System). 5 ml of Neem Cake oil is combined with 100 mg of urea, 50 mg of rock phosphate, and 50 mg of rock potash. The oil suspension is subsequently subjected to half cycles and 80 amplitudes of sonication for 30 minutes. 100g of Neem Cake is then combined with the sonicated sample. In order to solubilize the potash, pseudomonas fluorescence and potash solubilizing bacteria are added at a density of 2x108 CFU per 1 gramme of neem cake. Jaggery and sodium alginate are added to the powdered Slow-Release Fertilizer System and pelletized. In a pot research using a randomised block design, the effects of the Slow-Release Fertilizer System on the germination, mean germination time, seed vigour index, amylase, protease, total carbs, and total proteins of Vigna radiata were assessed. Vigna radiata germination was affected by SRFS as 100% of the time, which may be related to SRFS's capacity to maximise both organic and inorganic sources of plant nutrients. The mean germination time in the SRFS was 100, compared to 40 in the water control. Significant variation is also seen in the Seed Vigour Index, which is 226 in control and 629 in SRFS. The urease inhibitor found in neem cake is what caused the observed variation in seed vigour index. Additionally, in SRFS, fertilisers were given gradually to promote germination without having any negative effects on germination. Due to their harmful effects on phytopathogens, PGPR may have boosted and caused a stimulatory response for germination. The production of auxin, gibberellins, and cytokinin, which promote cell elongation and division, may have stimulated germination. 3.0 g/g of amylase specific activity was found in the water control and 10 g/g in the SRFS. Amylase is used to break down insoluble starch into soluble glucose that plants can easily utilise. This difference was noticed for a number of reasons, the first of which is that the fertiliser releases slowly in relation to how well the PGPR had solubilized it. Depending on the stage of plant growth and the fertiliser concentration, fertilisers stimulate the activity of certain enzymes. PGPR are also known to promote an abundance of nutrients close to roots, which is known to boost enzyme activity. Protease had a specific activity of 6.0 g/g in the control and 11 g/g in the SRFS. Proteins are broken down into amino acids by protease action to aid seedling growth. This might be as a result of seeds absorbing water at their optimal rate. Protease is activated during germination as a result of the activity of water, which allows nutrients to be mobilised for the growth of seedlings. As a result, the higher the protease activity, the greater the amount of nutrients that can be mobilised and the lower will be the concentration of proteins and carbohydrates in the seeds. The main biomolecule stores in Vigna radiate are proteins and carbohydrates. Total carbohydrate content was 1.25 mg/g in the control group and 0.38 mg/g in the SRFS group. When seeds are sown, starch, a type of sugar stored in the endosperm, is hydrolyzed to create simple soluble sugars that are mobilised to the embryo for growth. As a result, the concentration of total sugars decreased according to this mobilisation[9].

Currently, the majority of information about NPs in fertilisers comes from validation trials demonstrating that NPs can be used either directly as fertiliser or as auxiliary materials to increase the usage of fertilisers. The creation and application of nano-fertilizer formulations are hampered by the lack of comprehensive theoretical investigations on interactions and material exchange among NPs, plant root systems, and microbial environment.

9.0 Certification and Commercialisation Protocols

Because of its small size to big surface area ratio, NPs have special characteristics. Thus, they promote the creation of new goods and procedures and improve the functionality of those that already exist across numerous industries. In order to fulfil the demands of the expanding population, nano-technology has lately been incorporated into agricultural systems to increase crop output and improve crop protection. Innovative agro-sector interventions based on nano-technology may produce low-cost, highly effective goods and procedures that are better suited for developing countries. On the negative side, these characteristics might also cause NPs-related environmental and human toxicity. The standards for evaluating nano-products in agriculture are more complex than the current processes in India for evaluating fertilisers. DST and DBT are only two of the many government organisations that have supported nanoscience and technology in India. At the moment, India lacks defined laws and regulations that govern the use and implementation of NPs in agriculture. However, under the Fertilizer Control Order (FCO), 1985, certain assessments, such as the evaluation of safety, functionality, and other qualitative studies of nano fertilisers, are necessary in the case of nano fertilisers, which are conventional or organic fertilisers charged with NPs. The Essential Commodities Act of 1955, which established the requirement for fertiliser registration, is handled by the Department of Agriculture Cooperation and grants FCOs.

A few registration policies for nano-products have been released by the pesticide registration agencies in the US and the EU. The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) has been used by the US EPA to guarantee that nano-products are registered as “novel” compounds, to carry out pertinent analyses, and to adhere to registration procedures. The Plant Protection Goods Regulation, which applies to the registration of pesticides and their combinations, regardless of their size, and thus covers nano-pesticides, is used by the EU nations to register agricultural products based on nano-technology.

The multidisciplinary character of nano-technology and its fast expanding commercialization scope present regulatory authorities with various obstacles. Science from many disciplines, including chemistry, physics, biology, engineering, and medicine, are combined to create nano-technology. Additionally, as different ministries and departments work with nano-technology and nano-products, interdepartmental convergence is necessary. With a focus on a high benefit to low risk ratio, these guidelines seek to ensure both the safety of innovative products as well as the quality and efficacy of nano-technology-based interventions in agriculture. There are only a few international protocols in place for nano-agriproducts (NAPs), including those from the OECD, EPA, and FAO/WHO, which have precise requirements for efficacy, safety, and quality. None of the aforementioned rules is universally embraced by everyone.

The Statistic Bank reports that there are currently 9420 commercial nano-technology-based goods available, 229 of which have been introduced specifically for use in agriculture. The survival of plants against disease, pests, and other stresses is improved by 28% of these chemicals, which are nano-fertilizers and nanoformulations. The use of NPs in agriculture is a low-profit business that is unable to produce large economic returns on the initial investments due to the high cost and complex production method. The major obstacle to the widespread use of NPs in agrochemicals is this. In addition, there are no established processes or methods used by government agencies in relation to NPs. The current regulatory approaches used by the government are unreliable and unable to accurately assess the safety hazards posed by nano-products.There is an immediate need to study and establish robust evaluation models and standards for the large-scale application of NPs in agrochemicals[9].

10.0 Automation Process of Biofertilizer Production Unit and Devices used for Measurement of Physical and Chemicals Factors

With the development of IoT, wireless sensor enabled network applications are becoming more and more popular in the agricultural industry. In order to detect critical agricultural field factors including temperature, humidity, soil moisture, nitrite content, groundwater quality, and soil pH, wireless sensor networks are primarily employed in agriculture. To create a decision support system, these sensed characteristics are forwarded to a remote station where they are processed and analysed. IoT can also be utilised in socio-economic sectors, but it is hardly ever applied in the agricultural sector. Farmers still use traditional methods of crop cultivation in their farms nowadays. IoT is a fantastic solution to issues with production and security. When IoT is employed in the production of harvest as well as many areas of agriculture, the quality and efficacy of the solution are improved. We need effective and cost-effective solutions to be able to maximise IoT[9].

Solutions built on a Raspberry Pi provide practical and affordable solutions to implement IoT in agriculture. It is a computer the size of a credit card, very affordable, and loaded with useful features including an integrated Wi-Fi module, which forms the basis of IoT concepts. Python is used to run Raspberry Pi, which offers excellent performance for server- and cloud-based applications. There is a way to use a raspberry pi in the sector of agriculture by synchronising and linking the several farming-related sensors. A few of the sensor modules used in agriculture are as follows:

10.1 DHT11/ DHT22

Temperature and humidity are measured via the DHT11 and DHT22 sensors. One GPIO is utilised. The key factors separating the two are measuring range and precision. All humidity ranges from 0 to 100% can be measured by the DHT22 with an accuracy of 2%. The DHT11, in contrast, only has a measurement range of 20 to 90% humidity, and its accuracy is 5% lower than that of other devices.

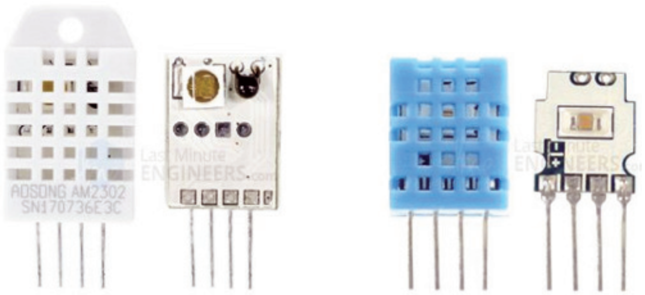

Figure 1: DHT22 & DHT11 (Source: lastminuteengineer.com: online)

10.2 BMP180 Barometer

In weather stations and agricultural projects, knowing the air pressure can be useful. The BMP180, which the Raspberry Pi controls via I2C, is the ideal device for this.

The probe also measures temperature and the altitude.

Figure 2: BMP180 (Source: lastminuteengineer.com: online)

10.3 Moisture Sensor

Systems for automatic watering make excellent use of the analogue humidity sensor. It is buried in the ground and uses the current that flows between the strands to measure humidity. The analogue signal is higher the farther away the earth is from the source.

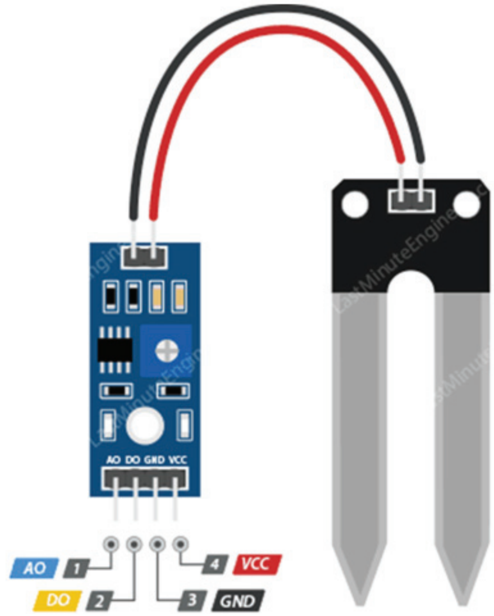

Figure 3: Moisture sensor (Source: lastminuteengineer.com: online)

10.4 Capacitive Ground Moisture Sensor v1.2

Analog moisture sensors lose accuracy over time and deteriorate. These issues are prevented with capacitive sensors. The frequency is used to calculate the relative humidity[9].

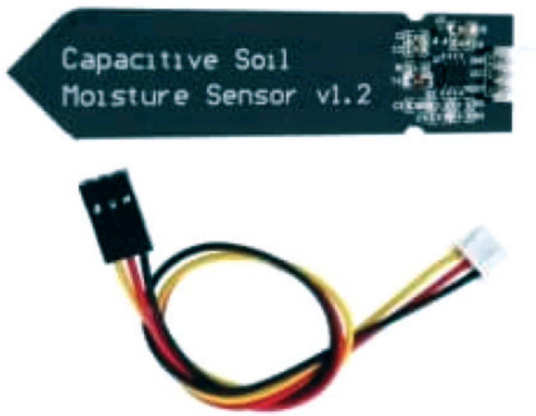

Figure 4: Capacitive ground moisture sensor (Source: how2electronics.com: online)

10.5 DS18B20

A very basic sensor is represented by the DS18B20/ DS18S20. The so-called 1-wire bus is used to address these

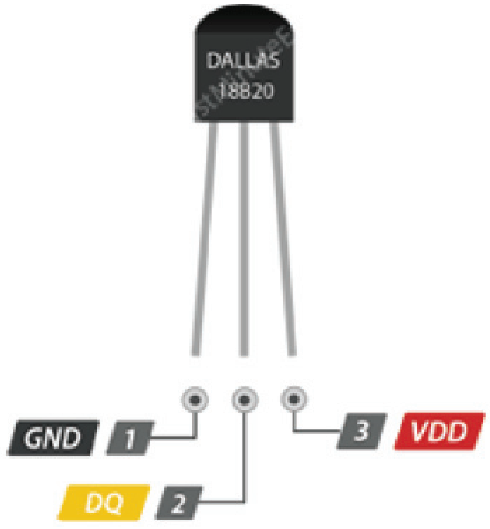

Figure 5: DS18B20 (Source: lastminuteengineer.com: online)

Raspberry Pi sensors. The ability to link numerous various 1-wire components in series and read out data by a single GPIO is advantageous. The DS18B20's water resistance makes it especially appropriate for outdoor use. Applications requiring temperature measurement can benefit from its wide measuring range of -55°C to +125°C

10.6 Soil NPK sensor

Using an NPK Soil Sensor and an Arduino, the fertility and nutrient content of the soil are assessed. To calculate how much extra nutrient content needs to be supplied to the soil to boost crop fertility, the N, P, and K contents of the soil must be measured. Nitrogen, phosphorous, and potassium make up a significant portion of soil fertiliser. Knowing the concentration of nutrients in the soil can inform us about nutritional abundance or deficiency in soils that support plant growth[9].

Figure 6: Soil NPK sensor (Source: how2electronics.com: online)

These devices can be utilised to innovate various IoT-based organic fertiliser manufacturing units and monitoring systems because the process of producing organic fertilisers for use in agricultural activities is labor-intensive and time-consuming. An IoT-based monitoring system for the conversion of organic waste into compost fertiliser was developed by Isyanto et al. in 2021. To track the composting fertiliser process, this gadget featured temperature, humidity, soil pH, soil moisture, and colour sensors. Additionally, the device could detect plant growth, which is a sign of high-quality compost fertiliser. The temperature sensor's experimental accuracy was 98.2%, the humidity sensor's was 96.1%, the soil pH sensor's was 95.26%, and the soil moisture sensor's was 98.55%. According to the test findings for the colour sensor, the measurement of the distance between the leaf object and the colour sensor's LED light was 2 cm, and the measurement of the slope angle was 5 degrees. The author intended for the design of their product to inspire the public to sort rubbish and use it for environmental improvement.

In order to produce Mokusaku, an organic fertiliser made from the condensed smoke of burning wood, Puno et al. (2019) built a prototype fertiliser reactor. Mokusaku is made in three to six months. By using Raspberry Pi and automating the entire process, the prototype hoped to reduce the amount of time needed for production. The production system included a DC motor, cooling system, DS18B20, Raspberry Pi, and a combustion chamber for burning the wood. To prevent oxidation, the cooling system was constructed of stainless steel, and the combustion chamber was oven-sized. The circuit for the centrifuge system and the DS18B20 were connected to the Raspberry Pi for monitoring and automation of each phase. The DC motor was used to set up the centrifugation system and to control the speed of the motor. To create smoke, the raw material is first placed inside the chamber. Second, the cooling system performs condensation on the smoke that exits the chamber. The liquid that has been condensed is then placed in a container and centrifuged. The end result of the entire procedure is the supernatant. Producers have historically had to wet the bamboo where the smoke is passing through for condensation to happen. The extraction of Mokusaku from the condensate, which is divided into three layers as a result of sedimentation, necessitates a lengthy waiting period of three to six months, making the process laborious and time-consuming for the producers. Authors wanted to automate the centrifugation mechanism and condensation component with this prototype. This led to a quicker, more effective production process and maybe a higher yield when the production unit was scaled. In conclusion, the prototype generated an amount comparable to that of the old method. The prototype produced an average of 2.6 kg for 1L while the conventional chamber produced 1L of mokusaku for 2.7 kg of plant or tree debris. Temperature monitoring is done for automation. The three-layered liquid was successfully separated by the centrifuge technique in 20 minutes as opposed to the usual 3-6 months. Comparing the prototype's design to the conventional chamber, which can only be constructed in a permanent location, it was found to be movable. The results of using the created mokusaku as fertiliser in pechay plants were likewise favourable[9].

Hussen et al. (2018) built an improved Internet of Things-based organic fertiliser mixer that can check on fertiliser production remotely and send updates. By further reducing labour requirements and expenses, the author hoped to improve the effectiveness of the mixing of organic fertiliser. The agricultural waste mixed weight in the storage drum was successfully recorded by the IoT monitoring system and transferred to the IoT platform. The timing of when to add more agricultural waste to the mixture or take the processed organic fertiliser out of the mixture was then determined using this information. The storage drum is continuously watched with the goal of detecting weight changes. The first version was made stationary since the authors encountered a problem when adding sensors to the drum to measure the weight if rotated. For the prototype, a rotating shaft system with perpendicular blades was built to accommodate the mixing process. The shaft inside the drum revolved after being powered at a proper speed by an electrical motor, mixing the contents. Steel bearings were used to secure the shaft to the drum's ends, and a steel pulley wheel was welded to one end of the shaft to enable rotation when the shaft was connected to an electric motor via a flat rubber belt. According to the corresponding wire colours, the load cell's wires are soldered to the HX711 amplifier module. The Raspberry Pi was next attached to the pins of the amplifier module. Python was used to create the Raspberry Pi's software. The amplifier module and the load cell are in contact. The appropriate libraries are imported, and the load cell is configured to send data to the amplifier module continually. To save energy, a sleep function that turned down the monitoring system when no load was detected was added to the code. The microcontroller receives the data collected by the amplifier module. 92 units to 1 g is the calibration unit's current setting. A calculation and printing of the actual load reading produced by the system were made. The system alerts the workers that the mixing process is complete when the mass falls below a set threshold, at which point they can either fill the drum with agricultural waste or remove the processed organic fertiliser from the drum[29].

In another research According to IoT principles, Pratama et al. (2019) created an automatic compost maker prototype that measures temperature and humidity during the composting process. The data is analysed by fuzzy logic, which serves as the primary control to operate the actuators. The compost bins, microcontrollers, and sensors made up the prototype. We employed a soil pH sensor (YL-39 YL-69 Soil), a temperature sensor (DS18b20), and a humidity sensor. The temperature sensor was maintained 15 cm above the composting container's base. The pH sensor was 6 cm and the humidity sensor 9 cm up from the composting container's base, respectively. A microcontroller system in the form of Arduino Uno, NodeMCU, and Raspberry Pi model 3 B were used to run the sensors. A 30L plastic barrel with a diameter of 27 cm and a length of 54 cm was utilised as the composting container. A heater, a water pump, and a stirrer were utilised as actuators to speed up the composting process. The Raspberry Pi's MQTT protocol was used to send the compost container's temperature, humidity, and pH values to a database, which was then displayed on the web server for monitoring reasons. In order to activate the actuator, which included a water sprinkler, heater, and mixing motor as a stirrer for the composting process in the container, the actuator's temperature and humidity data were evaluated using fuzzy logic to calculate the process's ideal temperature and humidity. When the temperature and humidity were above or below the recommended ranges for composting, which are 54–60°C and 45–60%, respectively, the actuator and motor activated. The prototype was able to produce compost in 14 days, which is 2.35 times quicker than it takes to do so with conventional tools, which takes 33 days[9].

11. Discussion and Conclusion

As opposed to the quick and automated release of nutrients from chemical fertilisers, nano-fertilizers nourish the plants gradually and deliberately. Compared to synthetic fertilisers, the release of nutrients is quite slow. By boosting the effectiveness of nutrient use, this strategy enhances nutrition management. Nano-fertilizers can be used in much smaller amounts compared to synthetic fertilisers, which must be employed in much larger amounts due to the significant volume that is lost through immersion and exhaust. The best benefit in terms of minimal losses that reduce the danger of pollution is provided by nano-fertilizers. In comparison with traditional synthetic fertilisers, high solubility delivers a higher level of nano-fertilizers. With the development of technology, IoT network applications in the agriculture industry are becoming more and more common. In order to measure variables such as temperature, humidity, soil moisture level, NPK content in the soil, groundwater quality, and others, IoT networks are utilised in agriculture. The remote stations process and analyse the measured parameters in order to trigger the required actions. Similar to smart agriculture, smart manufacturing systems for nano-structured fertilisers can be created using the same ideas. This review focused on how wireless networks and sensors were used to create such smart systems using IoT concepts. These methods are anticipated to shorten the time needed to produce organic fertilisers and hence speed up the procedure. Although the development of IoT has made it feasible for even the general population to make fertilisers, which would not have been possible a few years ago without organised factory setups, a tremendous lot of study is still required in this area.

Standardising the method for creating nano-biofertilizer from agricultural waste. identified the function of vermitechnology and microbial inoculants in the manufacture of nano-fertilizer. The nano-dimension showed increased nutritional content. According to bioassays, formulation 2 has a greater ability to promote growth in Phaseolus vulgaris. Micro and macronutrients are both included in nanoscale fertilisers, which are plant growth promoters that are administered to crops in a controlled manner. Devices with a single unit that is between 1 and 100 nm in size on at least one side are known as nano-particles (NPs). Through application techniques including targeted delivery and controlled delivery, nano-structured fertilisers can improve the efficacy of nutrients. Because phosphorus (P) and nitrogen (N) are crucial minerals for plant growth, artificial fertilisers containing these nutrients are increasingly used, which may have negative effects on the environment. The creation and application of novel fertilisers utilising nano-technology are demonstrating that they are the most efficient and environmentally benign methods for enhancing global agricultural production required to meet future demands. With the development of technology, IoT network applications in the agriculture industry are becoming more and more common. In agriculture, IoT networks are used to measure a variety of field variables, including temperature, humidity, soil moisture level, NPK concentration in the soil, and groundwater quality. The remote stations process and analyse the measured parameters in order to trigger the required actions. In the present study, we have established a process for producing nano-biofertilizer from agro-industrial residues to improve the nutritional bioavailability to the agricultural crops. In a similar manner, the principles used in smart agriculture can be implemented in making smart manufacturing systems for nano-structured fertilisers.

11. References

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