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Smart Fertilizers – Strategy for Sustainable Agriculture

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SMART Fertilizers are fertilizers that have a "**smart**" feature to release or provide nutrient only on demand by the crop, thereby optimizing fertilizer use for agriculture, enabling growers to maximize crop yields, save costs and increase their profits.

- This is a unique technology that will be a game changer in the world of fertilizers.
- Smart fertilizer is a designer molecule that allows sustained release of nutrients by a plant-root activated mechanism.
- The fertilizer molecule functions like a nutrient storehouse providing a continuous nutrient supply throughout the crop growth period.
- Smart fertilizers provides significant dosage reduction and yield improvement in an environmental – friendly way.
- With this technology, nutrient release is under the control of the plant itself. This makes it especially beneficial in increasing yields since a plant requires different quantities of nutrients at different stages of its life cycle.
- It has the potential to bring about far – reaching changes.

Need of Smart Fertilizers

- Agricultural land systems cover about 40-50% of the Earth's land surface on which humanity needs to secure food production.
- The global population is expected to increase to 9.6 billion by 2050, which will increase food demand and fodder requirements for feedstock.
- This implies sustainable intensification on existing agricultural land through innovation and collaboration between multiple sectors.
- One option to achieve greater crop production could be the improvement of plant fertilization strategies.
- Following are some of the emerging concerns/challenges in agriculture which brings an urgent need of smart fertilizers:
  - ✓ Declining/stagnating yield
  - ✓ Declining factor productivity
  - ✓ Higher cost of production
  - ✓ Deteriorating soil health
  - ✓ Receding groundwater table
  - ✓ Secondary salinization and sodicity
  - ✓ High surface water run-off and erosion
  - ✓ Susceptible to climatic variability and climate change

- Moreover, the negative environmental impacts of the green revolution due to massive fertilizer use call for the adaptation of more sustainable technologies.

Different Forms of Smart Fertilizers

- To enhance nutrient use efficiency, new types of smart fertilizers with controlled nutrient release are needed. The development of such fertilizers could be based on the use of microorganisms (biofertilizers) and nanomaterials (nanofertilizers).
- Different forms of smart fertilizers can be classified as follows:-
  - ✓ Slow-/Controlled-Release Fertilizers
  - ✓ Bio-formulation Fertilizer: Plant Growth Promoting rhizobacteria (PGPR)
  - ✓ Nano fertilizers
  - ✓ Polymers
  - ✓ Use of Harvesting Residues for Smart Fertilizer Formulations
  - ✓ Bio char

Slow/Controlled – Release Fertilizers

- According to **Trenkel (1997)**, slow or controlled – release fertilizers are those containing a plant nutrient in a form, which either delays its availability for plant uptake and use after application or is available to the plant significantly longer than a reference "rapidly available nutrient fertilizer" such as ammonium or urea (AAPFCO, 1995).
- There is no basic difference between slow-release fertilizers and controlled release fertilizes, but to say microbially decomposed N products, like urea – formaldehydes, are referred to as slow – release fertilizers, and coated or encapsulated products as controlled – release fertilizers.
- Delayed availability of nutrients or consistent supply for extended time periods can be achieved through a number of mechanisms.
- These include semipermeable coatings for controlled solubility of the fertilizer in water, protein materials, chemicals, slow hydrolysis of water-soluble compounds of lower molecular weights.
- The basic concept of slow release fertilizers is that they release their nutrient contents at more gradual rates that permit maximum uptake and utilization of the nutrient while minimizing losses due to leaching, volatilization or excessive growth.

Table 1: Common Slow Release Fertilizers

N-Source	Base Compound	Common name	N Content (%)	Inhibition Duration (Wks)
Urea Formaldehyde	Ureasforms, Methylol urea, and Methylene urea	Nitamin, Nitroform	35-40	6-10
IsobutylideneDiurea	IsobutylideneDiurea	IBDU	31	10-16
Neem Coated Urea	Urea	NCU, Nimin Coated Urea	-	-
Nitrapyrin	2-chloro, 6-trichloromethyl pyridine	N-Serve, Stay-N 2000	-	2-6

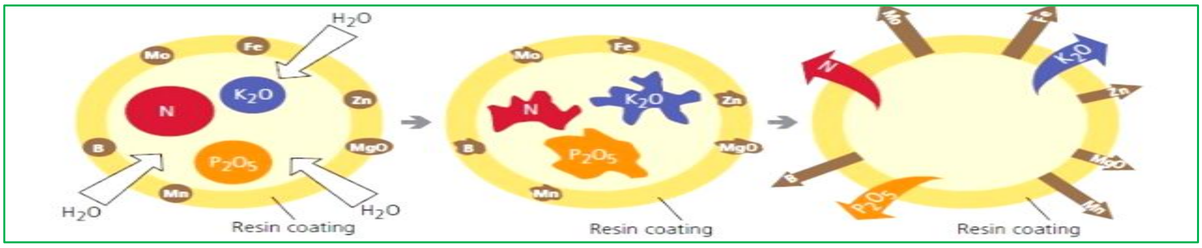

Fig.: Mode of action of a coated/encapsulated fertilizer

Bio–Formulation Fertilizer: Plant Growth Promoting Rhizobacteria (PGPR)

- PGPR, a heterogeneous group of bacteria that can be found in the rhizosphere, at root surfaces, and in association with roots.
- The term "plant growth promoting rhizobacteria (PGPR)" for beneficial microbes was introduced by **Kloepper JW, Schroth MN (1981)**.
- These bacteria have several functions, including production and regulation of phytohormones, release of nutrients to plants (e.g., P, N – fixation, siderophores, among others) and control of phytopathogens (production of antibiotics and siderophores).
- Phosphobacteria, phytate – mineralizing bacteria and phosphate – solubilizing bacteria have been commonly isolated from soil and proposed as inoculants for agricultural improvement.
- Low N acquisition by plants is a limiting factor in agricultural ecosystems, and there is space for using N_2 – fixing bacteria as an alternative to conventional fertilization.
- Diazotrophic bacteria are capable of converting atmospheric N_2 into NH_3, which can be used by plants.
- However, it is well known that bacteria directly inoculated in the soil system could be adversely affected by competition with native micro - organisms, unfavorable physicochemical conditions, and fluctuating pH and temperature.
- So, encapsulating microorganisms in carrier materials (bioformulation) is designed to protect them during storage and from adverse environmental condition, thus ensuring a gradual and prolonged release.
- Materials suitable for immobilization and preservation of bacteria include alginate gels, synthetic gels, polyacrylamide, agar and agarose, polyurethane, vermiculite, and polysaccharides.

Nano Fertilizers

- Nanofertilizers, as smart fertilizers, are designed to increase nutrient use efficiency and consequently reduce adverse effects on the environment compared to application of conventional mineral fertilizers.
- There are three main types of nanofertilizers: nanoscale fertilizer (synthesized nanoparticles), nanoscale additives (bulk products with nanoscale additives) and nanoscale coating or host materials (product coated with nanopolymer or loaded with nanoparticles).
- Slow – release Nanofertilizers are suitable alternatives to soluble fertilizers. Nutrients are released at a slower rate during crop growth, thereby reducing loss.
- Slow release of nutrients in the environments could be achieved by using zeolites (natural clays), which act as a reservoir for nutrients that are released slowly.
- The mineral nutrients required for plant nutrition can be encapsulated inside nanomaterials such as nanotubes or nanoporous materials, coated with thin protective polymer film, or nanoscale particles.
- Nanoclays, which naturally occur in soils, have been considered important tools in modern agriculture due to physicochemical properties.
- Nanoclays can be used to stabilize enzymes and therby increase their catalytic activity for different biotechnological purposes.
- Nanocomposites are hybrid materials consisting of a continuous (polymer) phase or matrix and a dispersed (nanofiller) phase. The dispersion of a small amount (<10%) of nanomaterial in the polymer matrix can lead to marked improvement in physical and mechanical properties (strengths, pH tolerance, storage stability, heat distortion, break elongation) compared with a single polymer matrix.

- These nanocomposites can be used to supply essential nutrients through smart delivery system, synchronizing the release of them with the crop uptake, so preventing undesirable nutrient losses to soil(*i.e.*, leaching and volatilization).

Table 2: Nanofertilizers for plant nutrition

Nutrients	Absorbent	Size
Nitrogen	Zeolite	7-10 nm
		20-30 nm
		60 nm
	Montmorillonite	35-45 nm
		50 µm
Phosphorus	Zeolite	25-30 nm
		60 nm
	Montmorillonite, bentominete and apatite	35-40 nm
Potassium	Zeolite	25-30 nm
	montmorillonite	35-40 nm

Polymers

- Polymers are widely used in agriculture especially for fertilizer development.
- A broad range of synthetic materials, such as petroleum – based polymers, have been used to encapsulate water-soluble fertilizers.
- Polysulfone, polyacrylonitrile, polyvinyl chloride, polyurethane, and polystyrene are the main materials currently used for coating.
- Jarosiewicz and Tomaszewska (2003) compared the use of the synthetic polymers polysulfone and polyacrylonitrile and the biodegradable cellulose acetate for the development of slow release fertilizers.
- They observed that physical properties of the coatings can influence the release rate of macronutrients (N, P, and K), which are present in the core of the coated fertilizers.
- They found that synthetic nondegradable materials had a slower release rate than cellulose acetate – based ones.
- Biodegradable polymers have also been used in bioformulations, acting as microbial carriers.
- These carriers protect microbial inoculants from various stresses and prolong shelf life.
- Sodium alginates are widely used for bioformulations and with pesticides.
- Despite the low cost and the environmental friendly properties of biodegradable polymers, in many cases the properties of these materials need to be blended with synthetic materials to improve their performance.

Use of Harvesting Residues for Smart Fertilizer Formulations

- Low – cost materials such as wheat straw are abundantly available resources in current agricultural systems.
- These harvesting residues contain lignin, hemicelluloses, and cellulose.
- Cellulose fibrils and lignin impart mechanical strength properties.
- Wheat straw contains surface carboxyl, hydroxyl, ether, amino, and phosphate, which enhance its reactivity and physicochemical properties, useful in the preparation of adsorbent materials for the treatment of wastewater and slow-release fertilizers.
- Xie *et al.* (2011) noticed the potential use of wheat straw for the development of slow-release N and boron fertilizers with water-retention properties. They prepared and used

the straw as skeletal material in copolymerization with other monomers to form a superabsorbent material.

- They introduced inorganic fertilizers (urea and borax) in order to develop an organomineral fertilizer within a core/shell structure. They found that the final product contained 23.3% N and 0.65% boron with potential slow release characteristics.
- Cellulose obtained from agricultural residues has been also used in bioformulaitons as carrier for bacterial inoculants with broad spectrum antifungal activity and suppression of fungal pathogens.
- Lignocellulose and compost are subject to rapid decomposition once incorporated into soil. In order to further improve their properties as slow release fertilizers, they could be combined with clay minerals or biochar to reduce their decomposition.

Bio char

- Biochar is a fine – grained, carbon-rich, porous product remaining after plant biomass has been subjected to thermo – chemical conversion process (pyrolysis) at temperature ranging from 350°C to 600°C in an environment with little or no oxygen **(Amonette and Joseph, 2009)**.
- It is also called as **Black gold of agriculture**.
- It is widely used as soil ameliorant with several applications in both laboratory and field studies.
- Biochar was found to increase the C sequestration potential of soil through its high stability and the reduction of native soil OM mineralization and to be an excellent microbial habitat.
- Combination of P fertilizers (triple phosphate and bone meal) premixed with sawdust and switch grass biomass prior to biochar production was a good strategy for the production of an effective slow release P fertilizer.
- The use of biochar as carrier for smart fertilizers could be highly beneficial, as it combines nutritional benefits for plants with improvement of many other soil functions due to the biochar itself.

Benefits and weekness of Smart Fertilizers

Benefits

- It helps in increasing agricultural productivity.
- High profitability as it reduced the amount of nutrient required.
- Demand based fertilizer application.
- Reduced import of fertilizers.
- Enhanced nutrient use efficiency.
- Improve soil health as less amount of nutrient is applied.
- Increase soil C – sequestration.
- Helps in alleviating green house gas emission.
- Reduce nutrient losses as nitrate (NO_3^-) and phosphate (PO_3^-) leaching, NH_3 volatilization, and nitrous oxide (N_2O) emission.

Weeknes

- Precise application is difficult as lesser amount is applied.
- High cost due to intensive technologies.
- Fragmented land holding of farmers.
- Diversion of by – products of farm.
- Soil specific smart fertilizer availability is rare.
- Farmer’s unawareness about new technologies.

- Low acceptability by farmers.
- Less availability of coating material at low scale.

Conclusion

- In order to meet sustainable development goals, agricultural production needs to be increased and the pollution and GHG emissions related to farming activity need to be decreased.
- Advances in the application of biotechnology and nanotechnology have the potential to facilitate improved nutrient management and use efficiency in agroecosystems.
- Smart fertilizers based on slow/controlled – release and/or carrier delivery systems have been shown to improve crop yields, soil productivity, and lower nutrient loss compared with conventional fertilizers.
- Several materials such as clays, nanoclays, non degradable and degradable polymers, and agricultural wastes are suitable for the development of smart fertilizers by acting as carrier matrices for nutrients and bacterial inoculants.
- Lignocellulosic organic waste, such as straw after chemical, physical or thermal transformations, may be an excellent carrier or coating material for fertilizer formulations.
- Such organic wastes occurring as harvesting residues in agricultural systems should be used in the sense of a circular economy to create innovative fertilizers form natural materials, which are urgently needed to ensure sustainable intensification of agricultural systems.

References

1. AAPFCO, 1995. Official Publication No. 48. *Association of American Plant Food Control Officials (AAPFCO)*. INC.; west Lafayette, Indiana, USA.
2. Amonette, J.E. and Joseph, S. (2009). Characteristics of biochar: microchemical properties. *In* J. Lehmann and S. Joseph (ed.) Biochar for environmental management: Science and technology. Earthscan, London 33-52.
3. Jarosiewicz, A. and Tomaszewska, M. (2003). Controlled – release NPK fertilizer encapsulated by polymeric membranes. *Journal of Agricultural and Food Chemistry*. **51**(2), 413-417.
4. Xie, L., Liu, M., Ni, B., Zhang, X. and Wang, Y. (2011). Slow-release nitrogen and boron fertilizer from a functional superabsorbent formulation based on wheat straw and attapulgite. *Chemical Engineering Journal*. **167**, 342-348.