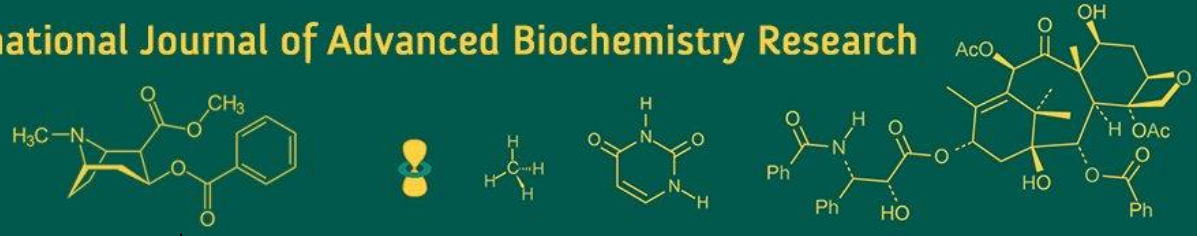
International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
IJABR 2024; 8(7): 1133-1139
www.biochemjournal.com
Received: 03-05-2024
Accepted: 06-06-2024

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The comparative impact of chemical fertilizers, nano-urea and nano-DAP on growth and yield of wheat crop

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DOI: https://doi.org/10.33545/26174693.2024.v8.i7n.1714

Abstract
The focus on sustainable agriculture compares the impact of chemical fertilizers, nano-urea, and nano-DAP on the growth and production of wheat crop. According to the results, chemical fertilizers are greatly out performed by nano-urea and nano-DAP, which improves the growth indices and yield. Nano-urea showed the increased nutrient absorption efficiency, which encourages strong plant growth and produces higher-quality grain. Similarly, Nano DAP shows impressive effectiveness through promoting root growth, increasing nutrient uptake, and enhancing photosynthetic efficiency, all of which boost wheat yield. Furthermore, these fertilizers made using nanotechnology have fewer negative effects on ecosystems and less nutrient leaching, which contributes to environmental sustainability. By optimizing nutrient utilization and lowering fertilizer application rates, the nano-sized particles of Nano urea and Nano DAP reduce ecological contamination. The findings demonstrate how fertilizers with nano-formulated ingredients can promote environmentally friendly farming practices while ensuring higher wheat yields and ecological responsibility.

Keywords: Inorganic fertilizers, nano urea, nano DAP, sustainable agriculture, crop production

Introduction
Since agriculture employs more than 50% of the population, it has been crucial to the economic growth of rural India. One of the major cereal crops that is grown extensively worldwide, which is essential as a staple diet in many nations. Wheat production spread across the different states contributing to the overall production. In India, the major wheat producing states include Punjab, Haryana, Uttar Pradesh, Madhya Pradesh, and Rajasthan (Singh *et al.*, 2021) [38]. These states have favourable climatic conditions and fertile soil, which make them ideal for wheat cultivation. According to the International Journal of Plant Research, wheat production in India is estimated to be around 106.47 million metric tons in the year 2020-21, with Punjab alone accounting for approximately 28% of the total production (Nain and Aneja, 2019) [27]. While wheat production varies by state in India, Punjab, Haryana, Uttar Pradesh, Madhya Pradesh, and Rajasthan are the country's main wheat-producing states. These states are perfect for growing wheat because of their favorable climate and nutrient rich soil. The "Breadbasket of India," Punjab, is renowned for its abundant wheat output. In India, crop diversification pushed during recent years in an effort to lessen the country's excessive dependence on the cultivation of wheat and rice. This aims to solve the problem of soil erosion and decreasing water levels brought on by ongoing rice and wheat farming (Kumar *et al*., 2020) [23].
The nutritional value of the wheat crop is another crucial element. Wheat contains a variety of essential elements, including dietary fibre, other carbohydrates, iron, zinc, and B vitamins. (Mallick *et al.*, 2013) [26]. Additionally, wheat contains gluten, which gives elasticity to dough and is responsible for the chewy texture in baked goods. It is worth mentioning that the nutritive quality of wheat can vary dependent on reasons such as the variety of wheat, growing conditions, and post-harvest handling. Furthermore, wheat harvest in different states may have variations in terms of protein content and gluten strength (Singh *et al.*, 2021) [38]. Wheat flour used to make a variety of foods, including bread, pasta, biscuits, and noodles (Asim *et al.*, 2018) [10] and act as a base ingredient in baking, providing structure and texture

to baked goods. Additionally, Wheat used in boiled or steamed to make different kind of dishes like oats or added to soups and stews for added nutrients and texture (Uthayakumaran & Wrigley, 2017) [43]. It is highly nutritious crop, providing essential components such as protein, vitamins, dietary fibre, and phytochemicals (Shewry & Hey, 2015) [37]. Fertilizers play a crucial role in wheat cultivation as they provide essential nutrients that are required for optimal growth and yield (Babu *et al.*, 2021) [12]. The choice of the right type and amount of fertilizer is important to ensure that wheat plants receive adequate nutrition. This can vary depending on various factors such as soil quality, crop rotation practices, and nutrient deficiencies. Farmers often conduct soil tests to determine the nutrient levels in their fields and make informed decisions regarding fertilizer application (López-Bellido *et al*., 1998) [24]. When it comes to wheat cultivation, the application of fertilizers is crucial for promoting optimal growth and maximizing crop yield. Wheat plants require key nutrients such as nitrogen, phosphorus, and potassium for healthy development. Nitrogen, in particular, is essential for promoting robust leaf and stem growth, as well as enhancing the overall protein content in the grain. Phosphorus contributes to root development and seed formation, while potassium aids in disease resistance and water uptake.

Overview on Chemical fertilizers, nano urea and nano DAP on wheat: In recent years, nanotechnology has been emerging as a promising tool in agriculture, offering potential benefits for crop production and nutrient management. Nano fertilizers, such as nano urea and nano DAP (diammonium phosphate), have been investigated for their effectiveness in enhancing crop growth and improving nutrient uptake in wheat (Khan & Rizvi, 2017) [22]. Studies have shown that the application of nano urea and nano DAP can result in increased wheat crop yields compared to traditional chemical fertilizers (Jayara *et al*., 2023) [21]. Nano fertilizers have the potential to decrease the quantity of conventional chemical fertilizers required while still giving the wheat crop enough nutrients when combined with them. Additionally, because of their tiny size, which improves absorption and utilization by plant roots, nano fertilizers have the benefit of focused nutrient delivery (Dhage *et al.*, 2020) [16]. Overall, increasing wheat crop yields, nutrient uptake efficiency, and grain quality may be possible with the application of nano fertilizers in conjunction with suitable nutrient management techniques (Choudhary *et al.*, 2020) [14]. Wheat crop production is heavily influenced by the use of chemical fertilizers, including nitrogen, phosphorus, and potassium. However, there is a growing recognition of the need to shift towards sustainable nutrient management practices, including the use of nano fertilizers (Alhassan *et al.*, 2019) [3, 4]. These nano fertilizers have shown promising results in enhancing wheat crop growth and improving nutrient uptake, leading to higher yields and improved grain quality. Adoption of Nano fertilizers in Wheat Crop Production (Ditta and Arshad, 2016) [19]. One of the significant advantages of nano fertilizers is their ability to improve nutrient use efficiency and reduce losses through leaching and volatilization (Sagar *et al.*, 2020) [33]. Nano urea, for example, has demonstrated the capacity to enhance nitrogen use efficiency, leading to increased wheat grain yields. Similarly, nano DAP has shown positive effects on wheat crop growth, particularly in phosphorus uptake. When used in conjunction with traditional chemical fertilizers, nano fertilizers have the potential to reduce overall fertilizer usage while still providing essential nutrients for the wheat crop (Dhansil *et al.*, 2018) [17].

Furthermore, the smaller size of nano fertilizers allows for targeted nutrient delivery, improving absorption and utilization by plant roots (Dhansil *et al.*, 2018) [17]. This targeted delivery can contribute to enhanced nutrient uptake efficiency, ultimately leading to improved grain quality and higher yields in wheat crops. The continued research and adoption of nano fertilizers in wheat crop production hold promise for addressing the challenges of nutrient management, sustainable agriculture, and increasing food production to meet the demands of a growing population. As technology evolves, the utilization of nano fertilizers may prove to be instrumental in achieving productive and sustainable wheat cultivation practices. With their ability to improve nutrient use efficiency, reduce losses, and provide targeted nutrient delivery, nano fertilizers have the potential to revolutionize wheat crop production (Dey *et al.*, 2018) [15]. The integration of nano fertilizers such as nano urea and nano DAP into existing nutrient management practices not only offers a pathway for sustainable agriculture but also aligns with the global movement towards environmentally friendly farming techniques. As research and practical applications of nanotechnology in agriculture continue to evolve, it is essential for farmers and agricultural stakeholders to stay updated on the latest advancements in nano fertilizers and their potential impact on crop production (Shah *et al.*, 2019) [36].

Composition of chemical fertilizers, application and effect on growth and yield of crop

The chemical fertilizers play a critical role in promoting the growth and yield of wheat crops. Chemical fertilizers typically contain nitrogen, phosphorus, and potassium, which are essential nutrients for plant growth (Solanki *et al.*, 2020) [39]. Nitrogen is necessary for the development of leaves and stems, while phosphorus promotes root growth and flower formation. Potassium, on the other hand, contributes to overall plant health and helps regulate various physiological processes (Ali *et al*., 2019) [5]. When applied correctly and in appropriate quantities, chemical fertilizers can significantly enhance the growth and productivity of wheat crops. However, excessive or improper use of chemical fertilizers can lead to negative environmental impacts such as water pollution and soil degradation. To ensure the effective application of chemical fertilizers, it is important to consider factors such as soil type, nutrient requirements of the specific wheat variety being cultivated and the stage of crop growth. Additionally, the timing and method of application should be optimized to maximize nutrient uptake by the plants (Assessment of the limiting nutrients for wheat (Triticum aestivum L.) growth using Diagnosis and Recommendation Integrated System (DRIS), 2018).

Chemical fertilizers have been widely used in agriculture for many years and provide several advantages (Alhassan *et al.*, 2019) [3, 4]. Some advantages of chemical fertilizers include

a. **Increase crop yield:** Chemical fertilizers provide plants with essential nutrients that are necessary for their growth and development. These nutrients include nitrogen, phosphorus, and potassium, which are present

in different ratios in chemical fertilizers depending on the specific needs of the crop (Scherer *et al.*, 2009) [34]. By providing plants with these necessary nutrients, chemical fertilizers can greatly increase crop yield and productivity.

b. **Nutrient specificity:** Chemical fertilizers can be formulated to provide specific nutrients that are lacking in the soil. I f a soil test reveals that a field is deficient in nitrogen, a nitrogen-rich chemical fertilizer can be applied to address this specific nutrient deficiency and promote healthy plant growth (Panhwar *et al.,* 2019) [28].
c. **Improved nutrient availability:** Chemical fertilizers are formulated in a way that allows for the immediate release of nutrients to plants. This means that plants can quickly up take the nutrients they need, leading to improved nutrient availability and uptake efficiency (Trivedi *et al.*, 2018) [40]
d. **Ease of application:** Chemical fertilizers are readily available and easy to apply. Farmers can easily purchase chemical fertilizers from local agricultural supply stores and apply them to their crops using conventional equipment.
e. **Increased shelf life:** Chemical fertilizers can help increase the shelf life of crops by promoting healthy plant growth and reducing susceptibility to diseases and pests. Additionally, chemical fertilizers can be stored for extended periods without losing their effectiveness, allowing farmers to have a ready supply of nutrients on hand

Comparative analysis of chemical fertilizers versus nano fertilizers on Wheat: Chemical fertilizers have long been used in agriculture to provide essential nutrients to crops and enhance their growth and yield (Astaneh *et al.*, 2021) [2, 11]
However, the use of chemical fertilizers has raised concerns due to their negative impacts on the environment and human health. On the other hand, nano fertilizers, such as nano urea and nano DAP, offer a potential alternative with several advantages. These nano fertilizers have shown promising results in increasing nutrient use efficiency and enhancing crop growth and yield. Several studies have revealed that nano fertilizers, including nano urea and nano DAP, have the potential to improve seed germination, seedling growth, photosynthesis, nitrogen metabolism, and protein and carbohydrate synthesis in wheat crops (Poudel *et al.*, 2023) [29, 30]. Additionally, nano fertilizers have been found to improve the stress tolerance of wheat crops. In, comparison chemical fertilizers require larger amounts for application, leading to higher transport expenditures and potential environmental pollution. Furthermore, the use of chemical fertilizers can result in nutrient leaching and soil degradation over time. In contrast, nano fertilizers can be applied in smaller amounts, reducing transport costs and minimizing environmental impact (Dhansil *et al.*, 2018) [17]. These nano fertilizers have shown potential to improve crop growth and yield, enhance nutrient use efficiency, and reduce environmental impacts. Additionally, nano fertilizers can provide a more sustainable solution for agricultural practices, as they offer targeted nutrient delivery and minimize the risk of nutrient wastage and environmental pollution (Ditta & Arshad, 2016) [19]. According to (Al-Khuzai & Al-Juthery, 2020) [8, 9] the investigation, the effects of nano fertilizers more especially, nano urea and nano DAP on the growth and yield of wheat crops may be superior to those of conventional chemical fertilizers. The use of nano fertilizers more especially, nano urea and nano DAP in wheat production has shown promise in terms of improving crop growth and yield, nutrient utilization efficiency, and environmental sustainability when compared to conventional chemical fertilizers. Comparison research indicates that the effects of nano fertilizers, particularly nano urea and nano DAP, on wheat crop growth and yield may be better than those of traditional chemical fertilizers (Astaneh *et al.*, 2021) [2, 11].

Effect of nano urea on wheat crop: Nano urea has been shown to have positive effects on wheat crop development. According to (Upadhyay *et al.*, 2023) [42] the studies, using nano urea can improve early seedling growth, boost seed germination, and raise the amount of chlorophyll in wheat crops. Nano urea can also improve nitrogen metabolism in wheat plants, leading to increased protein synthesis and overall plant biomass (Al-Juthery *et al.*, 2019) [6]; (Astaneh *et al.*, 2021) [2, 11] Furthermore, nano urea has been found to stimulate the activity of enzymes such as peroxidase and catalase, which help protect plants from oxidative stress and enhance their tolerance to abiotic stressors such as drought (Mahmoodi *et al.*, 2017) [25]. The use of nano urea in wheat cultivation has shown to have positive effects on crop development, including improved seed germination, seedling growth, chlorophyll content, nitrogen metabolism, and stress tolerance (Abbasi *et al.*, 2016) [1]. Additionally, nano urea has been found to have high stability and easy absorption, allowing for efficient uptake by plants (Astaneh *et al.*, 2021) [2, 11]. Nano urea has been shown to have positive effects on wheat crop development, including improved seed germination, seedling growth, chlorophyll content, nitrogen metabolism, and stress tolerance (Astaneh *et al.*, 2021) [2, 11]. Higher grain production, better nutrient uptake, and increased nutritive quality were the outcomes of using nano urea in wheat crops (Jayara *et al.*, 2023) [21]. Nano urea has several characteristics that make it beneficial for wheat crops (Sagar *et al.*, 2020) [33]. First, nano urea has a higher nutrient use efficiency compared to conventional urea (Jayara *et al.*, 2023) [21]. This means that a smaller amount of nano urea can provide the same or higher levels of nutrients to the wheat crops, resulting in cost savings for farmers and reduced environmental pollution (Upadhyay *et al.*, 2023) [42]. Nano urea has garnered significant attention in the field of agriculture due to its potential to revolutionize nutrient management and crop production. With its nanoscale particles, nano urea offers a novel approach to providing essential nutrients to crops. The production of nano urea involves the conversion of conventional urea into nanoscale particles, which enhances its nutrient uptake efficiency and controlled release mechanism (Shaaban *et al.*, 2017) [35]. In the technique of producing nano urea was highlighted. The study concentrated on producing homogeneous nanoparticles that improve plant nutrition delivery through advanced nanotechnology. By dissolving urea into minute particles, nano urea increases crop solubility and bioavailability while also enhancing nutrient uptake and utilization.

Effect of Nano DAP on growth and yield of wheat crop
Nano DAP has also demonstrated beneficial effects on wheat crop growth and yield. (Dhansil *et al.*, 2018) [17]

studies have shown that the application of nano DAP can enhance wheat crop growth and increase yield.

Nano DAP provides a more controlled and targeted release of phosphorus, which is crucial for wheat crop development. This leads to improved root development, nutrient uptake, and overall plant growth. Additionally, nano DAP has been found to increase the number of tillers and grains per spike in wheat plants, resulting in higher grain yield (Dhansil *et al.*, 2018) [17]. The effects of nano urea and nano DAP on the growth and productivity of wheat crops have been encouraging. When it comes to crop development, the use of nano urea and nano DAP in wheat farming has shown promise in surpassing conventional chemical fertilizers (Al-Juthery *et al.*, 2021) [7]. The application of nano urea and nano DAP in wheat farming has demonstrated encouraging results in terms of crop yield and growth. It has been discovered that nano urea and nano DAP both improve the development of wheat crops, including nutrient uptake, seed germination, seedling growth, and chlorophyll content. Additionally, it has been discovered that these nano fertilizers increase number of tillers, tress tolerance, making them more resistant to abiotic stresses like drought (Dimkpa *et al*., 2020) [18]. By enhancing nutrient uptake, encouraging root growth and development, and enhancing the efficiency of photosynthesis, nano DAP can increase growth and yield. Because of its nanoparticles, which boost nutrient absorption and produce healthier plants with higher yield potential, agriculture is more sustainable and food security is increased (Poudel *et al.*, 2023) [29, 30]. (Alhassan *et al.*, 2019) [3, 4] reported the application of nano DAP as a fertilizer has been found to have a significant positive impact on the growth and yield of wheat crops. the application of nano-DAP as a fertilizer has been found to significantly improve the growth and yield of wheat crops. Therefore, incorporating nano DAP as a fertilizer can be a viable solution to enhance the growth and yield of wheat crops. In conclusion, the use of nano DAP as a fertilizer has been found to significantly improve the growth and yield of wheat crops. Therefore, incorporating nano DAP as a fertilizer can be a potential strategy to enhance the growth and yield of wheat crops (Poudel *et al.*, 2023) [29, 30].

Evaluating the efficacy of Nano Urea and Nano DAP: Nano Fertilizers, as a Sustainable Solution for Wheat Crop Growth Recent studies on the efficacy of nano urea and nano DAP have provided valuable insights into their potential impact on wheat crop growth and yield (Dhage *et al.*, 2020) [16]. These studies have indicated that the application of nano urea and nano DAP can significantly enhance the development and productivity of wheat crops compared to traditional chemical fertilizers. The enhanced seed germination, seedling growth, and increased chlorophyll content observed in wheat crops treated with nano urea suggest its positive influence on early growth stages. Additionally, the improved nitrogen metabolism and stress tolerance in wheat plants treated with nano urea further support its potential as an effective fertilizer in wheat cultivation (Ranjan *et al.*, 2023) [31, 32]. Similarly, nano DAP has exhibited promising effects on wheat crop growth and yield. The more controlled release of phosphorus provided by nano DAP has been linked to enhanced root development, nutrient uptake, and overall plant growth in wheat crops. Moreover, the increased number of tillers and grains per spike in wheat plants treated with nano DAP points to its positive impact on enhancing grain yield (fahdawi & Musleh, 2020) [20]. It is evident from these findings that both nano urea and nano DAP have the potential to outperform traditional chemical fertilizers in their effects on wheat crop growth and yield. The comparative analysis of these nano fertilizers suggests that they offer a more sustainable and environmentally friendly solution for wheat cultivation (Poudel *et al.*, 2023) [29, 30]. Further research and field trials can contribute to a deeper understanding of the long-term efficacy and potential benefits of incorporating nano urea and nano DAP in wheat cultivation.

The role of Nano fertilizers as a sustainable Agriculture: Nano fertilizers play a crucial role in sustainable agriculture by promoting efficient nutrient management, reducing environmental pollution, and enhancing crop productivity. They offer several advantages, including enhanced nutrient uptake efficiency, reduced environmental pollution, improved crop resilience, controlled nutrient release, and reduced fertilizer use. By reducing adverse effects on the environment and maximizing resource utilization, these advantages support sustainable crop production. Farmers can increase crop output while using less conventional fertilizer by employing nano fertilizers (Al-Juthery & Alzreejawi, 2020) [8, 9]. This minimizes the harmful effects that excessive fertilizer use has on the environment while simultaneously lowering production costs for farmers. There are several advantages of using nano fertilizers in sustainable agricultural production (Astaneh *et al*., 2021) [2, 11]. In general, the usage of nano fertilizers increases crop tolerance to abiotic challenges, decreases environmental pollution, increases nutrient use efficiency, releases this minimizes the harmful effects that excessive fertilizer use has on the environment while simultaneously lowering production costs for farmers (Astaneh *et al.*, 2021) [2, 11]. Numerous advantages are provided by nano fertilizers for crop production that is sustainable. nutrients in a regulated way while lowering the total quantity of fertilizer applied (Bhardwaj *et al.*, 2022) [13].

Challenges and opportunities in Nano fertilizers application: One of the main challenges in the application of nano fertilizers is their potential toxicity. Extensive research and testing are necessary to ensure the safety of nano fertilizers for both the environment and human health. Additionally, there is a need for standardized guidelines and regulations for the production, distribution, and use of nano fertilizers to ensure responsible and sustainable practices (Bhardwaj *et al*., 2022) [13] Nano fertilizers have the potential to revolutionize sustainable crop production by improving nutrient uptake efficiency, reducing environmental pollution, and enhancing crop quality and yield. Therefore, the use of nano fertilizers such as nano urea and nano DAP can contribute to sustainable crop production by optimizing nutrient management, reducing environmental pollution, and improving crop resilience and productivity (Astaneh *et al.*, 2021) [2, 11]. For crop yield and environmental sustainability, nano fertilizers such as nano urea and nano DAP offer a numeral of benefits over conventional fertilizers. Nano fertilizers have demonstrated significant promise in sustainable agricultural production, including nano urea and nano DAP. They can minimize the need for fertilizer, improve crop resilience, optimize nutrient

management, and lower environmental pollution. Moreover, compared to conventional fertilizers, nano fertilizers have a greater nutrient utilization efficiency, which allows crops to absorb and use the nutrients more effectively (Astaneh *et al*., 2021) [2, 11].

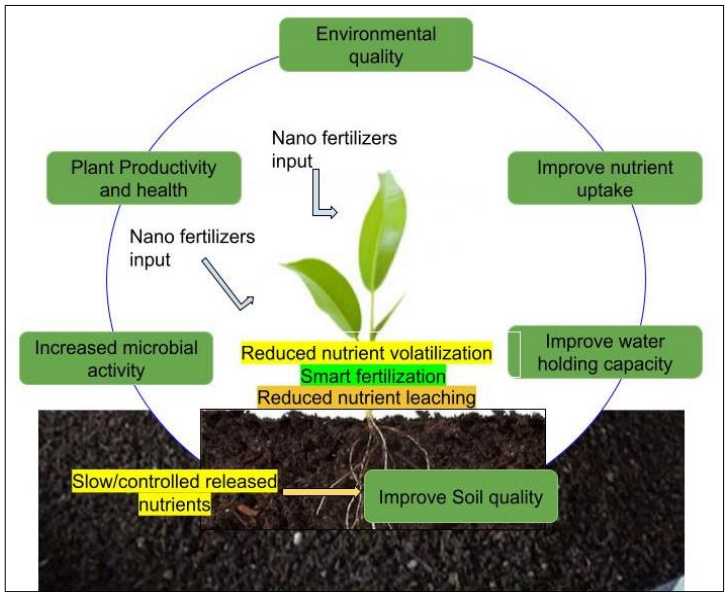

Fig 1: overview of nano fertilizers

Best Practices for using Nano fertilizers in Agriculture: When using nano fertilizers in agriculture, it is important to follow best practices to ensure their effectiveness and minimize any potential risks. These best practices may include

- Testing and evaluating nano fertilizers before widespread use to assess their efficacy and safety
- Ensuring proper application and dosage of nano fertilizers according to crop requirements and soil conditions
- Monitoring plant response to nano fertilizer application and making necessary adjustments
- Implementing proper storage and handling protocols for nano fertilizers to prevent contamination and ensure product integrity.
- Regularly monitoring soil and water quality to assess any potential impacts of nano fertilizers on the environment.
- Engaging in ongoing research and development to further improve the safety and efficacy of nano fertilizers
- Implementing proper labeling and transparency in the use of nano fertilizers to ensure consumer awareness and choice.
- Providing education and training to farmers on the proper use and benefits of nano fertilizers.
- These best practices can help promote the sustainable use of nano fertilizers in agriculture, maximizing their benefits while minimizing potential risks to plants, soil organisms, and the environment. The use of nano fertilizers has been shown to have several advantages in crop production.

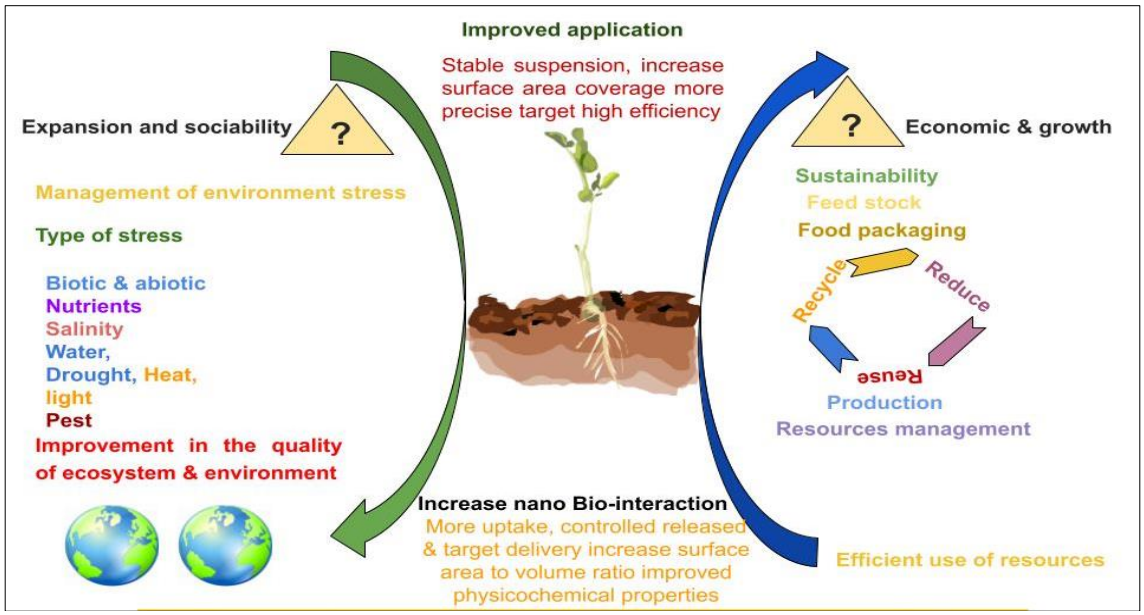

Fig 2: nanotechnology based agriculturally important nano fertilizers

Conclusion

The study found that the effects of chemical fertilizers, nano urea, and nano DAP on the growth and production of wheat crops varied little. Chemical fertilizers demonstrated traditional effectiveness, yielding significant growth and productivity gains. Nano urea, on the other hand, showed encouraging possibilities; it outperformed chemical fertilizers in terms of growth and production while also potentially benefiting the environment by reducing leaching and volatilization. The results of Nano DAP were inconsistent, showing different effects on metrics related to growth and yield. Though they have different effects on the environment, all three types of fertilizers increase agricultural output. To maximize its incorporation into agricultural practices and guarantee sustainable crop production systems, more research is needed into the long-term impacts, economic viability, and environmental sustainability of Nano urea and Nano DAP.

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