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Efficient Use of Nano Fertilizers Using Sensor-Based Technology

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Abstract: Precision farming has been a long-desired goal for the whole world to maximize crop production with minimizing the inputs like use of fertilisers, pesticides, herbicides, etc. along with monitoring the environmental variables and applying targeted action. Research and development of Nanofertilizer Technology is a bold step towards the era of precision farming. But the nano fertilizers developed should be slow release or sustained release to prevent loss of fertilizers as well as to lower the negative impact on environment. Application of nanofertilizer if controlled by suitable sensors can serve the purpose. Present work proposes a model where soil fertility parameters like Nitrogen, Phosphorus, Potassium and moisture status of soil during the cropping time will be monitored by electrochemical sensors and any lowering of nutrient status will trigger the release of nanofertilizer. The nanofertizers will be encapsulated in a shell made up of biocompatible substance with good swelling capacity and thus fertilizer application will be need based.

Keywords*:* Nano fertilizers, sensors, Smart delivery system, soil moisture sensor, NPK Sensor

I. INTRODUCTION

Agriculture is the backbone of most of the developing countries and more than 60% of their population are dependent on agriculture for their livelihood. But the agriculture industry is going through various challenges like decrease in organic matter, micronutrient deficiency, imbalanced fertilization etc. Large-scale use of chemical fertilizers to increase the crop productivity is not a suitable option in the long run as crops utilize less than half of the chemical fertilizers applied [1]. The remaining minerals may leach down and become fixed in soil and contribute to soil pollution or enter the aquatic environment causing eutrophication.

Considering the situation, there is an urgent need to develop smart materials that can systematically release required dosage of chemicals to specific targeted sites in plants. "Smart delivery system" means combination of specifically targeted, highly controlled, remotely regulated, and multifunctional characteristics to avoid biological barriers for successful targeting [2]. In recent years, nanotechnology has extended its relevance in plant science and agriculture which can be exploited in the whole chain of agriculture system moving towards the era of precision farming. Nanoparticles have high surface area, sorption capacity, and controlled-release kinetics to targeted sites making them "smart delivery system." Nanofertilizer can increase Nutrient use efficiency (NUE) by 3 times and also improves the stress tolerating ability. Advancement in nanotechnology has improved ways for large-scale production of nanoparticles of physiologically important metals, which are now used to improve fertilizer formulations for increased uptake in plant cells and by minimizing nutrient loss. Nanostructured fertilizers can increase the nutrient use efficiency through mechanisms such as targeted delivery, slow or controlled release. Fertilizers encapsulated in nanoparticles will increase the uptake of nutrients. Site-targeted delivery and stability of active ingredient is another advantage of nanocarriers in plant protection. However, to date, monitoring of the complete discharge time and discharge rate of controlled released fertilizers is not completely understood by the researchers. Further different types of sensors are being developed to monitor the discharge parameters of controlled release fertilizers.

The proposed work will review different types of sensors for monitoring the controlled release fertilizers, reported in the past literature. Special emphasis will be placed on nanosensors, optical sensors, electrochemical sensors, proximal sensors, and airborne sensors.

Rock phosphate if use in nano form may increase availability of phosphorus to the plants because direct application of rock phosphate nano particles probably prevents phosphate fixation in the soil. Similarly, there is no silicic acid, iron and calcium for fixation of the phosphorus hence it increases phosphorus availability to the crop plants [3]. Foliar application of nano fertilizers significantly increases crop yields [4-5]. It was observed that 640 mg ha-1 foliar application (40 ppm concentration) of nanophosphors gave 80 kg ha-1 P equivalent yield of cluster bean and pearl millet under arid environment. Prasad et al. [6] observed that treatment of nano zinc at lower concentration (1,000 ppm) had positive effects on plant. It was reported that usage of 15 times lower dose of ZnO nanoparticles compared to the recommended dose of $ZnSO_4$ and recorded 29.5 % higher pod yield. Likewise, ZnO nanoparticles showed root elongation in Glycine max at 500 ppm concentration but reduction in size at higher concentration of ZnO [6]. Nanomaterials have potential contributions towards the preparation of slow release of fertilizers. Fertilizers with sulphur nanocoating (~100 nm layer) are useful slow-release fertilizers as the sulphur contents are beneficial especially for sulphur deficient soils. Cui *et al.*vividly studied the nanotechnology-based formulations compared to the conventional fertilizers and reported that the nano-sized formulation of micronutrient has increased bio availibity to plants compared to the conventional fertilizers [7]. Other nanomaterials with potential application include kaolin and polymeric biocompatible NPs. Polymeric chitosan NPs (~ 78 nm) are used for controlled release of the NPK fertilizer sources such as urea, calcium phosphate and potassium chloride [8-9].

Recent trend is to develop organic nanoparticles due to their high potentialities in a wide spectrum of industrial areas ranging from electronic to photonic, conducting materials to sensors, medicine to biotechnology. The choice of the synthetic route is the key point to optimize the final properties of nanoparticles designed for a specific application. This choice has to be guided by a series of factors such as Physico-chemical parameters of the organic compound, chemical composition, nanoparticles diameter, structure, morphology and most importantly environmental considerations.

This suggests that new nutrient delivery systems that exploit the nano scale porous domains on plant surfaces can be developed. But the nano fertilizers should show sustained release of nutrients on-demand while preventing them from prematurely converting into chemical/gaseous forms that cannot be absorbed by plants.

To achieve this, biosensor could be used to control the timely release of this nano fertilizer i.e. selective nitrogen, phosphorus and potassium release linked to time, environmental and soil nutrient condition.

Types of sensors for soil quality monitoring

i. Electrochemical Sensors
ii. Electromagnetic
iii. Mechanical
iv. Optical
v. AirFlow

Electrochemical sensors are used to measure the most important soil characteristics for precision management; soil nutrient levels and pH. It's a great replacement for standard chemical soil analysis, which is expensive and takes more time to get the results. These sensors use an ion-selective electrode (ISE) or an ion-selective field effect transistor (ISFET) to measure the voltage between the sensing and reference part of the system related to the concentration of specific ions (H^+, K^+, NO^{3-}).

The electrochemical sensing combined with ion selective-membrane based transducers is an attractive approach to monitor soil parameters such as nitrate, phosphate, potassium and other soil parameters. But, the deployable electrochemical sensors for in-field measurements need a necessary electronic circuit for sensor readout and battery.

Ayranci et al.,[10] developed an electrochemical sensor for the detection of iron (III) ions using pyrene-substituted poly(2,5-dithienylpyrrole)-based electrode with a limit of detection of 1.73×10^{-7} M. A conductive polymer (electrochemically synthesized rhodamine-based polymer) was used make solid-state sensor platform to detects mercury ions with a low limit of detection (3.16×10^{-8} M). Ali et al., developed a deployable electrochemical soil nitrate sensor using a nanocomposite of molybdenum disulfide (MoS_2) and poly(3-octyl-thiophene) coated on printed circuit board [11]. This ion-selective membrane-based sensor is capable to detect nitrate-nitrogen and is highly sensitive in range of 1ppm to 1500 ppm in soil slurries.

BIOSENSOR:
Biosensor can be the major component of smart farming. Controlled use of biosensor can foster the growth of crops as they can sense various pesticides herbicides. Recently, TFET-based biosensors based on dielectric modulation has gained concentration for label free sensing due to potentials of early detection. In Kannan et.al., [12] , the application of impact-ionization MOS transistor as a biosensor is proposed where a high sensitivity to the presence of biomolecules as well as low variability of the sensitivity to the charges on the biomolecule at small channel lengths is observed.

NANO SENSOR:
A nano sensor is a very small chemical or mechanical sensor that can detect extremely small changes like the presence of chemical species and nanoparticles, or monitor physical parameters such as temperature, on the nanoscale. Nano sensors are used in a variety of fields, including healthcare, environmental monitoring, and manufacturing and can exploited in the field of agriculture also.

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II. PROPOSED MODEL

1. Nano-Fertilizers will be encapsulated in a polymeric shell.
2. Sensors will record the NPK status of the soil.
3. Lower level of fertilizers will send signal and trigger the release of moisture
4. Released moisture will help the polymeric shell will swell up and release nano-fertilizers

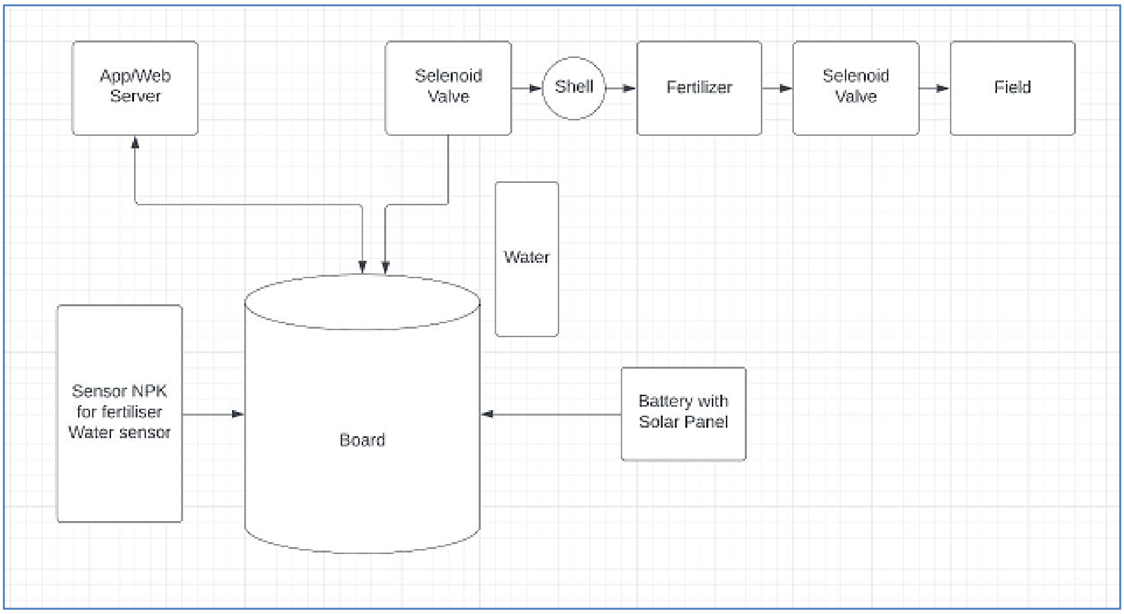

Fig. 1 Proposed model

Different Components

1) Soil Moisture Sensor

One type of inexpensive electrical sensor used to measure soil moisture is a soil moisture sensor. The volumetric content of water in the soil can be determined with this sensor. The Sensing Probs and the Sensor Module are the two primary components of this sensor. The probes allow current to flow through the soil, and they then calculate the resistance value based on the soil's moisture content. The Sensor Module receives data from the sensor probes, processes it, and outputs the result as either a digital or analogue signal. Consequently, the Soil Moisture Sensor may produce both Digital Output (DO) and Analog Output (AO).

2) NPK Sensor

The soil NPK sensor can be used to measure the soil's nitrogen, phosphorus, and potassium concentration. It facilitates the systematic evaluation of the soil condition by assisting in assessing the soil's fertility. Long periods of time can be spent with the sensor buried in the ground. To ensure the long-term functionality of the probe component, it has a high-quality probe that is corrosion resistant to salt and alkali, rust, and electrolysis. It is therefore appropriate for all types of soil. Alkaline, acidic, substrate, seedling bed, and coconut bran soil can all be detected using this method. Chemical reagents are not necessary for the sensor. Any microcontroller can use it because of its high measurement accuracy, quick response time, and strong interchangeability.

3) Solar-powered rechargeable battery

A solar-powered rechargeable battery is an electric battery that saves the energy captured by a solar panel to be utilized later. These batteries can be charged, used, and recharged multiple times before they die. They were made specifically for photovoltaic systems and consist of a solar cell and a battery. In standalone systems (off-grid solar systems) and hybrid solar systems, solar panels' energy is stored in solar rechargeable batteries.

4) Solenoid valve

A valve is a device for controlling the passage of fluid or air through a pipe, duct, etc., especially an automatic device allowing movement in one direction only. A solenoid valve is an electro-mechanical valve that is commonly used to control the flow of liquid or gas which as a result, reduces the need for an engineer to manually control the valve. This also saving time of the engineers and it also saves the money. Solenoid valves are used whenever the flow of media has to be controlled automatically. The valve is opened or closed by the movement of the magnetic plunger. Here we are using this valves for the control of water as well as the fertilisers to the soil.

5) Sprinkler irrigation

It is a device used to water the agricultural field. It is less wasteful. Using a pump, a sprinkler irrigation system enables the delivery of water at high pressure. Through a small diameter nozzle installed in the pipes, it releases water that is comparable to rainfall. Due to the wide range of discharge capacities, water is disseminated through a network of pipes, sprayed into the air, and irrigates most soil types. Here we will use this sprinkler irrigation to provide the deficiency chemical in the soil.

II. CONCLUSION

Nanotechnology will play a vital role in the development of the agricultural sector in near future, as it is capable of being used in agricultural products that protect plants and monitor plant growth and detect diseases. A large amount of fertilizers get wasted as the farmer is not aware of the exact amount of fertilizer required by the plant and this problem can be addressed by the development Nanocomposite fertilizers. Though automated techniques for seeding, weeding, harvesting the crops etc. have been proposed and implemented, none of the techniques target at maintaining soil fertility. Scientists have been working towards exploring new applications of nanotechnology in agriculture and the food industry, if these discoveries are applied sensibly, the environment, the agricultural sector and the food industry will indeed see tremendous changes for the better in the coming years. Nanotechnolgy in combination with sensor technology will help to move towards the age of precision farming.

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