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Slow-Release Nitrogen Fertilizers as Excellent Way to Reduce Nitrogen Losses: A Review

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ABSTRACT: Around one-fourth to one-third of applied fertilizer nitrogen is lost to the atmosphere as ammonium and nitrous oxide gases, or as nitrates in surface and ground waters, causing a slew of environmental and health issues. With a worldwide nitrogen use of about 102 million tonnes (mt) in 2009, the loss of applied nitrogen may vary from 25 to 34 mt, or $12.5 to $17 billion USD; India's N loss estimates could be 3-4 mt, or 1.5-2.0 billion USD. Globally, projections for 2050 range from 27.5 to 36.6 billion US dollars, with India accounting for 3.25 to 4.35 billion US dollars. This is a massive waste of natural resources, energy, and money that must be minimized, if not eliminated entirely. Controlled release fertilizers (CRF), slow release fertilizers (SRF), and bio-supplemented fertilizers (fertilizers amended with nitrification/urease inhibitors) are all options for increasing production and reducing nitrogen losses. International financing, similar to that available for carbon bonds, is needed to support the use of such N fertilizers in South, Southeast, and East Asia, the area that consumes approximately 60% of the world's total N fertilizer use and is home to the majority of the world's poor. This study focused on the many kinds of delayed release fertilizers that are widely used, their worldwide consumption, and their impact on crop growth and nitrogen losses.

KEYWORDS: Environmental Issues, Fertilizers, Nitrogen losses, Yield Increase; Slow-Release.

1. INTRODUCTION

With the rise in population, the need for plant nutrients will continue to rise, and by 2020, fertilizers will be used in approximately 70% of food grain production. By 2020, the world population will have increased by 2.3 billion people, and by 2050, it will have doubled. The demand for grain and nutrients is projected to treble if food and meat consumption continue to grow in the same manner. The efficiency of food production is decreasing when the nutritional load per unit area increases owing to a reduction in the quantity of land utilized for food production. This necessitates the most intense and efficient food production ever. The continuous decline in nitrogen usage efficiency, among other nutrients, is a major source of worry. Nitrogen is the most frequently used plant nutrient since it is considered the yield limiting nutrient. Anthropogenic N inputs in fertilizers, irrigation water, seeds, and other forms account for approximately 85 percent of the 170 Tg N reaching the world's farmland each year. However, the worldwide agricultural output of nitrogen is only 23 Tg N per year, suggesting that N use for food production is inefficient. Cereals have a 40-50 percent apparent nitrogen recovery, whereas rice has the lowest. The amount of nutrients recovered from N fertilizers depends on the crop species, soil characteristics, and environmental circumstances, as well as management methods and nutrient source[1].

Increased usage of chemical fertilizers and other agro-chemicals, as well as the introduction of dwarf high yielding and nutrient sensitive cultivars, have resulted in remarkable improvements in crop production, especially in rice and wheat. Fertilizer usage is responsible for around half of the growth in food grain output, with nitrogen fertilizers accounting for more than a third of the increase. Despite increasing fertilizer usage throughout the nation, the partial factor productivity of fertilizers has been decreasing recently, as shown by stagnating food grain output. Losses owing to ammonia volatilization, leaching, denitrification under flood conditions, run-off, fixation as non-exchangeable NH4 +, and immobilization by soil microorganisms are all reasons of poor nitrogen use efficiency (NUE). Unrecovered nitrogen has the potential to pollute groundwater, cause eutrophication, acid rain, and contribute to global warming. Excessive and injudicious use of nitrogen fertilizers has a negative impact on crop quality, human and animal health, and may induce lodging in cereals, reducing crop production and quality. The presence of excessive nitrogen in surface water promotes the development of algae and other planktonic organisms, lowering water quality and use. There have been reports of stomach cancer in humans and methamoglobinemia (blue baby syndrome) in newborns and ruminants as a result of consuming nitrate-contaminated water, as well as hypoxia causing fish mortality in estuaries and gulfs. Nitrosamines, which are formed when nitrates are consumed, are said to be carcinogenic. These issues are constantly bringing agricultural experts' attention to the need for effective nitrogen usage and the halting of fertilizer response decline. Standards for nitrate content in drinking water have been established at 10 mg-N litre-1 in the United States and 50 mg-NO3 litre-1 in the European Union due to increasing health and environmental concerns. As a result, reducing nitrogen losses from nitrogen fertilizers is critical.

Slow release nitrogen fertilizers (SRNF) are a solution to this issue since they release tiny quantities of nitrogen when the crop needs it, improving nitrogen efficiency by reducing nitrogen losses. However, the overall usage of delayed and controlled release fertilizers (SRFs and CRFs) is much less than the total quantity of fertilizer used worldwide. In 1996-97, the global usage of CRFs/SRFs was projected to be about 560,000 tons, with processed organic products accounting for almost twice that amount. Despite the fact that the usage of SRFs/CRFs has increased in the past decade, they still account for just 0.15 percent of total nutrient consumption. The majority of these fertilizers are utilized in non-agricultural sectors (for example, lawn care, golf courses, and landscaping), with annual demand increasing by approximately 5%. Agriculture consumes just around 10% of the total quantity of SRFs/CRFs in use, but demand is growing rapidly at a rate of roughly 10% per year. The United States, Canada, Japan, and Europe produce and consume the most CRFs/SRFs[2].

1.1 Available options

By 2050, the world's population is expected to reach 9.0 billion, necessitating a 50% increase in grain output. Furthermore, South, Southeast, and East Asia (SSEEA), where rice and wheat are the main foods, will account for a significant portion of this population growth. Because agricultural land per person in the SSEEA is currently scarce and will continue to be scarce, the majority of the growth in grain output must come from improving crop productivity. Fertilizer nitrogen is responsible for a 30-40% boost in grain yield. The use of nitrogen fertilizers in this area is expected to rise significantly, as will the associated losses of N2O to the atmosphere and nitrate to groundwater and estuaries. If one-fourth (25%) to one-third (33%) of applied fertilizer nitrogen is lost as ammonia and nitrous oxide to the atmosphere and as nitrates to surface and ground waters, about 25.5 to 34 million tonnes (mt) of fertilizer N was lost in 2009, and if fertilizer materials and management remain the same in the future, as much as 55 to 73.3 mt could be lost. In 2009, India's N loss may be 3-4 mt, rising to 6.5-8.7 mt by 2050. Using current urea pricing of US $500 per tonne, India's financial loss in 2009 is 1.5-2.0 billion US dollars, rising to 3.25 to 4.35 billion US dollars in 2050, while the world financial loss is 12.75 to 17 billion US dollars in 2009, rising to 27.5 to 36.6 billion US dollars in 2050.

This is a huge waste of natural resources, energy, and money that has to be stopped as soon as feasible. One option is to use slow release fertilizers (SRF)[3].

2. REVIEW OF LITERATURE

Hans-Werner Olfs in his study discloses about increased crop N absorption efficiency and reduced N losses should, in theory, reduce the quantity of N2O emitted by agricultural sources. Precision in agricultural nutrient management is rapidly improving, which should boost efficiency. Guidelines on excellent agricultural practices for low N2O emissions in specific circumstances, such as irrigated agriculture, and for unique activities, such as deep fertilizer and manure placement, should be feasible to design. Current data, on the other hand, is inadequate for such recommendations. Slow-release fertilizers and fertilizers containing soil enzymatic process inhibitors show potential as solutions that decrease N2O emissions, but they are costly and have a small market share. Benefits and potential issues with its usage need to be clarified more[4].

Avi Shaviv in his study discusses about the agriculture's massive intensification and growing awareness of human health and natural resource sustainability, there has been a movement toward the development of environmentally friendly N application methods that promote sustainable land use and food production. The ability of such methods to synchronize plant nitrogen demand with supply, as well as the capacity to apply preferred N-species compositions and doses, determines their efficacy. They are also affected by the size and complexity of the agricultural operation, and they contain the following important concepts: I Better application modes, such as split or localized (“depot”) application; (ii) Bio-amendments, such as nitrification and urease inhibitors, and combinations of I and (ii); (iii) Use of controlled and slow release fertilizers; (iv) Fertigation-fertilization via irrigation systems, including fully automated and controlled systems; and (v) Precision fertilization in large-scale farming systems The article analyzes the agronomic and environmental implications of the methods as well as their action mechanisms. The methods' applicability to various agricultural sizes, degrees of agronomic intensification, and agro-technical complexity is also investigated[5].

A. Shaviv in his another study focuses on the the use of advanced fertilizers or fertilization techniques to increase nutrient usage efficiency and reduce environmental harm is described. The following are the major variables that influence usage efficiency and pollution: — economic aspects of nutrient losses; — stress conditions imposed on plants at various growth stages; — stress imposed by deficiencies resulting from poor fertilization management; — environmental factors affecting plant-nutrient interactions; — pollution accumulation in the environment or in plants; and — soil degradation caused by improper fertilization. Measures that provide control over the above-mentioned variables are addressed: — provision of favorable nutrient compositions based on synergistic effects in the rhizosphere or in plant tissues; — synchronization of nutrients supply with demand (controlled supply). Controlled or delayed release fertilizers (CRFs or SRFs) or ammonium rich fertilizers modified with nitrification inhibitors (NIs) are used to match nutrient delivery with plant needs and provide preset "beneficial" compositions. Basic issues about the creation of such fertilizers are raised, as well as the necessity to evaluate standards and recommendations for that purpose[6].

3. DISCUSSION

3.1 Slow release nitrogen fertilizers (SRNF):

Slow release nitrogen fertilizers, often known as controlled release fertilizers (CRF), are a novel method to nitrogen fertilization. In agriculture, non-point pollution is minimized. The aim of creating SRNF is to have N release rated to the highest level possible. Nutrient requirements of the developing crop, decreasing the loss of administered nitrogen fertilizer and boosting nitrogen usage effectiveness (NUE). Increased nutrient usage efficiency (NUE) and decreased environmental issues as a result of the management of nutrient delivery is mostly based on two factors: balancing nutrient supply with plant needs and nutrient availability is maintained The complex influences nutrient availability in the soil-plant system. The chemical processes and pathways involved in interactions between plant roots and soil microorganisms in the midst of nutritional depletion The majority of nutritional conversions from one phase to another are dependent on concentration, suggesting that a nutrient supply that exceeds the plant's capacity to absorb it will cause processes to occur. aiming to reduce the nutrient content in the soil Transformations caused by these mechanisms are among them. Chemical reactions (e.g., exchange, fixation, and volatilization) and physical processes (e.g., leaching, runoff, and volatilization) microbes (precipitation and hydrolysis) (e.g., nitrification, denitrification, and immobilization). The degree to which The NUE and the ecosystem are affected by how these mechanisms extract nutrients from soil solution. There is a surplus as a result, better management techniques should decrease the supply of nutrients both temporally and geographically. As the entire nutrient need, the appropriate kind of fertilizer should be administered in the correct quantity and at the right time crop and variety particular peak time of fertilizer need and preferred chemical forms In most cases, the temporal pattern of Seasonal crops, as well as perennials and trees, have sigmoid macronutrient uptake when a plant goes from dormant to physiologically active. As a result, adopting a sigmoidal pattern of nutrient intake is recommended. The optimum nutrition for plant growth and development will be achieved by increasing nutrient absorption and synchronizing nutrient supply with plant demand. Losses caused by mechanisms that compete with nutrient absorption are reduced. The benefits that come with controlling and optimizing nutrition delivery is also addressed in terms of three key factors[7].

3.2 Aspects of Economics:

Potential for Reducing Nutrient Losses: From a practical standpoint, nutrient losses caused by various processes may be deemed "irreversible," at least in the near term. Poor N recovery is frequently caused by such processes, which range from 30-40 percent in poorly managed techniques like paddy rice to 70 percent in well managed ones. To reduce such losses, several researchers have suggested using CRF/SRFs or nitrification inhibitors.

Fertilizer application cost reduction: Fertilizers with a slow or controlled release minimize fertilizer spreading expenses by allowing for a single application of fertilizer for the whole season. Furthermore, like in paddy, SRFs/CRFs decrease the labor requirement for top dressing. Bio-amendments, such as nitrification inhibitors, may be used to reduce the extra application cost[8].

3.3 Aspects of Physiology:

With the use of germination, crop growth and quality, as well as decreased disease infestation, leaf burns, and stem breakage, there are many agronomic benefits linked to improving plant growth conditions. Preferential nutrition formulations are available: The issue of which type of plant nutrients is preferable, especially in the case of ammonium or nitrate nutrition, is receiving a lot of attention right now. In compared to single application of ammonium or nitrate, many articles have shown a substantial increase in grain production or protein content owing to combined ammoniumnitrate feeding. Such results were obtained in experiments where the ammonium/nitrate ratio in the soil could be kept under reasonable control. CRFs with greater amounts of NH4 resulted in better millet yields and enhanced proteinaceous material buildup in plants[9].

3.4 Environmental Considerations:

Any technique of fertilizer administration that increases NUE and synchronizes nutrient supply with plant demand has the potential to minimize environmental losses. Because SRFs/CRFs have a lag in their release, the supply is matched by plant absorption, lowering the risk of environmental contamination. Apart from the immediate savings, SRFs/CRFs are beneficial.

Stress Management: The root zone becomes saturated with high concentrations of soluble salts due to rapid nutrient delivery from traditional soluble fertilizers. This may cause physiological drought and particular damage at various stages of development. The usage of SRFs/CRFs, on the other hand, improves[10].

3.5 Classification of controlled/slow release fertilizers:

Fertilizers with a regulated or delayed release are divided into two categories. SRNFs are divided into two categories: I those with poor solubility by nature, and (ii) coated conventional fertilizers. The first group includes urea form (UF), isobutylidene diurea (IBDU), crotylidene diurea (CDU), oxamide, guanylurea, difurfurlidene triueid, glyculuril, triazines, N-enriched coal, and metal ammonium phosphates, among which UF, IBDU, and CDU are the most important and have been tested extensively. Sulphur coated urea (SCU), polymer coated urea (PCU), neem coated urea (NCU), and N/NP/NPK fertilizers coated with inert materials such as resins, waxes, paraffin, gums, tars, gypsum, ground rock phosphate, and other materials, of which SCU, PCU, and NCU are the most important and have been widely tested and used as SRNF. The phrases controlled release and gradual release are often used interchangeably. However, it has been suggested that the term "controlled release fertilizers" (CRF) be reserved for fertilizers whose rate, pattern, and duration of release are well defined and controllable, whereas "slow release fertilizers" (SRF) be used for fertilizers whose nitrogen release is slowed but the rate, pattern, and duration of release are not well defined and controllable[11].

3.6 Isobutylidene diurea (IBDU):

IBDU has a 32 percent nitrogen concentration. Unlike UF, where the condensation of urea with formaldehyde produces a variety of polymer oligomers with various chain lengths, the reaction of urea with isobutylidene (a liquid) produces a single oligomer. [54] Standards provide for a minimum of 30% nitrogen, with 90% of it being cold water insoluble (CWIN) (prior to grinding). The rate of N release from IBDU is influenced by particle size, soil moisture, temperature, and pH, as well as chemical makeup. Experiments with rice in Japan showed that IBDU resulted in a 12-25 percent greater grain yield when compared to ammonium sulphate and urea. It was also discovered that the release of nitrogen from IBDU was significantly faster in acidic soils than in alkaline soils. In a field trial in New Delhi, IBDU generated 6.6 percent more rough rice than a split urea treatment, and 11.2 percent more rough rice than a single urea application. The advantage of IBDU over urea was much greater under alternate wetting and drying moisture regimes, where N losses are higher, and at 150 kg N/ha, where IBDU produced 26% more rough rice than a single application of urea. When IBDU was compared to split application of urea, the increase was 11%. IBDU is often sold in mixes with traditional nitrogen fertilizers, and its use is currently limited to speciality agriculture[4].

3.7 Crotylidene diurea (CDU):

CDU is produced by an acid catalyzed reaction of urea with acetaldehyde and contains approximately 32.5 percent nitrogen. Like IBDU, particle size affects the rate of N release; the bigger the particle size, the slower the release. Hydrolytic and microbiological reactions release nitrogen from CDU. It's a specialized agricultural fertilizer once again[6].

3.8 Sulphur coated urea (SCU):

It has a sulphur content of 30-40%. The Tennessee Valley Authority (TVA) was the first to build it in 1961. In a revolving drum, preheated urea granules were sprayed with molten sulphur (10-20% by weight). After that, a wax-like polymeric sealer is used to cover the pores and fissures in the coating (2-3 percent by weight). Finally, a conditioner (2-3 percent by weight) is added to create a free-flowing, dust-free product. Coating thickness and quality influence nitrogen release in SCU, as well as the rate of microbial and hydrolytic decomposition. The release of nitrogen from SCU was greater under a field capacity moisture regime in a laboratory research in New Delhi than under continuous flooding or alternating wetting and drying. Under continual flooding, however, the release of N from IBDU was greater. During rabi (dry) season, SCU provided 1.8 t/ha more rough rice than urea given in a single dressing in field trials under the ICAR's All India Coordinated Rice Improvement Project, but findings were not as promising during kharief (wet) season (AICRIP, 1970). SCU, on the other hand, provided 0.7 to 1.7 t/ha more rough rice than urea during the kharief season in New Delhi. Further, in decreased waterlogged circumstances, such as those seen in rice, some S may be converted to ferrous sulphide, preventing urea particles from coming into touch with urease and therefore lowering its availability. This may explain why SCU failed to perform well in certain tests. SCU has a significant benefit in terms of providing S, which may be particularly helpful in India, where almost half of the country's soils are low in S. SCU has the drawback of floating in standing water and is washed away when applied on sloping terrain. Depending on the quantity and thickness of the coating, polymer coated urea (PCU) contains 40-44 percent nitrogen. In terms of nitrogen concentration, PCU outperforms SCU and urea aldehyde condensates, which contain just 30-38 percent nitrogen. PCU has received much more research than any other coated fertilizer.

Polymer coatings on urea are porous membranes that are semi-permeable or impermeable. Unlike SCU, IDBU, FU, CDU, and NCU, where soil characteristics influence N release, PCU relies mainly on temperature and the permeability of the polymer used for coating to release N. PCU may be programmed to release nitrogen for 70 to 400 days, depending on the crop's needs. Although the majority of the polymers utilized are photodegradable, some may remain in soil for a long time. In Japan, PCU is utilized in rice cultivation, and it has been observed that using less PCU than urea results in the same yield. A single dosage of PCU may decrease rice production costs by 30-50 percent in zero-till farming methods. In a field trial, however, PCU (3 or 6% coating) provided comparable rice yields to urea, but much greater N uptake than urea; the AREn was 55.9% with PCU compared to 35% with urea. In a laboratory research, PCU resulted in lower ammonia volatilization losses than urea[8].

3.9 Neem coated urea (NCU):

The Indian Agricultural Research Institute (IARI) in New Delhi produced a neem (Azadirachta indica Juss) coated urea (NCU). It all began with a rice field experiment, when urea supplemented with an acetone extract of Neem kernels improved crop production and even outperformed SCU. It was followed by the creation of urea-coated Neem cake (left over after oil extraction) (NCCU, generally referred to as NCU). Because there was an energy crisis at the time, neem cake was utilized to conserve oil. A coaltar:kerosene (1:2) solution was used as a sticker to cover neem cake (15-20% by weight of urea) on urea in a revolving drum. NCCU has been shown to outperform urea in a variety of crops, including rice. The anti-nitrification effects of neem cake have been documented. The fertilizer business, however, could not adopt this method since it required huge quantities of neem cake. A factory generating 1000 t/day of NCCCU will need 150-200 t/day of neem cake.

A neem oil micro-emulsion method was subsequently developed since nitrification inhibitors in neem are lipid associated. This method only required 0.5 kg neem oil per tonne of urea. The results of this modified neem coated urea (NCU) were promising, with NCU yielding 8-11 percent more rice grain than urea in a significant number of on-farm experiments in the states of Haryana, Uttar Pradesh, Punjab, and Delhi. Due to a modest government subsidy, this method or a variation of it is presently being utilized to produce NCU in India, and it is now being supplied to farmers at the same price as urea. NCU is free-flowing, and storage caking is considerably lower than urea.

Because neem products may manage a wide range of plant diseases, including insects, nematodes, disease-causing bacteria and fungus, NCU should be considered not just as a slow-release or nitrification inhibitor mixed fertilizer, but also as a "soil health fertilizer." On addition, most Asian farmers who spread urea in rice fields by hand experience discomfort, but this is not the case with NCU[10].

3.10 Nitrification inhibitors and SRNFs:

Although a vast variety of compounds have been claimed to impede nitrification, only four have been commercially manufactured and extensively studied. In the United States, N-serve or nitrapyrin (2-chloro-6 trichloromethyl pyridine) is used, whereas in Japan, AM (2 amino-4-chloro-6 methyl pyrimidine) and ST (sulphathiazole) are used, while in Germany, DCD (dicyandiamide) is used. N-serve is the only one of them that is commercially available in the United States for crop production. It is widely known that combining these minerals with urea lowers nitrate production and therefore reduces nitrogen loss via leaching and denitrification. According to extensive analyses of such research, most crops and cropping methods may achieve a 10-20% improvement in NUE when compared to PU. The use of these materials has also been proven to reduce 30-40% of the crop's nitrogen requirements. As a consequence of these findings, the Indian government has decided to include NCU in the fertilizer (Control) Order. Increased NUE and PUE may be achieved by combining ammonium N sources with the nitrification inhibitor 3, 4-dimethylpyrazole phosphate (DMPP). Phosphogypsum (PG), diammonium phosphate (DAP), zinc sulfate ($ZnSO4$), and potassium chloride (KCL) compacted individually with urea delayed urea hydrolysis and decreased $NH3$ volatilization loss[5].

3.11 Crop growth and SRNFs:

Since the early 1970s, many studies have shown that neem coated urea (NCU) outperforms prilled urea (PU) in boosting rice grain production under irrigated circumstances. In comparison to PU, NCU and pusa neem golden urea (PGNU) enhanced apparent N recovery in rice. Coating PU with PGNU gives it anti-caking and anti-dusting characteristics, as well as increasing its agronomic efficiency (crop response to fertilizer application). However, as compared to uncoated PU, covering urea with lac, coaltar, lisa (resin), and wax has had little success. The IARI's urea coating technique, which uses a neem oil emulsion and requires 0.5-1.0 kg neem oil per tonne urea, outperformed prilled urea. National Fertilizers Limited's neem coated urea has a longer shelf life, a slower dissolving rate, and a nitrification inhibitory effect. In Punjab, Uttar Pradesh, and Himachal Pradesh, the product had a higher NUE with a somewhat higher coating cost.

Sulphur coated urea (SCU) has outperformed other materials in lowland rice because it releases nitrogen for a longer length of time, synchronizing with key phases of crop development. Because leaching and denitrification losses occur only after the formation of nitrates, attempts have been undertaken to keep applied fertilizer in ammonical form using a class of compounds called as nitrification inhibitors. Increased NUE or perceived N recovery efficiency may be aided by the use of nitrification inhibitors. Maintaining a higher level of NH4 + in the soil may improve P absorption and, as a result, P usage efficiency (PUE)[2].

3.12 Response of yield and nitrogen loss to efficiency fertilizers:

CRFs have been shown to be superior than traditional fertilizers in a number of agronomic studies. Table 4 shows the enhanced production of cereal crops, oil seeds, and vegetables when CRFs are used. Experiments were performed at IARI in New Delhi, and it was shown that NCU and PNGU generated substantially greater grain yield than PU among various nitrogen sources. Similarly, when NCU was administered at planting or at planting and panicle start, grain production was substantially greater than when PU was applied at planting. This was attributed to a delay in the conversion of ammonia to nitrite, which improved and extended the rice crop's continuous supply of nitrogen. The use of delayed release N fertilizers over prilled urea, either basal or split, resulted in substantially greater N absorption by rice grain. NCU ranked first, followed by LGU, MRPU, and PU in terms of fertilizer nitrogen recovery. With basal and split applications of NCU, maximum nitrogen recovery was achieved. Thus, NCU applied at planting or at the planting and panicle initiation stage was most suited in the rice environment, since it met the rice plant's N requirement slowly over time, minimizing groundwater pollution. Because there was more N available following rice harvest, NCU resulted in a higher grain yield of subsequent wheat than PU. Furthermore, NCU, MRPU, and LGU all had a comparable impact on wheat production. However, the impact of NCU was substantial when compared to the use of prilled urea alone[5].

4. CONCLUSION

CRF/SRF fertilizers have a nitrogen release pattern that is more likely to meet crop growth and demand, resulting in better yields and nitrogen usage efficiency. In general, CRF/SRF are claimed to improve crop production by 5-40%, and in many instances, the additional yield more than compensates for the higher fertilizer cost, which may be 2-3% more than urea. Despite increasing fertilizer usage throughout the nation, the partial factor productivity of fertilizers has been decreasing recently, as shown by stagnating food grain output. Losses owing to ammonia volatilization, leaching, denitrification under flood conditions, run-off, fixation as nonexchangeable NH4 +, and immobilization by soil microorganisms are all reasons of poor nitrogen use efficiency (NUE). Unrecovered nitrogen has the potential to pollute groundwater, cause acid rain, and contribute to global warming. Slow release nitrogen fertilizers solve this issue by releasing tiny quantities of nitrogen at the right time for the crop and improving nitrogen efficiency by reducing nitrogen losses. SRNF lowers fertilizer application costs, decreases stress and particular toxicity, and minimizes pollution in the environment. However, a greater knowledge of nutrient release from such fertilizers is required, as is the development of improved methods for the manufacture of low-cost SRNF/CRNF.

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