Intelligent, Nano-fertilizers: A New Technology for Improvement Nutrient Use Efficiency (Article Review)

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Abstract
Nano fertilizers are essential resources in agriculture in order to increase crop production, quality, productivity, and boost nutrient uptake. Nano-fertilizer is efficient for specific use of nutrients at appropriate time of plant growth and can provide nutrients as a whole with the crop. Growing crops with heavier fertilizer concentrations further increases may be limiting to crop growth due to nutrient toxicity. Nano-fertilizers provide more area for photosynthesis, leading to more sunlight absorption and greater yields of the crop. It will help plants survive challenging environmental factors such as drought. Limitations in agricultural land and water supplies can improve production land and water use productivity through the use of new technologies. Nanotechnology has the potential of transforming both personal use and development. Nanostructured formulations may also be developed in order to deliver active ingredients in response to environmental cues and biological demands more properly. The principle of fertilizer use is known to use less resource and to be free from chemical side effects. Nanotechnology has enormous potential to contribute significantly to sustainable agricultural production, particularly in developing countries.

Keywords: Nano-fertilizers, A Novel Way, Growth, Productivity.

1. Introduction
To address the significant concerns of sustainable food production and development, several great technological advances have occurred in recent years in the field of farming [1,2]. Innovation in agriculture is important to meet global food demand because of rising natural and synthetic resources. Nanotechnology may be used to solve a variety of agribusiness-related problems. There is a great scientific interest in bridging the gap between bulk materials and atomic or molecular structures, which can be accomplished with the aid of nanoparticles. In the last two decades, a lot of research on nanotechnology has been performed in agriculture sectors [3,4]. Fertilizer application plays a crucial role in increasing the agricultural production, however, excessive fertilization limits the available area for crop production. Sustainable agriculture requires a minimal use of agrochemicals that can protect the ecosystem and spare biodiversity from extinction. Nanomaterials are useful in raising the production of crops by increasing the quality of agri-inputs. The growth in nanotechnology in herbicides has improved crop yields. Food sustainability is the main concern in agricultural production as research is undertaken in order to adapt plants to changing climates without affecting existing ecosystems [5]. Controlling soil and plant quality and health are a plus for sustainable agriculture and conservation of climate [6]. Nanotechnology is another revolutionary agriculture method that can enable the efficient production of agricultural fields [7,8]. Nanotechnology may as well save human capital and wastage. Agro-nano-technologies provide short-term solutions to the difficulties of modern industrial agriculture.

Nutrient efficiency is one of the most relevant principles for assessing crop production systems since they are strongly affected by fertilizer management and soil and plant-water relationships. Improving the nutrient use efficiency research is very relevant and challenging nowadays. Nutrients are applied to crops and cropping systems to ensure the optimal production and contribute to crop and soil health. Nano formulated nutrients were transported to different parts of the plant. Nano-fertilizers performs extremely efficiently in contrast to traditional fertilizers due to their high surface area to volume ratio. At the same time, encapsulation of nutrients to vegetable crop increases the supply of nutrients to the plants [9]. In this study, the efficiency of nano-fertilizers in agriculture fields is to be assessed.

2. Nanofertilizer
Nanofertilizer technology is very innovative and scanty reports in scientific journals are available. Nutrient usage efficiencies of conventional fertilizers are 30-35%, 18-20% and 35-40% for nitrogen, phosphorus and potassium respectively. Data has remained consistent for past several years and investigation of this matter did not produce positive result. Researchers are
creating new nano particles to provide us with nutrients. In the sense that nano technology has considerable surface area, it is capable of storing various types of nutrients in plentiful quantities for long duration without any relevant side effects of customized inputs [10].

An understanding of the importance of the phenomenon is the basis of this increasing commercial interest in the production of a synthetic zeolite-based fertiliser, [11], found the positive effects of peaty mixtures on maize growth. Another research showed how N, P, K and micronutrients mannose and amino acids have been used to improve the uptake and use of nutrients in this way [12]. It is worthwhile to apply a balanced dose of NPK with S, Zn, B and Mo where possible. Fertilizer treatment increased green and blackgram yields by 13% and 38% over the control. [13], revealed that adding organic layer to the clay could regulate release of nutrients. Nanotechnology would be used to release nutrients from membranes. It has been investigated by Subramanian et al. that nano-fertilizers and nano-composites can be utilized to protect the fertilizers from negative impacts which boost the nutrient use efficiency and minimize the lost of nutrients through the degradation of the soil. Recently, [14] has investigated the release pattern of nanofertilisers. Data shows that the nano-clay based fertilizer formulations that can release nitrogen for around 1000 hours have comparable effects with the traditional fertilizers that release nitrogen for only 500 hours. Nanotechnology can be exploited in order to increase the food production. Nanofertilizer technology can increase crop productivity. There is an increasing interest in the integration of nanoporous zeolites in agricultural inputs over the years as a result of society's growing concern for the harmful effects of chemical fertilizers on the agro-ecosystem [13,15]. Nanofertilizer may be a strategy to enhance crop yields and productivity in nutrient usage [10].

### 2.1. Characteristics of zeolites:

Zeolites are commonly used as a substrate for plants because of its great physicochemical properties [16]. They are three-dimensional crystals with voids and channels that occur as a result of the replacement of aluminum oxide with silicon oxide in the tetrahedral framework of their crystal structure [17,18]. By adsorbing positively charged particles like ions, it is positive [19]. The characteristic of zeolite was introduced by [20], which reported that the zeolite was considered representative in term of the composition of CaC (133.92 mmol (p+) kg⁻¹), K (19.83 mmol kg⁻¹), SiO₂ (71 percent ), Al₂O₃ (11 percent ), Fe₂O₃ (3.13 percent ), Na₂O (1.09 percent ), MgO (0.61 percent ), and K₂O (2.54 percent ), respectively. The nano-zeolite has hexagonal symmetry, two dimensional pores with 0.71nm apertures, cavities of around 0.48x124x1.07nm, and the Si/Al ratio is usually 3.0. [21]. The 6-membered double rings and the cage arrangement of nano-zeolite are characteristic characteristics. These three concentric hoops give rise to 12-membered rings with a free diameter ranging from 0.71nm to 1.26nm [22]. Zeolite is a naturally occurring mineral with a perfect chemical composition [10].

### 2.2. Macronutrients - Nitrogen nano fertilizer

Nitrogen is a very important chemical for plant cells. Chlorophyll is the key ingredient used in extracting sugars from water and carbon dioxide by plants (i.e. photosynthesis). Proteins are a significant component of amino acids, as well as building blocks of proteins. Some proteins act as structural units in plant cells while some act as enzymes which carry out chemical reactions. Nitrogen is a major component of energy transferring compounds such as ATP which enable cells to conserve and reuse energy. Nitrogen is a significant part of proteins such as DNA, the genetic material which allows cells to develop and reproduce. There are three types of nitrogen available: organic nitrogen compounds, ammonium (NH₄⁺) ions, and nitrate (NO₃⁻) ions that can be absorbed by plants. Most of the nitrogen is not released by the soil completely. This is because negatively charged nitrate is very unlikely to stick on soil particle surfaces. Overcoming problems connected with nitrogen leaching during application of fertilizers, researchers tested various coating materials including polyurethane resin-coated urea, neem coated urea, sulphur coated urea. Slow-release fertilizers are too costly and it takes more time to release N. NH₃ can also be regulated by cation exchanger as additives in fertilizer because of ion exchange behavior. The use of zeolite would boost crop production in an outstanding way. Clinoptilolite zeolite (CZ), a porous mineral with a high CEC and great affinity for ammonia, was used by Chinese researchers to minimize ammonia emissions from manure and also to reduce ammonia toxicity to plants. The amendment of clinoptilolite zeolite (CZ) to sandy soil resulted in lowering NO 3 - and NH 4 -concentrations in the leachate and to increasing of moisture retention in the soil . Urea nitrogen is the most common nitrogen source because of its lower cost per unit of nitrogen. Nitrification can be decreased as a result of volatilization of ammonia to atmosphere by the agricultural method. One of the most important consequences of urea is the degree of its effectiveness, often about seventy percent. Ammonium retained by chemical fertilizer is normally treated with slow release by cation exchange and nitrification by soil [23]. Clinoptilolite zeolite is used to extract NH₃ from manures and solids. Application of (NH₄)2SO₄ loaded into CZ was observed to prevent N leaching, whereas it did not help to increase N usage by crops planted in sandy soils compared with (NH₄)2SO₄ alone [24,25]. Clinoptilolite not only increased nitrogen fertilization rate, but it also inhibited the nitrification of ammonium to nitrate. [26], said that zeolite has the ability to minimize ammonia volatilization. Adding 6.25% of zeolite reduced ammonia volatilization by 50% Another benefit of zeolite is that it is a good slow-release nitrogen source for animals. Unlike conventional fertilizers, fertilizer made from plant growth content greatly decreases nitrogen loss to the groundwater and the environment. The N-urea losses can be decreased using zeolites as fertilizer additives. There are
literatures showing that the addition of zeolite to nitrogen source will boost \([27,28], \[29]\) developed the feasibility of using surfactant-modified zeolite (SMZ) as an effective sorbent for nitrogen. Bhardwaj \[30\] investigated nanoparticle adsorption mechanisms using laboratory batch experiments to investigate sorption of nitrate from aqueous solutions using hydrothermally synthesized and surface adjusted zeolite. Surface modification of HDTMA and Diodocetyl dimethyl ammonium greatly improve the sorption and gradual release of nitrate. Dr. Latifah's study found that mixture of urea with zeolite and sewage waste water had better effect than urea alone, due to the formation of ammonium and available nitrate ions. Mixing in organic matter continued to prolong preservation of exchangeable ammonium and supply of nitrate. \[14\] tracked the nutrient release pattern of nafonfertilizer formulations. They had successfully shown that nano-fertilizer lasted at least 1200 hours while conventional fertilizer would be able to last only for 300-350 hours. It was clear from the data that zeolite as nano-fertilizer could increase N efficiency.

2.3. Phosphorus nano-fertilizer
Phosphorus is a common essential element for plants. Phosphorus is an essential nutrient for use as an energy transfer and storage molecule in the plant cell. Phosphate plays very important roles in cell energy transfer. Phosphorus plays a significant role in metabolism by supplying structural components including phospholipids and phosphatides. Supplying phosphorus at an early stage of crop production is important for its development of reproductive structures. Some particular growth factors that have been correlated with phosphorus are stimulation of root growth, promotion of stalk and stem power, better crop maturity, more uniform and more resistant to plant diseases, more positive levels of N fixation. Allen \[31\], performed studies to investigate the cation exchange and solubility in the mixtures of rock phosphate and NH4+ and K-saturated clinoptilolite to find out the potentials to deliver fertilizer. Malhi \[32\], found that zeolites, when saturated with mono-valent nutrient cations, such as NH4+ and K+, increases the solubility of phosphate rock. \[PR\] The performance of phosphorus fertilizer usage by crops ranged from 18 to 20 per cent for different crops. The remainder 78 to 80% goes to the field soil P tank, that is released to the crop over the following months and years. \[33\], demonstrated that P releases were around 90.5% and 71.5% for unmodified zeolite, 55.7% and 80.6% for SMZ and 52.5% and 58.9% for solid KH2PO4. Results show that it is able to absorb phosphate fertilizer due to the physical adsorption. In the analysis, SMZ was found to be a strong sorbent for PO4-3 and the release of P was controllable. SMZ properties indicates that it would be a good fertilizer carrier as a slow release agent. To improve growth of plants, it is easier to water plants with solutions made up of natural minerals than ordinary tap water. For example, the reaction in soil solution is: \((\text{P-rock}) + (\text{NH4-zeolite}) = (\text{Ca - zeolite}) + (\text{NH4+}) (\text{H2PO4-})\)
Zeolite purifies ammonium minerals from extracted phosphate rock. Unlike leaching of very soluble phosphate, controlled-release form of the fertilizer is released from soil from complex chemical reaction. Phosphate can affect plant and soil growth both biologically and chemically. The rate of phosphate release is regulated by varying the ratio of primary phosphate solution to zeolite. Calcium is also released from the rock by the lower of pH when ammonium ions convert to nitrate. Zooponic is a nutrient and phosphate output plant and from this PO4-3- and other nutrients released by dissolution of phosphate and synthetic apatite. NPK were supplied when plants needed them from the zooponic. The mechanism is a mixture of dissolving and ion exchanging reactions. Soil microorganisms play a crucial role in mobilizing organic, inorganic, and The fertilizer is "recharged" by the addition of water. In effect, zeoponic systems increase nutrition retention, reduce environmental nutrient losses and reduce fertilizer requirements. \[14\], analyzed the Po4- release pattern of PO4- adjusted surfaces produced using various nanoclays and zeolites in a percolation reactor. Nano-fertilizers release phosphorus for 40-50 days, and conventional fertilizers release phosphates for just 10-12 days. Literature in this field indicates that surface-modified zeolite systems can increase P usage efficiencies.

2.4. Potassium nano-fertilizer
Potassium is an essential nutrient for plant growth. Potassium plays an essential role in controlling many things in plants. For growth and reproduction, it is necessary in almost all processes. Potassium plays a crucial role in various processes, even though not all of them have been identified yet. Glucosinolates are known to activate about sixty different enzymes. Plants deficient in potassium are susceptible to drought, high temperature, excess water. They are less susceptible to pest, pathogen and nematode attacks. Potassium is often referred to as a nutrient with physical dimensions such as height, shape, color, taste, shelf life, fiber quality and more. Some natural zeolites contain a considerable amount of exchangeable potassium that enhances plant growth. For example, Hershey \[34\], published some quantitative data on the slow release effect of K from K-zeolite. According to \[35\], applying 625 kg ha-1 of fertilizer mixed with Zeolite increased the soil level of potassium. Zeolites are basically selective for K because of their dimensions and existence of the negative charges \[6\]. According to the author's argument, potassium is the only element that has been decreased from soil. It is suggested that slow and steady release of K from zeolites has the benefits of providing plant roots with additional nutrients at the same time. Guo \[36\], indicates that zeolite should be "refreshed" by the addition of more dissolved nutrient. Their selectivity for ion exchange on zeolite was demonstrated in a relative order of potassium (+) > sodium (+) > calcium (+) > magnesium (+) > ammonium (+). The research conducted by Rezaei et al. \[2009\] showed that the equilibrium K concentration increased with the increase in potassium sorbed on zeolite. Li et al., \[2010\] studied a slow-release fertilizer composed of potassium (K+) - loaded zeolite (K-Z) in hotsoce peppers as an example. Sharmila Rahale conducted experiment on slow release of potassium fertilizers,
investigating their effectiveness. Without depending on chemical fertilizers, nanotechnology can help to further increase the abundance of potassium in soil.

2.5. Secondary nutrients nano-fertilizer

Sulphur, calcium and magnesium are essential nutrients needed in large amounts for good crop development. Some plant species require a greater concentration of phosphorus than other plant species. In the case of soil sulphur reactivity, the dominant reaction is an organic or microbial process. Ca2+ and Mg2+ are tied to soil clays and both behave similarly to potassium. [37], discovered that tricalcium silicate is a slow-release fertilizer for calcium and magnesium. They claim that zeolite increases calcium and magnesium levels in the soil. Fansuri [38], observed that zeolite can exchange ions such as calcium and magnesium. In 2010, [39], conducted batch and column experiments which indicate that surfactant-modified zeolite (SMZ) can be a good carrier for sulfate. The leaching of sulfate is significantly reduced and the gradual release of sulfate can be accomplished if we use the SMZ fertilizer as fertilizer additives. Biological secondary nutrients are frequently ignored as research on them is minor.

2.6. Micronutrients nano-fertilizer

Micronutrients are those elements that are needed in far smaller quantities than vitamins and minerals. Micronutrients are vitamins such as boron (B), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), zinc (Zn) and chloride (Cl). Even though they are needed in minute amounts, micro nutrients are vital for healthy plant growth and productive crop production. The climate is adversely affecting micronutrient supply in many Asian countries. Some adverse effects of micronutrient deficiencies in plants include low crop yield and quality, irregular plant structure and lesser number of xylem vessels, disease and pest infestation and less productivity in application of fertilizers [40]. Sheta [41], aimed to characterize the capacity of the different natural zeolites and natural bentonite minerals to adsorb and release zinc and iron. Both the Langmuir and Freundlich are applied to determine the potential for sorption of these ions. The results indicate that natural zeolites are potentials for slow release fertilizers.

According to the analysis conducted by [42], the slow release of Zn is due to the sparingly solubility of the mineral and its sequestration effect of the exchange. Thereby the ions released are more readily available for absorption by plants. They researched the effects of foliar treatments with ion-exchanged zeolite on winter wheat for three years. The effect of zinc zeolite was greater than that of copper-zeolite. Zeolite in soil can increase trace nutrient uptake in plants. The release of cationic micronutrients has been improved by the existence of neutral soil. The concentration of Cu and Mn in Sudan grass was greatly affected by the concentration of P-rock, the soil, and the experimental method with various sources of NH4+ ions. [43], reported that zinc oxide nanoparticles penetrate the root tissue of ryegrass and enhanced the germination. [44], performed a classic experiment on pumpkin plants to demonstrate the effect of carbon coatings on plant cells. This can be used to derive a smart nutrient transportation mechanism in plants. Pandey [45], have claimed that Zinc rich ZnO NPs could increase the level of IAA in roots sprouts, which in turn indicates the increase in plant's growth rate.

Boron is an important nutrient for plants but it can be harmful to species if exposed to high concentrations. Many research regarding the adsorption of boron by soils and other minerals have been performed. Molybdenum is used by nitrate reductase. Mo is an important element of nitrogenase in Nitrogen fixing bacteria essential for legume crops. According to [46], MCM-41 zeolite seemed to have Mo incorporated into its system [10].

2.7. Nano fertilizers in crop nutrition

The quality of plant nutrition can be assured by supplying the nutrients in form of nano-fertilizers.

a. The nanostructured carriers contain "nanoparticle" elements. Enzymes may be inserted into an absorbent substrate such as chitosan, polyacrylic acid, clay or zeolite to enhance their use.

b. Utilizing the necessary nutrients in nanostructured based therapies (either in suspension or encapsulated) The problem could not always be the quantity of essential elements in soil. But there is problem in distribution of planting materials. Experiments are being performed to study the encapsulation of microfertilizers in nanomaterials. Some of the examples are metallic nanotubes, nanoclays of Montmorillonite, clay nanoparticles of Urea, silicon nanoparticles, porous and mesoporous silica and synthetic zeolites [47].

2.8. Higher nutrient use efficiency through nano-fertilizers

Nano-fertilizers possess certain unique properties, which assist in more effective nutrient uptake. Relevant properties are:

a. The tiny size of the nano-fertilizers makes them useful in providing sites for plant food metabolism, while having high surface area enhances their action. This results in more plant development through less consumption of essential nutrients.

b. They are extremely soluble in water.

c. The particle size of nano-fertilizers is very small (less than 100 nm), which means the penetration rate of micronanos is increased in the plant system.
d. Nano fertilizer particles have greater surface area and smaller particle size than the surface area of plant roots and leaves. This improves the penetration into the plant system from the applied surfaces, resulting in increased utilization and bioavailability of the nano-fertilizers.

e. Lesser the particle size, more surface area and more particles per volume is used by applicators of the chemicals. This increases performance and effectiveness.

f. The micro-particles being combined with fertilizers provide greater absorption and supply of plant nutrients to crops. The nanofertilizers release nutrients slowly into the crops and thus increase their availability over the entire growing cycle. This is an important mitigation measure as it prevents loss of Nitrogen through the process of denitrification, volatilization, leaching, and fixation in the soil particularly into Nitrate (NO₃⁻) and Nitrate (NO₃⁻) forms of Nitrogen [10].

**Table 1.** Effect spraying fertilizers of nano micronutrients and their combination in soft tubers yield Mg ha⁻¹, fertilizer use efficiency and nutrients use efficiency of (*Helianthus tuberosus L.*) [48].

| Tr. No | Soft tubers yield Mg ha⁻¹ | FUE% of Zn | ZnUE % | CuUE % | CuUE% | Fe UE % | Mn NUE % |
|--------|----------------------------|------------|--------|--------|--------|--------|----------|
| T₁     | 22.655 h                   | 0.0        | 0.00   | 0.00   | 0.00   | 0.00   | 0.00     |
| T₂     | 27.333 g                   | 18.62      | 93.10  | 0.00   | 0.00   | 0.00   | 0.00     |
| T₃     | 28.100 fg                  | 0.0        | 0.00   | 12.75  | 85.00  | 0.00   | 0.00     |
| T₄     | 29.355 fg                  | 0.0        | 0.00   | 0.00   | 12.87  | 99.00  | 0.00     |
| T₅     | 30.223 f                   | 0.0        | 0.00   | 0.00   | 0.00   | 0.00   | 15.39    |
| T₆     | 45.335 d                   | 6.13       | 30.65  | 6.46   | 43.10  | 0.00   | 0.00     |
| T₇     | 45.488 d                   | 16.52      | 82.60  | 0.00   | 8.39   | 64.54  | 0.00     |
| T₈     | 45.602 d                   | 6.17       | 30.85  | 0.00   | 0.00   | 11.87  | 65.90    |
| T₉     | 45.700 d                   | 0.0        | 0.00   | 10.69  | 71.30  | 0.00   | 12.75    |
| T₁₀    | 45.688 d                   | 0.0        | 0.00   | 7.83   | 52.20  | 10.8   | 83.10    |
| T₁₁    | 45.720 d                   | 0.0        | 0.00   | 0.00   | 10.85  | 83.46  | 13.97    |
| T₁₂    | 62.442 c                   | 15.84      | 79.20  | 10.45  | 69.70  | 10.5   | 80.77    |
| T₁₃    | 65.556 b                   | 0.0        | 0.00   | 10.66  | 71.10  | 11.43  | 87.92    |
| T₁₄    | 66.434 b                   | 14.6       | 73.00  | 0.00   | 0.00   | 11.07  | 85.15    |
| T₁₅    | 66.552 b                   | 15.86      | 79.30  | 11.33  | 75.50  | 0.00   | 12.7    |
| T₁₆    | 77.928 a                   | 18.32      | 91.60  | 12.2   | 81.30  | 11.94  | 91.85    |
| T₁₇    | 34.320 e                   | 3.57       | 17.85  | 2.22   | 14.80  | 2.19   | 16.85    |

Treatments of spraying of nano chelate micronutrients fertilizes T₁-Control, T₂-Nano(Zn) 20% Zn, T₃-Nano(Cu) 15% Cu, T₄-Nano(Fe) 13% Fe, T₅-Nano(Mn) 18% Mn, T₆-Nano(Cu+Zn), T₇-Nano(Zn+Fe), T₈-Nano(Zn+Mn), T₉-Nano(Cu+Fe), T₁₀-Nano(Mn+Fe), T₁₁-Nano(Cu+Fe+Zn), T₁₂-Nano(Cu+Fe+Mn), T₁₃-Nano(Fe+Mn+Zn), T₁₄-Nano(Cu+Mn+Zn), T₁₅-Nano(Fe+Mn+Zn) and T₁₆-Traditional (Zn+Fe+Mn+Cu) and the solutions were sprayed early in the morning after 60 days of planting and it was repeated at 25, 50, 75 and 100 g fertilizer 100 L⁻¹. Water for to spray the first, second, third and fourth respectively, and according to the recommendation by 1 kg Naon fertilizers h⁻¹, and another 400 liters of spray solution h⁻¹.

**Table 2.** Effect fertigation of nano fertilizers NPK in Fresh tubers Yield Mg ha⁻¹, Starch Yield Mg ha⁻¹, water use efficiency, agronomic efficiency and NPK use efficiency of (*Solanum tuberosum L.*) [48].

| Tr. No | Fresh tubers Yield Mage ha⁻¹ | Starch Yield Mage ha⁻¹ | WUE Kg m⁻² | AE Kg fresh tubers Kg⁻¹ | NUE % | PUE % | KUE% |
|--------|-------------------------------|------------------------|------------|------------------------|-------|-------|------|
| T₁     | 30.666 g                      | 4.872 d                | 16.85      | 0.00                   | 0.00  | 0.00  | 0.00 |
| T₂     | 42.444 ed                     | 5.542 c                | 23.32 ed   | 294.44 bc              | 85.30 | 0.00  | 0.00 |
| T₃     | 37.334 f                      | 6.147 ab               | 20.51 f    | 666.7 a                | 94.34 | 0.00  | 94.06|
| T₄     | 39.334 ef                     | 6.183 ab               | 21.61 ef   | 433.35 b               | 0.00  | 0.00  | 94.06|
| T₅     | 46.665 ab                     | 5.851 abc              | 25.64 ab   | 319.97 bc              | 96.35 | 97.51 | 0.00 |
| T₆     | 44.664 bc                     | 5.895 abc              | 24.54 bc   | 233.28 c               | 92.52 | 0.00  | 95.42|
| T₇     | 40.832 de                     | 5.737 bc               | 22.44 de   | 338.85 bc              | 95.56 | 95.77 | 0.00 |
| T₈     | 48.221 a                      | 6.315 a                | 26.50 a    | 250.78 c               | 97.43 | 98.11 | 97.03|
| T₉     | 39.998 ef                     | 5.838 abc              | 21.43 ef   | 27.77 d                | 52.27 | 35.02 | 44.04|

T₁-control, T₂-Nano Nitrogen25%N40Liter of Nano Nitrogen fertilizer ha⁻¹, T₃-Nano phosphorus25%P10Kg Nano Phosphorus fertilizer ha⁻¹, T₄-Nano Potassium 35%K20 Kg of Nano Potassium ha⁻¹, T₅-Nano(N+P), T₆-Nano (N+K), T₇-Nano (P+K), T₈-Traditional (20:20:20) NPK, T₉-Nano (N+P+K), T₁₀-Traditional (20:20:20) NPK, T₁₁-Nano (N+P), T₁₂-Traditional (20:20:20) NPK.
Table 3. Effect of fertigation of Urea and nano-nitrogen and spray of nano Mo, and B fertilizers on water use efficiency, agronomic efficiency and nutrients use efficiency of (*Solanum tuberosum* L.) [49].

| Tr. No | Fresh tubers yield, kg/ha | WUE kg m⁻³ | AE kg kg⁻¹ | NUE % | UE % | MoUE % | BUE % |
|--------|---------------------------|------------|------------|--------|------|--------|-------|
| T1     | 21.583 i                   | 11.86 h    | 0          | 0      | 0    | 0      | 0     |
| T2     | 22.967 h                   | 12.61 g    | 2748.3a    | 0      | 0    | 80     | 0     |
| T3     | 23.517 h                   | 12.92 g    | 1934.0a    | 0      | 0    | 78.88  | 0     |
| T4     | 25.032 g                   | 13.75 f    | 2299.3a    | 0      | 0    | 84     | 11.1  |
| T5     | 30.437 f                   | 16.72 e    | 29.48 b    | 0      | 40.3 | 0      | 0     |
| T6     | 30.912 f                   | 16.98 e    | 31.04 b    | 0      | 42.1 | 88     | 0     |
| T7     | 32.278 e                   | 17.73 d    | 35.49 b    | 0      | 45.3 | 0      | 85.55 |
| T8     | 33.029 de                  | 18.20 d    | 38.26 b    | 0      | 50.5 | 92.0   | 89.22 |
| T9     | 34.016 cd                  | 18.14 d    | 285.82 b   | 90.6   | 0    | 0      | 0     |
| T10    | 34.534 c                   | 18.97 c    | 319.77 b   | 92.9   | 96.0 | 0      | 0     |
| T11    | 35.770 b                   | 19.65 b    | 346.02 b   | 94.5   | 0    | 0      | 91.11 |
| T12    | 37.525 a                   | 20.62 a    | 384.14 b   | 96.7   | 96.4 | 97.77  | 97.77 |

T1: Control spray water only, T2: Foliar application of nano Mo 5 %, T3: Foliar application of nano B 9 %, T4: Foliar application of nano (Mo+B), T5: Fertigation of Urea + Foliar application of water, T6: Fertigation of Urea + Foliar application of nano Mo, T7: Fertigation of Urea + Foliar application of nano B, T8: Fertigation of nano N + Foliar application of water, T9: Fertigation of nano N + Foliar application of nano B, T10: Fertigation of nano N + Foliar application of nano (Mo+B). The fertilizers were applied at levels of (40) liters h⁻¹ of nano-N-fertilizer (25% N) and (300) kg h⁻¹ urea fertilizer (46% N) four times. The solutions were sprayed early in the morning after (40) days of planting four times with periods of two weeks from an application and another and as recommended by (1) kg nano fertilizer of B h⁻¹ and (500) g nano fertilizer of Mo h⁻¹.

3. Nanoparticles based delivery systems

Fertilizers made from nano materials have a slow release nutrient effect as described above. Surface coating helps to retain fertilizer particles more firmly due to higher surface tension provided by the surface coatings of nanomaterials on the materials. Here are several nanoparticle-based delivery systems [9].

3.1. Chemical system

Slow release fertilizers made with nano coated particles of sulfur are particularly useful because they supply sulfur element as well as the primary nutrient elements. Thus, the soil bindedability is the toughness of the coating. Coating of urea and phosphoric fertilizers with nanosize materials can improve their efficiency and reliability. Some other interesting nanoparticles that can be used for biomedical applications include kaolin and polymeric nanoparticles [50].

3.2. Biological system:

The preparation, storage and application of bio fertilizer are crucial to success in the field. Many different types of particles are attractively ideal for their use in coating of wetting agents to yield tolerant formulations.

3.3. Field application of fertilizers:

How the fertilizer gets applied determines their efficacy and environmental effects [51]. The restrictions associated with the droplet size of foliar sprays can be resolved by using nanosized fertilizer.

3.4. Control release of Nano fertilizers

When stabilizing Nano fertilizers, a variety of methods are used. The following are to be discussed:

a. The NanoFerts are combined with other materials such as Hydrogels, special films or other biopolymers such as Chitosan to decrease the uncontrolled release [52]. These included materials aggregate fertilizers with mineral nanoparticles obtained from clay in soil or other types of ceramic material, which are used for producing controlled-release blocks, pots, or film. They are programmed to satisfy the unique needs of various kinds of plants [51].
b. Amongst the options to avoid the release of nano fertilizers to the atmosphere is by applying them as foliar sprays. For this reason, the encapsulated organic nanoparticles can be quite useful. Another choice to use is to ensure that the quantity of nutrients applied to the soil is sufficient for the stage of crop production.

3.5. Movement of nano fertilizer elements inside the plant

When stabilizing Nano fertilizers, a variety of methods are used. We address below:

a. The NanoFerts are combined with other materials such as Hydrogels, special films or other biopolymers such as Chitosan to decrease the uncontrolled release [52]. These included materials aggregate fertilizers with mineral nanoparticles obtained from clay in soil or other types of ceramic material, which are used for producing controlled-release blocks, pots, or film. They are programmed to satisfy the unique needs of various kinds of plants [51].

b. Amongst the options to avoid the release of nano fertilizers to the atmosphere is by applying them as foliar sprays. For this reason, the encapsulated organic nanoparticles can be quite useful. Another choice to use is to ensure that the quantity of nutrients applied to the soil is sufficient for the stage of crop production.

3.6. Achievements of nano-fertilizers

Over the years numerous studies have shown that the use of nano-fertilizers increased and advanced the crop yield and quality parameters. The benefits of a high content of nitrogen are discussed below:

3.6.1. Yield

Several research studies have shown that the application of nano-fertilizers lead to improving crop yield. This is primarily because of enhanced photosynthesis from increased growth of plant parts and enhanced metabolism, leading to higher accumulation and translocation of photosynthesis. Foliar application of nanofertilizer greatly improved yield of crops [53].

3.6.2. Nutritional Value

Nano-fertilizers can improve nutrient availability. This helps to increase quality parameters like protein, oil and sugar content in plants by increasing the rate of the chemical reaction or synthesis process in plant cells. Nano formulation of zinc and iron increased the total carbohydrate, starch, indole-3-acetic acid, chlorophyll and protein contents in crops [51].

3.6.3. Health

Some plant element elements improve the resistance of the plants to diseases. Nano-nutrients protect the plants from pests, bio-diversity stresses and nutrient deficiency [51].

3.6.4. Effects of nano-fertilizers on seeds germination and growth parameters of the plant

Numerous scientists have stated that nano-fertilizers affected the growth of seeds and the production of plants. Nano-fertilizers can form a favorable foundation for seed growth and production of the plant. Nano formulation of zinc oxide demonstrated higher germination rate and root vigor as compared to bulk zinc sulphate [54]. Positively impacted on soya bean seeds germination [29]. Nano-fertilizers cause the fruits to be more succulent and nutritious than natural. It was recorded that the spectra treated seeds grown more up weight, higher rate of photosynthesis, and formation of chlorophyll.

3.6.5. Concluding notes

Nano nutrients are more efficient and economical than conventional ones. Application of different types of nano-fertilizers has a major impact on yield of crops, the protection of natural resources and the reduction of fertilizer cost for crop production. With the use of nano-fertilizers in agriculture fields, nutrient use quality will be increased. The nano-fertilizers promote good crop growth and yield by proper dosage and concentration. Exceeding certain cap would have inhibitory effect on the crops. Optimal doses of various nitrogen fertilizers would be of crucial importance. With optimizing dosing for different nanosubs and different crops, in near future, the production system will be highly productive and eco-friendly.

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