Slow and Controlled Release Nitrogen Fertilizers: Options for Improving Rice Productivity : A Review

ABSTRACT

Rice (*Oryza sativa* L.) is the most important food crop not only in Asia but also in the entire world. Over the past several decades, conventional fertilizer application for rice has caused the loss of nutrients, which could lead to a series of environmental problems such as eutrophication and greenhouse effects. The emergence of slow and controlled-release fertilizers provides a new option for more efficient fertilization of rice. International Fertilizer Association (IFA) included controlled release fertilizers (CRFs), slow release fertilizers (SRFs), sulphur coated urea (SCU), stabilized nitrogen fertilizers (SNFs), WSFs, liquid NPKs, and chelated micronutrients and boron in their assessment study of the global market for special products. In India, the specialty fertilizers are categorized broadly as water soluble fertilizers, neem coated urea, fortified fertilizers, customized fertilizers (CFs), micronutrient fertilizers, and liquid fertilizers. Controlled-release fertilizers, such as sulphur and/or resin coated urea, can reduce N losses (e.g. nitrogen leaching, ammonia volatilization), while increasing N availability in plant and enhance rice grain yield upto 22.1% in rice. These, slow release controlled fertilizer increase crop yields by maintaining soil health over time.

Key word: Slow released controlled fertilizer, importance, Rice yield , soil health

1. INTRODUCTION

"Rice (*Oryza sativa* L.) is the most important food crop not only in Asia but also in the entire world, as it feeds almost half of the world population" [27]. "It satiates the hunger of nearly 60% Indian population and accounts for 40% of the total food grain production of the country" [1]. "Rice is being cultivated under diverse agro ecologies varying from irrigated, upland, rainfed lowland to flood prone rice ecosystems. To overcome the production vulnerabilities in rice, the scientific taskforce at the Indian Council of Agricultural Research has developed many high yielding, input responsive cultivars with productivity more than 6.0 tha^{-1} and good cooking quality characteristics. Despite significant progress, the average productivity of rice in India is low. One of the prime reasons for the lower productivity of Indian rice is improper nutrient management. In rice, intensive cultivation and introduction of input-responsive high-yielding varieties combined with application of major nutrients in rice lead to multiple nutrient deficiencies" [39].

"Over the past several decades, conventional fertilizer application for rice, mostly divided into 3–4 applications and consisting of basal and top-dressing, is a high-demand, time-consuming and labor-intensive approach. This method might cause the loss of nutrients, which could lead to a series of

environmental problems such as eutrophication and greenhouse effects" [41]. The emergence of slow and controlled-release fertilizers (SCRF) provides a new option for more efficient fertilization of rice.

1.1.Impact of Non Judicious Use of Conventional Fertilizes

India made rapid growth in fertilizer consumption after the introduction of high yielding varieties in mid-1960s and by 2005, the country became the 2nd largest user of fertilizers in the world in terms of total nutrients. However, the per hectare fertilizer consumption is still low and imbalanced at the macro level. The imbalanced and inefficient use of fertilizers have led to the accelerated emergence of multi nutrient deficiencies, low nutrient use efficiencies, declining partial factor productivity, a lowering of crop yields and farm profits, and environmental pollution [23]. "Though the chemical fertilizer increases the plant growth and vigour, hence meets the food security of the world, but the plants grown in this way does not develop good plant characters such as, good root system, shoot system, nutritional characters and also will not get time to grow and mature properly. Chemically produced plant will accumulate in the human body, toxic chemicals, which are very dangerous. The deleterious effect of the chemical fertilizers will itself start from the manufacturing of these chemicals, whose products and byproducts are some toxic chemicals or gases like NH4, CO2, CH4 etc. which will cause air pollution. And when the wastes from the industries are disposed off untreated into nearby water bodies it will cause water pollution. It also includes the most devastating effect of chemical waste accumulation in the water bodies i.e., the water eutrophication. And when added in soil, its continuous use degrades the soil's health and quality hence causing soil pollution"[6]. "Repeated applications of chemical fertilizer may result in a toxic buildup of heavy metals such as arsenic, cadmium, and uranium in the soil. These toxic heavy metals not only pollute the soil but also get accumulated in food grains, fruits and vegetables. For example, Fertilizers like Triple superphosphate has trace elements like cadmium and arsenic that accumulate in plants through food chains reach to human that may cause health problems. The effects of chemical fertilizers on soil are great and irreversible" [28].

Other Deleterious Effects of Chemical Fertilizers

i. Excessive use of chemical fertilizer, especially N, can contribute to crop tip browning, lower leaf yellowing, wilting and crop lodging. When fertilizer scorches roots, the root may blacken and go limp. All these symptoms occur due to salt accumulation in the soil which would cause difficulty in water absorption by plants.
ii. "Using higher doses of N fertilizers in malt barley may cause undesirable effect on quality of the beer. Over-application of chemical fertilizer to plants may cause the leaves to turn yellow or brown, damaging the plant and reducing the crop yield" [5].
iii. "The excessive accumulation of nitrate or nitrite in plant parts consumed by humans or animals is likely to cause the same detrimental effects associated with nitrate contamination of water sources" [5].

iv. Over-fertilization effects reduce the biodiversity resulting from ammonia deposition in forests and waters

v. “They reduce mycorrhizal root colonization and inhibit symbiotic N fixation by rhizobia due to high N fertilization” [32].

vi. 7. Nutrients are easily lost from soils through fixation, leaching or gas emission, can lead to reduced fertilizer efficiency

1.2.Challenges in Fertilizer Production

The fertilizer industry faces a continuing challenge to improve its products to increase the efficiency of their use, particularly of nitrogenous fertilizers, and to minimize any possible adverse environmental impact. This is done either through the improvement of fertilizers already in use, or through the development of new specific fertilizer types. “Rice is the most consumed cereal grain in the world, constituting the dietary staple food for more than half of the planet’s human population with an ever increasing population; demand for rice continues to increase. India need to raise its food grains targets at a rate of more than 4 million tonnes per annum and to maintain self-sufficiency, annual production needs to increase by two million tonnes every year. The annual consumption of fertilizers, in nutrient terms (N, P & K), has increased from 0.07 million MT in 1951-52 to more than 28 million MT in 2010-11 and per hectare consumption, has increased from less than 1kg in 1951-52 to the level of 135 kg 2010-11”[18].

1.3.Availability of Slow Release Fertilizers

Specialty fertilizers include an array of products ranging from low-end stabilized nitrogen fertilizer products for broad area cropping systems, to high value premier products ranging from water soluble fertilizers (WSFs) for foliar fertilization and drip-fertigation to controlled release fertilizer products for turf and ornamental plants. There is no universal definition or category of specialty fertilizers. International Fertilizer Association (IFA) included controlled release fertilizers (CRFs), slow release fertilizers (SRFs), sulphur coated urea (SCU), stabilized nitrogen fertilizers (SNFs), WSFs, liquid NPKs, and chelated micronutrients and boron in their assessment study of the global market for special products (Fig.1). In India, the specialty fertilizers are categorized broadly as water soluble fertilizers, neem coated urea, fortified fertilizers, customized fertilizers (CFs), micronutrient fertilizers, and liquid fertilizers. Nitrogen (N) has drawn maximum attention in the specialty nutrition. A number of products such as CRFs, SCU, SRFs, SNFs have been developed to bring significant increase in nitrogen use efficiency. Because specialty fertilisers are more expensive than bulk products, they are mostly used in developed countries. These fertilizers are mostly used in high value crops, horticulture, turf, landscape, etc. justifying for premium value[23].

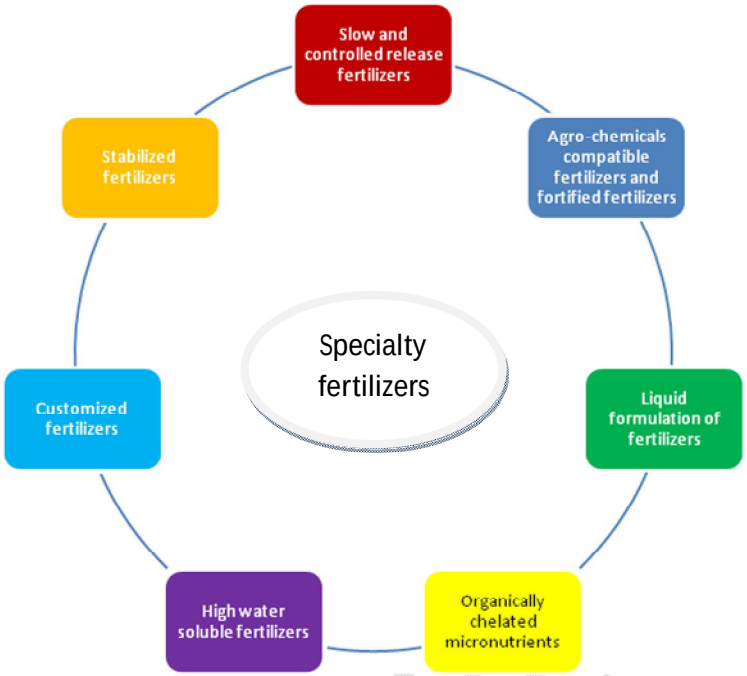

Fig. 1. Specialty fertilizers [7]

1.4.Current status of specialty fertilizers

Global specialty fertilizers market registered a significant growth over the last decade with compound annual growth rate (CAGR) ranging from 6% in Water Soluble Fertilizers to more than 16% in controlled release fertilizers (Fig.2). The global consumption of specialty fertilizers reached 20.4 million tonnes (Mt) in terms of products and 9.0 Mt in terms of nutrients in 2018. These fertilizers represent 10% of the total fertilizer market in terms of value and nearly 5% of nutrient volume. The main drivers for growth of specialty fertilizers are base fertilizer, cropping systems, soil and climate conditions, regulations, and value-in- use. East Asia, North America, Latin America, and West and Central Europe are the major markets for specialty fertilizers. The country has witnessed sharp increase in consumption of water soluble fertilizers in recent years, reaching a level of 2,65,000 t in 2019-20. Expansion in area under horticulture and high value crops, and increased coverage under micro-irrigation have been the key drivers of growth in the consumption of Water Soluble Fertilizers. With a view to promote and regulate their use, the Government of India (GOI) notified Water Soluble Fertilizers in FCO in 2003. The use of Water Soluble Fertilizers is largely concentrated in the horticulture growing areas of Maharashtra, Karnataka, Andhra Pradesh, Tamil Nadu, Gujarat, and Uttar Pradesh. It may be mentioned here that there is no subsidy on Water Soluble Fertilizers. Farmers have accepted these fertilizers on merits in terms of increase in yield, quality of crop and net income [23].

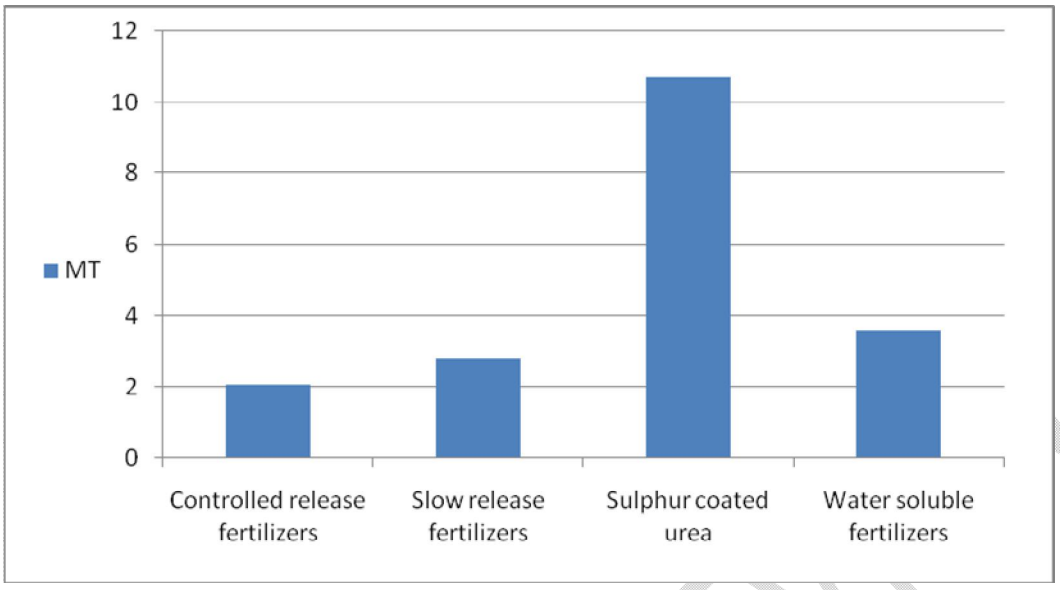

Fig. 2. Global consumption of specialty fertilizers

1.5.Reason for concentrating on Nitrogen management through slow release fertilizers

"The efficiency of fertilizer nitrogen is only 30-40% in rice and 50-60% in other cereals, while the efficiency of fertilizer phosphorus is 15-20% in most crops. The efficiency of K is 60-80%, while that for S is 8-12%" [22]. Slow release fertilizer is a fertilizer containing a plant nutrient in a form that delays its availability for plant uptake and which extends its availability to the plant significantly longer than a normal fertilizer such as ammonium nitrate, urea, ammonium phosphate or potassium chloride . Nitrogen (N) has drawn maximum attention in the specialty nutrition. It poses maximum risk to environment as the N not used by plant either leaches down to groundwater as nitrate or lost to the atmosphere in gaseous form namely, ammonia and nitrous oxide (a highly potent greenhouse gas). The production and consumption of N is largest among all the plant nutrients. Improvement in nitrogen use efficiency is critical to address the challenges of global food security, environmental degradation, and climate change. A number of products such as CRFs, SCU, SRFs, SNFs have been developed to bring significant increase in the nitrogen use efficiency. Being costlier than bulk products, use of these specialty fertilizers is limited largely to the developed countries. These fertilizers are mostly used in high value crops, horticulture, turf, landscape, etc. having justification for premium value[23]. Development of neem oil coated urea (NCU) in India has drawn global attention and the milestone of neem oil coated urea given in Table 1.

Table 1. Milestone of neem coated urea

S.No.	Particulars	Year
1.	Indian scientists reported nitrification inhibiting properties of Neem	early 1970s
2.	developed neem cake coated urea (NCCU)	1983
3.	Superiority of NCCU over prilled urea was established	1980s & 1990s.
4.	zincated urea (2% Zn) was the first fortified fertilizer notified by FCO but its commercial production	1992

5.	GOI permitted NFL and two other companies to produce and market NCU	2004
6.	There was not much production and sale due to additional cost incurred for NCU	2007-8
7.	Government of India introduced a policy for encouraging the production and availability of fortified and coated fertilizers	2008
8.	GOI allowed urea manufacturers to recover the cost of coating from farmers by selling NCU at a price of up to 5% above maximum retail price	2008
9.	GOI made it mandatory to produce 100% of indigenous urea as neem-coated urea and coating of entire imported urea on its arrival at the ports.	May, 2015,

It must be recognized that the nutrient needs of Indian agriculture are now bigger and more varied. Fertilizers are a costly input and their availability is also limited. These should be used in the most efficient manner under fertilizer best management practices developed on the 4R Nutrient Stewardship principles. The use of specialty fertilizers except WSFs remains low. To encourage the production and use of specialty fertilizers, GOI should bring in policy reforms in terms of easy introduction of new innovative fertilizers, NBS for all fertilizer products in schedule I of FCO subject to some safeguards and uniform tax structure. The present issue of Indian Journal of Fertilizers is devoted to the theme of 'Role of Specialty Fertilizers in Indian Agriculture' with contributions from specialists both from research institutions and industry [23].

1.6.Need of Slow Release Controlled Fertilizer

Rice is an important crop and plays a vital role in Indian production and economy. The livelihood of almost 83% of rural population of the state is dependent only on rice cultivation, but the productivity of rice in the state is very low (1.3 t/ha) even below to the national average (2.37 t/ha). "The decrease in productivity was observed to be associated with the new emerging problems of deficiency of nutrients such as Nitrogen and zinc (Zn).In cultivation of rise, health and nutrient status of the soil were noted decline even in irrigated areas due to application of inadequate and unbalanced quantity of fertilizers" [24]. "There is yield gap due to inadequate and imbalance supply of fertilizers and lack of distinct fertilizer recommendation for plenty of varieties and hybrid of rice. The balance nutrients supply for the crops resulted no or minimal deleterious effect on environment as well as soil" [11].

The main causes of low and declining crop response to fertilisers are: continued use of fertiliser N alone or in combination with insufficient P and K application, resulting in mining of native soil P and K; continued use of intensive cropping systems with high yielding varieties even under recommended NPK use; and use of high-analysis fertilisers lacking secondary and micronutrients, resulting in imbalanced fertilization.Slow-release fertilisers based on crop response will be developed to improve fertiliser use efficiency through balanced fertilization.

1.7.Functions of Slow Release Controlled Fertilizer in Soil.

Specialty fertilizers are innovative sources of nutrients which applied in special condition of soil and plant for special action in plant for achieving higher recovery, efficiency and economy. Specialty fertilizers restrict the amount of moisture contact and help gradually release fertilizer nutrients, usually over a few weeks or a few months. Specialty fertilizers contribute to advanced fertilizer management programs and to innovative farming systems such as no-tillage farming. They significantly reduce possible loss of nutrients, particularly losses of nitrate nitrogen between applications, uptake by the plant through gradual nutrient release. They also reduces the loss of ammonia due to evaporation, which substantially decreases the risk of environmental pollution.

"Controlled or slow-release fertilizers have been developed to overcome the demerits of ordinary urea. Urea dissolved in soil within 7-10 days after its application. As we know, N plays an important role in vegetative growth of plant. Most of Urea applied at the time of planting when N utilized by the crop is very less so most of the applied urea is wasted whereas at vegetative growth stage when the demand of nutrient is more the crop suffered mostly by nutrient stress. Controlled release fertilizer (CRF) is developed which-releases nutrients in slow manner and provided to the crop throughout the life cycle" [25]. "The most widely used agriculturally important slow or controlled release fertilizers are coated urea such as sulphur coated urea (SCU), neem coated urea (NCU) and polymercoated urea, nitrification inhibitors, urease inhibitors etc. The shelf life of ordinary urea is improved with the coatings of different emulsions and helps to retain urea in the field for a long time to increase the yield and improve the crop qualities" [20].

1.8. **Characteristics of Slow Release Stabilized Fertilizer**

The growing requirement for high quality crops, environmental concerns, and thrust on improved nutrient use efficiency (NUE) have driven the growth of specialty fertilizers world over. These fertilizers bring additional benefits to growers by way of enhancing nutrient availability, slowing down bacterial activity, and meeting the exact nutrient needs of the crop. "The specialty fertilizers are developed through sustained experimentation to suit matrix of soil fertility status, type of crop, and availability of water under specific climatic conditions. The application schedule for these fertilizers is also developed taking into account the crop growth stage and the physical, chemical and biological properties of the soil" [23].

"They are multi nutrient carrier designed to contain macro and/or micro nutrient forms, both from inorganic and/or organic sources, manufactured through a systematic process of granulation, satisfying the crop's nutritional needs, specific to its site, soil and stage, validated by scientific crop model capability developed by an accredited fertilizer manufacturing/marketing company. The polymer or sulfur coated urea fertilizers used in this study have a protective (water-insoluble) coating around the urea nucleus. Nitrogen release from coated controlled release fertilizers is mainly controlled by the thickness of the coating material, and is also affected by temperature and humidity" [34].

"UF fertilizer is formed by the controlled reaction of formaldehyde with excess urea under controlled conditions, resulting in a mixture of methylene urea with different long-chain polymers. Nitrogen release from UF is influenced by the length of polymer chains as well as soil organisms and their activity. N release from UF was more stable and effective than polymer or sulfur-coated urea at high temperatures and humidity in southern China" [8].

1.9.Role of Slow Release Stabilized fertilizer in Nutrient Management

Urease inhibitors and nitrification inhibitors are commonly known as stabilized fertilizers. Urease inhibitors prevent or suppress over a certain period of time, the transformation of amide-N in urea to ammonium hydroxide and ammonium through the hydrolytic action of the enzyme urease. By slowing down the rate at which urea is hydrolyzed in the soil, volatilization losses of ammonia to the air (as well as further leaching losses of nitrate) is either reduced or avoided. Thus, the efficiency of urea and of N fertilizers containing urea (*e.g.* urea ammonium nitrate solution), is increased and any adverse environmental impact from their use is decreased. N-(n-Butyl) thiophosphoric triamide (NBPT), phenyl phosphorodiamidate (PPD/ PPDA) and hydroquinone are probably the most thoroughly promising urease inhibitors.

"Compared with urea, SCRF with a regulated release of nutrients is considered an effective way to satisfy crops' nutrient demand during the whole growth stage with a single basal application. According to the production process, SCRF can be divided into three main types: coated fertilizers, stable fertilizers and chemically synthesized organic fertilizers" ([31]. "Coated fertilizers are formed by applying or wrapping a layer of inorganic or organic matter on the granule surface, such as sulfur-coated fertilizers (SCU) and polymer-coated fertilizers (PCU). Nutrients from SCU are released through the micro pores on the coating material and the cracks that develop after the sulfur film is broken. However, the sulphur material itself is inelastic and fragile, which may cause incomplete coating or cracks. SCU are prone to "burst release" at a certain stage, with a release period of 30–90 days" [37].

"In contrast, PCU controls the release through the osmotic adjustment of semi permeable or impermeable membranes with micro pores. As a result, the release will be more precise and can even be synchronized with rice absorption efficiently, if soil temperature and humidity conditions are suitable. Stable fertilizers are mainly produced by adding urease inhibitor, nitrification inhibitor or other materials that slow the release of fertilizers, such as urease inhibitor urea (AHA). Of these, urease inhibitors and nitrification inhibitors can delay fertilizer release by competing with urea through a sulfhydryl reaction and inhibiting nitrification thanks to its toxicity to nitrifying bacteria, respectively" [40].

1.10.Effect of Slow Release Stabilized Fertilizer on Rice Yield

"Nitrogen The fertilizers tested in these experiments were mainly divided into three types: controlled-release fertilizers, slow release fertilizers and rapid-release fertilizers. Relative difference in release period of the three types is shown as: controlled-release>slow-release>rapid-release; but based on SPAD values, the release period was not equal to the effective duration time, particularly as the effective duration time of rapid-release fertilizers could continue until heading stage. Rice yield increased significantly under controlled release fertilizers, while slow-release fertilizers had little effect on yield, and rapid-release fertilizers had varying effects on yield as they were susceptible to environmental factors. Therefore, given a fixed amount of nitrogen is applied to the pot, the stronger the nitrogen supply capacity and the longer the effective duration time of the fertilizer, the higher the dry matter accumulation at the late growth stage, and the higher the rice yield" [21].

"The results of this study suggest that selection of S/CRF type and fertilization mode can positively impact rice yield and quality while also saving associated labor costs (Table 2). However, the effects of S/CRF type and fertilization mode on rice yield and quality differed by the mechanism of nitrogen release (i.e., slow or controlled). The polymer or sulfur coated urea fertilizers used in this study have a protective (water-insoluble) coating around the urea nucleus. Nitrogen release from coated controlled release fertilizers is mainly controlled by the thickness of the coating material, and is also affected by temperature and humidity" [34].

"Controlled-release fertilizers, such as sulphur and/or resin coated urea, can reduce nitrogen losses (e.g. nitrogen leaching, ammonia volatilization) to the environment [40], while increasing nitrogen availability for plants. The utilization of CRU could enhance rice grain yield and nitrogen use efficiency compared to CF" [30]. "In rice fields, previous studies have shown that CRU application had no (Ji et al., 2014) or a negative effect [2] on CH4 emission, but mitigated N_2O emission relative to the application of CF" [13]. "The application of CRU slows down the release of available N, which may affect soil C/N cycling and then alter CH4 and/ or N_2O emissions" [29].

"Nitrogen plays a key role in rice production and it is required in large amount. Nitrogen is the most important limiting nutrient in rice production and has heavy system losses when applied as inorganic source in puddle fields. It is necessary to find out the suitable rate of nitrogen fertilizer for efficient management and a better yield of rice. Urea is the most frequently used nitrogen fertilizer globally. Urea can be applied in different ways. It was observed that urea super granules (USG) can minimize the loss of nitrogen from soil and hence the affectivity increased up to 20-25% compared to crystal urea" [10].

"It is important to provide rice plants with sufficient available nutrients in order to avoid yield reduction. The nutrients should be easily available during the time of highest consumption and demand of the plant. Plant feeding is considered an important part of 2030 Agenda for Sustainable Development, which

includes 17 Sustainable Development Goals (SDGs). Farmers face the challenge of avoiding causing damage to the environment and producing agricultural products sustainably whilst maintaining high plant yields. The goal of nutrition management is to supply plants with suitable amounts of necessary nourishing materials during the growth season" [9]. "Foliar feeding is a common agricultural management practice used to increase plant growth and yield" [4].

Table 2. Effect of controlled slow realese fertilizer on yield of rice.

S.No.	Particulars	% increase in yield	Reference
1.	Urea supper granuels	22.03%	*10*
2.	Prilled urea and Urea super granules	18%	9
3.	Single carbon-based slow-release urea	3.3–7.2%.	17
4.	PCU and SCU	8.6 and 1.2%	16
5.	Slow- and controlled-release fertilizers	5.0–6.9% & 12.3–13.7%	35
6.	Single application of PCU	6.0–21.0%	29
7.	Neem coated urea	12.4%	3
8.	Controlled-release fertilizers	6.8-18.2 %	29

1.11.Role of Slow Release Stabilized fertilizer on Soil Properties

The release period of stable fertilizers depends on soil conditions, and is usually short, resulting in unstable applications. The chemically-synthesized organic fertilizers mainly consist of urea-formaldehyde fertilizers produced by the polycondensation reaction of urea and formaldehyde, and act to enhance soil microbial activity and root vitality. The most widely used urea-formaldehyde (UF) releases nutrients through microbial decomposition, affected by size, microbial activity, soil texture, and pH [25].

1.12.Role of Slow Release Stabilized fertilizer in Cost Economics

Multiple applications require additional time and labor, which will not meet the high efficiency demand of modern rice production. Slow or controlled release nitrogen fertilizer (S/CRF) contain nitrogen in a form which delays availability for plant uptake post-application, thus eliminating the need for multiple applications. Some research indicates that using S/CRFs can decrease NH4 + concentrations in the surface and soil solution, which could lead to reduced loss through ammonia volatilization. The continual release of nitrogen from S/CRFs ensures adequate nitrogen supply for plant uptake throughout the growing season. Therefore, use of S/CRFs in rice production can lead to increased yield, increased N use efficiency, improved root structure increased activity of nitrate reductase and glutamine synthetase [38], and delayed leaf senescence in late growth stages. At the same time, use of S/CRFs have reduced greenhouse gas emissions including methane and nitrous oxide compared to use of common urea in rice paddies [33], thus having a lower impact on the environment. According to the production process, S/CRF can be classified into two main groups. One is condensation products of urea and urea-aldehydes (slow release fertilizers) and the other is a coated or encapsulated fertilizers (controlled-release fertilizers). Compared to sulfur-coated urea, polymer coated urea releases nitrogen more slowly, which can dramatically increase above-ground biomass and grain yield with the continuous nitrogen supply,

particularly at the late growth stage [35]. Furthermore,[36] reported that use of a mixture of sulfur and polymer coated controlled release urea led to enhanced rice yield, larger leaf area index, and higher photosynthetic potential compared to use of these fertilizers individually. Although the effects of S/CRF on rice yield, N absorption and N utilization have been thoroughly studied, little is known about the influence of fertilizer type and fertilization mode on rice quality. To achieve these comprehensive goals (i.e., steady yield, high quality, reduced labor, environmentally friendly), improved fertilization methods will be essential. In this study, experiments were designed to study the effects of S/CRF type and fertilization mode on rice yield and quality. These experiments included three types of S/CRF (polymercoated urea (PCU), sulfur-coated urea (SCU), and urea formaldehyde (UF)) and two fertilization modes (both S/ CRF and common urea (CU) as basal fertilizer, S/CRF as basal and CU as tillering fertilizer.

1.13.Benefits of Slow Release Control fertilizer

Indian fertilizer companies started the R&D work on specialty products in early 1980s. IFFCO developed urea super granule (USG), a slow release nitrogenous fertilizer and conducted large scale field demonstrations/trials to evaluate its agronomic efficacy. These demonstrations /trials established the superiority of USG over the prilled urea and USG was included in the FCO in 1990. The absence of suitable applicator for placement of USG in soil was the main constraint in its adoption by the farmers. The National Fertilizers Limited (NFL) developed urea ammonium nitrate (UAN), a liquid nitrogenous fertilizer. Based on agronomic advantages, UAN was included in FCO in 1995. Again, the use of UAN could not be commercialized due to transportation and storage problems [23].

According to FCO, Customized fertilization means the use of the fertilizers best management practices (BMPs) and is generally assumed to maximize crop yields while minimizing unwanted impacts on the environment and human health. Present scenario of nutrient deficiency in our country is not uniform over the regions but location, region, soil and crop specific. Thus, it requires the soil, crop and action specific fertilizers best management practices (BMPs). Customized fertilizers are such specialty fertilizers which are being made for specific condition of soil and recommended for special crops. Scientific principles such as geo-referencing, sampling of soil, plant and water samples from the chosen area, defining management zones, yield targeting, calculating nutrient requirement, blending of nutrients based on the generated information are used as an ultimate guiding factor in deciding the grades of customized fertilizers.

Featured benefits of slow release neam coated urea [7]

1. Slow down the process of nitrification of urea.
2. Neem Coated Urea reported improved yield up to 48%,
3. Decrease urea requirement by 50% and
4. Controls soil born nematodes, termites and another pest due to pesticide properties.

The utilization rate of N, P, K and micronutrients in mineral fertilizers is about 50-60%, 10-25%, 50-60%, and 2-5 % respectively in the first year. Loss of nutrient from the applied fertilizers takes place through a number of processes such as leaching, volatilization, denitrification and fixation by soil particles. Quick or uncontrolled release of nutrients intensifies these processes. Thus, slow or controlled release specialty fertilizers gained importance since they improves the nutrient recovery and nutrient use efficiency by controlling the loss of nutrients. Slow or controlled release fertilizers containing a plant nutrient in a form which delays its availability for plant uptake and use after application, or which extends its availability to the plant significantly longer than a reference rapidly available nutrient fertilizer such as ammonium nitrate or urea, ammonium phosphate or potassium chloride. Such delay of initial availability could be due to controlled water solubility of the material by semi permeable coatings, occlusion, protein materials, or other chemical forms, by slow hydrolysis of water-soluble low molecular weight compounds, or by other unknown means. Slow and controlled release fertilizers (SRF) increases N use efficiency (NUE) by keeping the availability of nitrogen for a longer period and reducing emissions of greenhouse gases (GHGs), without compromise in crop productivity of crops like rice and thus found that SRF significantly improved NUE, so crop yield was also improved. Various types of slow and controlled release fertilizers are produced in India with different materials like sulphur, polymer, neem *etc*. Nimin is a product derived from neem. It is reported that neem coated urea improves the efficiency of applied nitrogen by inhibiting nitrification process and slow release of nutrients. Coating urea with neem cake has helped in reducing volatilization as well as leaching losses.

2.Future Thrust

The crop is generally fertilized by farmers with only nitrogen, phosphorus and potassium, though micronutrients are also equally important. Micronutrients are elements which are essential for plant growth, but are required in much smaller amounts than those of the primary nutrients, nitrogen, phosphorus and potassium. The imbalanced fertilization and continuous nutrient mining from native soil led to secondary and micronutrient deficiency, declining productivity and deterioration of soil health. Balanced fertilization maintains a dynamic equilibrium between nutrient application and nutrient uptake by crops and thereby aims to harness benefits for farmers, consumer and the nation. Customized fertilizer is the implication of the fertilizers best management practices and is generally assumed to maximize crop yields while, minimizing unwanted impacts on the environment & human health. Application of customized fertilizer is compatible with existing farmers system can be comfortably accepted by the farmers. Customized fertilizer satisfies crop's nutritional demand, specific to area, soil, and growth stage of plant. As the micronutrients are also added with the granulated NPK fertilizer the plants can absorb the micronutrient along with macronutrient which prevents nutrient deficiency in plant. Customized fertilizer is a balanced distribution of plant nutrients in the field and provides the best nutritional package for premium quality plant growth and yield [26]. Currently, a limited number of Customized fertilizer is available for a limited number of crops and need to be invented for all location and most of the Indian crops.

3.CONCLUSION

Fertilizer is one of the key inputs in crop production. Better yield and economic return through the adoption of controlled –slow released fertilizers convinced the farmers to adopt them in rice. Based on the findings above, it can be concluded that controlled slow release nitrogenous fertiliser can play an important role in fertiliser conservation and soil health in rice farming areas.It is concluded that application of controlled slow release nitrogenous fertilizer in rice system exerted a beneficial effect on reduction in fertilizer requirement and also cost of cultivation.

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