Neem Coated Urea: A Boon for Agriculture and Environment Protection

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Introduction:

With limited scope for horizontal expansion in the net cultivable area due to demand of an ever – increasing population, it is essential that highly efficient management practices and modern scientific techniques are adopted to increase agricultural production. Efficient water and nutrient management are the key elements of intensive agriculture. In India at the Present levels of use of primary nutrients (N, P, and K) of 25.6 million tons, almost two thirds of this quantity (Nearly18 million tons) is accounted for, by nitrogen alone. Globally, nitrogenous fertilisers are produced in 72 countries, the total production being 95 million tons in 2013 – 14 as compared to nearly 50 million tons in 1970. Forecasts suggest that the consumption of nitrogenous fertilisers is likely to rise to 134 million tons in the next decade.

In 2013 – 14 urea alone constituted about 84% of the total nitrogenous fertilisers' consumption in India. In quantity terms nearly more than 30 million tons of urea is used in India currently, and it is safe to presume that urea would continue to maintain its predominant position among nitrogenous fertilisers in foreseeable future. On the other hand, globally, due to use of other nitrogenous fertilisers, namely, liquid ammonia, ammonium sulphate and ammonium nitrate, the contribution of urea is nearly half to the total consumption of nitrogenous fertilisers.Mosier et.al.(2004) reported that Nitrogen fertilizers have made a substantial contribution to the tripling of global food production over the past 50 year which was 631 million tons of grains in 1950 which touched 1840 million tons at the beginning of this century.

Under the environmental conditions encountered in most parts of tropical and sub – tropical regions, urea after application to soils hydrolyses fairly rapidly to ammonium carbonate, over a maximum period of 5 – 7 days. The ammoniacal form of nitrogen is subsequently converted to nitrite and then to nitrate by the action of nitrifying bacteria viz. Nitrosomonas sps and Nitrobacter sps, respectively. The processes of hydrolysis and nitrification of urea fertilizer are to a large extent completed in about 15 – 20 days under most agro climatic conditions. In this context, it should be noted that the duration of most cultivated crops extends beyond 90 – 100 days, and therefore, nitrates formed as a result of the relatively rapid hydrolysis and nitrification of urea, being highly soluble, and in excess of the limited quantities required by the crops at their early stages of growth, are liable to be leached down the soil profile, beyond the active root zone of crops. Moreover, under waterlogged conditions nitrates are reduced to nitrous oxide and elemental nitrogen by the action of denitrifying bacteria to meet their oxygen demand. This leads to development of nitrogen deficiency, extremely low N – use efficiency (35 – 40%), especially by rice even under best managed conditions. While Krishnappa and Shinde, 1978, using N – 15 tracer technique reported crop uptake of fertilizer nitrogen as 27.9% only, Roy and Mishra, 2002 have indicated that nitrogen use efficiency, in most Asian countries, by rice would continue to be as low as 40 – 45 till 2015 and beyond. In view of these it is vitally important that Fertilizer Use Efficiency is improved so as to render fertilizer use economically viable and more attractive.

Fertilizer Nitrogen Loss mechanisms in brief can be summarized as follows:

Leaching	:	Water Soluble, forms below root zone
Volatilization	:	Gaseous losses in the form of ammonia
Denitrification	:	Gaseous losses as nitrogen and nitrous oxides under anaerobic conditions
Runoff	:	During heavy rains and flooding
Immobilization	:	Conversion into organic forms
Clay Fixation	:	Inter lattice fixation (temporary loss)

It would be important to note that any form of lost fertilizer nitrogen leads to environmental pollution either through leaching of nitrates to ground water or gaseous emissions to atmosphere, adding to Green House effect by nitrous oxide emission.

The situations mentioned above lead to the development of nitrogen deficiency and poor crop yields. Due to the reasons mentioned above, i. e. rapid hydrolysis and nitrification, the recovery of fertilizer nitrogen by rainy season rice crop seldom exceeds 35% and that for other crops is not more than 55 – 60% under the best managed conditions.

Research Trends:

Literature survey of the last 25 years reveals that a large number of studies have been undertaken in regard of regulating the nitrogen supply to crops by slowing down the rate of hydrolysis of nitrification or both, so as to ensure continuous and optimal supply of nitrogen to match the requirements of crops at different stages of growth. In this context, slow – release urea forms such as sulphur – coated urea, lac – coated urea, neem cake – coated urea, polymer coated urea and urea super granules have been extensively evaluated (Katyal, et. al. 1985; Prasad et. al. 1971; Tandon 1987; Vyas and Mistry 1985; Youngadahl et. al. 1986; Prasad et. al. 1993). Simultaneously synthetic chemicals such as phenylphosphorodiamidate (PPDA), thiourea and dicyandiamide (DCD) have also been examined (Slangen and Kerkhoff, 1979; Amberger, 1986; Zacheri and Amberger 1990) for inhibition of either hydrolysis or nitrification or both in soils. Compounds like DCD and N – serve (Nitrapyrin) have shown good results under laboratory conditions but these products are yet to prove their usefulness under field conditions. Moreover, owing to their higher costs these products are not seen to be cost effective in comparison to saving of nitrogen and increase in crop yields.

The failure of chemically synthesized nitrification and urease inhibitors in making commercial impact and need for regulating nitrogen transformations under field conditions, necessitated intense and focused efforts in developing slow release nitrogenous fertilisers utilizing indigenous materials such as different oil cakes, lac, rubber, rock phosphate etc. (Prasad et. al., 1971). As indicated in preceding section on urea transformations, the process of nitrification in soils takes place in presence of soil bacteria, namely, Nitrosomonas sps and Nitrobacter sps and therefore materials possessing antimicrobial properties were expected to exhibit nitrification inhibition properties. In this context, significance of neem in general, and neem cake in particular, in increasing fertilizer nitrogen efficiency has been studied extensively and excellent review of available data has been published by Prasad et. al., 1993. Results on the effect of neem cake coating/ blending of prilled urea available from a large number of experiments on several crops, including rice in which losses of nitrogen are reported to be maximum, reveal that increase in yield due to neem cake coating/ blending of prilled urea ranged from 0.9 to 54.2% and the average value was 9.6%. The average increase in the yield of wheat, potato, sugarcane, cotton and finger millet was 6.9, 10.5, 15.5, 10.3 and 5.3%, respectively. Data on other crops, namely, jute, Japanese mint, maize, tea have also shown an increase in yield due to use of neem cake along with urea.

While neem cake has been evaluated extensively as a neem product for enhancing the efficiency of urea fertilizer, some other forms, namely, neem oil, neem seed extract, neem leaf extract, isolated neem triterpenes, etc. have also been examined to study their effects on nitrification inhibition, ammonia volatilization, leaching and crop yields and results of those have been reviewed by Prasad, et. al. 1996. Briefly evaluation of coating neem oil on urea and its affect on nitrification inhibition, (Patil, 1972), volatilization losses (Singh et. al.; 1996), improvement in crop yields (Prasad et. al., 1986; Singh & Singh, 1989; Pal, 1996) have been reported in literature. Similarly, other literature reports (Sharma and Parmar, 1975; Surve and Daftardar, 1985; Patel et. al. 1995; Raju and Reddy, 1997) indicate positive attributes of neem extracts as potential nitrification inhibitors.

Commercial Developments:

In view of the positive response of neem cake blending of urea, Indian Council of Agricultural Research in its publication entitled 'Technology for Rice Production' for different states has recommended the use of neem cake blended/ coated urea. Briefly, the coating procedure involves use of making slurry of coal tar and kerosene, mixing with urea and followed by addition of finely powdered neem cake and finally drying the finished product before use. It is interesting to note that in spite of encouraging results obtained with the use of neem cake coated urea, this practice has not attracted the attention of farmers on large scale, mainly due to cumbersome methodology involved in coating urea with neem cake and lack of ready availability of raw materials at farm level.

Having noticed the highly encouraging response of neem cake coated urea under field conditions and limitations associated with its preparation and use, several commercial products have been developed and are currently being marketed. In the following section, a case study is presented with *Nimin® (Vyas etal.1991)* as one example to illustrate the potential relating the use of neem extract coated urea.

Neem Extract (*Nimin*®):

The neem bitters (tetranortriterpenoids) as lipid associates responsible for nitrification inhibition such as epinimbin, salannin, deacetylsalanin, azadirachtin, nimbin, nimbinin Nimbidin, nimbidinin and others have been identified and constitute about 2% (w/ w) of oil.

A concentrated neem extract, trade name *Nimin*®, which contains as much as 5 – 10 % neem bitters responsible for nitrification inhibition in soils, has been prepared by processing neem seeds and industrial – grade neem oil. *Nimin* contains Unsaponifable matter, out of which nearly 80% is composed of neem bitters responsible for nitrification inhibition in soils. The elemental composition of *Nimin* shows carbon 75 – 79%, hydrogen 11 – 12% and nitrogen 0.45 – 0.55% and the remainder consists of oxygen, sulphur and traces of phosphorus and potassium. Quality Assurance parameters are checked using equipment like HPLC and UV – Visible Spectrophotometer.

In order to prepare neem coated urea (NCU), *Nimin* (0.5 – 1.0% w/ w depending on triterpenes content in extract) needs to be mixed with urea. For small quantities of urea, say 50 – 100 kg, no mechanical mixer is required. A urea bag is emptied on a clean floor and *Nimin* is uniformly spread over it. The constituents are mixed thoroughly by hand to obtain a uniform coating. For larger quantities of urea, rotary mixers can be used. Urea is added to the mixing container and *Nimin* is added from the top while mixing continues. Generally, coating requires 2 – 5 minutes, however, mixing duration can vary depending on the type of mixer and the quantities of urea involved. Recently process has also been developed for on – line coating of urea at manufacturing site itself. Our extensive trials have shown that the uniform coating of *Nimin* over prilled urea is indicated by the golden yellow appearance of urea prills without the presence of dark brown spots due to presence of unmixed *Nimin* in the product. Further details on the development on the product (*Nimin*) are published by Vyas et. al. 1996.

Nimin coated urea (NCU) has been evaluated extensively over the past decade in many field trials and salient findings obtained in those trials on the evaluation of NCU for rice, wheat, maize, sugarcane and plantation crops are summarized below:

<u>Rice</u>: Results obtained from several trials during 1987 – 2002 at different locations indicated that there was an increase in grain yield of rice ranging from 4.2 to 70.2% in NCU treated plots as compared to uncoated urea – treated plots. *Nimin* – coated urea was also included in the research trials of the All India Co – ordinated Rice Improvement Programme (AICRIP) of the Indian Council of Agricultural Research in kharif 1990 – 1994. On the basis of those trials it was evident that large granular urea and *Nimin* Coated Urea (NCU) applied in two split doses performed better than uncoated prilled urea at several locations in increasing grain yield and nitrogen use efficiency of rice.

<u>Wheat and Maize</u>: A large number of field experiments on wheat demonstrated an average increase in the grain yield of 16.7 and 36.9, respectively, in NCU related plots over plots treated with uncoated urea.

<u>Sugarcane</u>: In a recently concluded study on sugarcane at Madurai in Southern India it was observed that there was a conspicuous increase in the cane yield with use of NCU at 100% N (106.33 t cane/ ha), prilled urea (88.3 t/ ha) and urea coated with neem cake (97.3 t/ ha). It was also observed that volatilization and leaching losses monitored for a period of 13 weeks were reduced to a greater extent on application of NCU at 45 and 90 days after planting. The reduction in nitrogen losses resulted in a saving of at least 25% of applied nitrogen. In this study as well as in earlier studies conducted at the farms of sugar factories in Tamil Nadu, namely, *Nizam Sugar* and *EID Parry*, it was found that values of bricks, pol% and commercial cane sugar were higher in NCU treated plots than in plots treated with uncoated urea.

Plantation Crops: A field experiment was laid out in a laterite soil at the experimental farm of the National Research Centre for Spices, Calicut at Peruannamuzhi, Kerala, to evaluate the efficiency of slow – release nitrogenous fertilisers in black pepper. The results indicated that application of NCU at 100 g N/ vine increased the yield of Panniyur – 1 black pepper by 280% compared to uncoated urea. Laboratory incubation as well as field studies showed the superiority of NCU over the other slow – release nitrogenous fertilisers, namely, urea formaldehyde, cycloid – urea and urea pellets, as evidenced by the release patterns of ammoniacal, nitrite + nitrate N and total N in the soil during different stages of crop growth.

A brief summary of results obtained from several large scale field trials at Universities and Research Stations is presented in Table 1.

Cost: Benefit Ratio of NCU Application:

The cost: benefit ratios for the use of NCU were calculated considering the rate of fertilizer nitrogen application at which maximum produce was obtained in the given trial, and the current procurement price of the produce. A detailed analysis on the cost: benefit of using *Nimin* Coated Urea in 6 different crops, namely, rice, wheat, maize, sugarcane, vegetables and tea is presented in Table 2. It is quite obvious from the data that a minimum increase of 5% in yield can result in cost: benefit ratios ranging from 1:7.8 –1:20.8.

Use of Neem and Environment Protection:

It is fairly well known now that global amount of nitrogen removed by crop harvest does not exceed 50% of that added through fertilizers and the remaining 50% enters the atmosphere through leaching to lower zones, volatilization losses as ammonia gas, denitrification losses from anaerobic environs as oxides of nitrogen and nitrogen gas to upper part of atmosphere. Chitra, 1992, while working on sugarcane, reported (Table 3) a significant reduction in leaching and volatilization losses due to use of *Nimin* Coated Urea as compared to uncoated urea. Further evaluation of the magnitude of reduction in leaching losses with different types of Neem Coated Urea under field conditions showed a reduction in losses of NO_2 and NO_3 - N ranging from 5.92 – 36.84% and 8.90 – 43.94% in case of rice and wheat, respectively. Reduction in nitrous oxide emissions under laboratory conditions in case of vertisol (pH 7.8) and ultisol acidic (pH 5.6) was observed to be ranging from 7.56 – 56.97% and 1.06 – 43.66% respectively. A significant reduction in nitrous oxide emission under field conditions was observed under irrigated rice and irrigated wheat to the extent of 21 – 31% and 21.8 – 45%, depending on content of neem triterpenes used for coating urea. It may be noted here that nitrous oxide is one of the Green House gases, which is released into atmosphere as a result of denitrification of excessive nitrates under anaerobic conditions. Leaching of nitrates beyond root zone leads to ground water pollution and is known for causing blood cancer and therefore WHO has specified the limit for NO_3 content of 50 mg/ litre in drinking water. It is clear that leaching as well as denitrification losses emanate from predominance of nitrates in agricultural systems, it is quite natural to assume that inhibition of the process of nitrification will not allow accumulation of nitrates in soils. It is of paramount importance that in agricultural systems an optimal concentration of nitrates (plant available form of nitrogen for most crops except rice) matching the crop requirements is maintained and accumulation of nitrates in excess of plant requirement is minimized. It is seem from the results in preceding sections that use of neem cake or neem extract (*Nimin*) inhibits the process of nitrification, which in turn increases nitrogen use efficiency as well as crop yields. It would be out of place to mention here that, in economic terms, 20% losses of the current global urea consumption (46.66 million tons) amounts to total annual loss of 9.33 million tones of fertilizer nitrogen at the cost of 6.16 billion US$. Hence, it is quite evident that an effective nitrogen management programme would not only be beneficial for agriculture on one hand, but also be helpful in minimizing the possible adverse impact of nitrogen fertilizers on environment and human health on the other hand.

Conclusions:

It is evident from the description mentioned above that neem treated urea either in the form of neem cake coated/ blended urea, neem extract coated urea or neem oil coated urea inhibits the process of nitrification which in turn increases nitrogen use efficiency of crops. It is of paramount importance that in agricultural systems an optimal concentration of plant available form of nitrogen (nitrates) matching the crops requirements is maintained, and use of neem coated urea in most agricultural systems ensures such a situation by minimizing the accumulation of nitrates in soils.

From the foregoing presentation, it is quite clear that neem treated urea can either be prepared locally at farm level or at small scale industrial scale, say at village level or on a large scale at the site of production of urea itself. It appears from the experience of market that the acceptance of the product is quite high when it is offered in ready to use form.

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Table 1: Summary of Results emanated from Trials at Universities and Research Stations

Crop	Period	No. of Trials	Increase in yield due
Paddy (Oryza sativa)	1989 – 2006	58	4.7 – 28.4
Wheat (Triticum aestivum)	1989 – 2002	12	5.5 – 40.4
Sugarcane (Saccharum officinarum)	1989 – 2001	9	8.2 – 14.5
Maize (Zea mays)	1989 – 1998	7	6.6 – 28.7
Tea (Camellia sinensis)	1991 – 1993	3	2.1 – 5.1
Black Pepper (Piper nigrum)	1988 – 1990	2	10.3 – 50.8
Cauliflower (Brassica oleracea)	1989	3	36.6
Brinjal (Solanum melongana)	1989	2	19.2
Rubber (Hevea brassiliensis)	1994	1	41.29

* NCU – *Nimin* Coated Urea

Table 2: Cost: Benefit Analysis of using *Nimin* Coated Urea (NCU)

Sr. No.	Crop	Rate of N (kg/ ha)✷	Av. Yields (kg/ ha)✷	Quantity of additional produce @ 5%* increase with NCU vis-à-vis uncoated urea (kg/ ha)	Unit Price of produce (Rs./ kg)✷	Net Addition Return (Rs./ kg)
	Rice	100.0	3000.0	150.0	4.5	675.0
	Wheat	80.0	2500.0	125.0	4.25	531.0
	Maize	80.0	3000.0	150.0	3.5	450.0
	Sugarcane	200.0	80000.0	4000.0	0.7	2800.0
	Vegetables (Cauliflower, Brinjal)	120.0	10000.0	500.0	2.0	1000.0
	Tea	100.0	5000.0	250.0	6.0	1500.0
			(Green Leaf)			

* Appraisal of available data showed an increase in the yield of produce as high as 50% in some cases, however, for the purposes of present cost:benefit analysis a minimum increase of 5% has been considered.

✷ Assumptions based on prevailing situations in the country.

Table 3: Effect Of *Nimin*™ Coating On Losses Of Fertilizer Nitrogen*

Treatments	Cumulative Losses over 13 weeks	
	Leaching (kg/ ha)	Volatilizat (kg/ ha)
Control (NO - N)	12.01	Traces
275 kg N/ ha - 3 Splits. PU*	38.48	43.39
275 kg N/ ha - 3 Splits. NCU**	30.33	39.27
220 kg N/ ha - 3 Splits. PU	32.28	38.26
220 kg N/ ha - 3 Splits. NCU	26.45	34.13
LSD (5%)	3.02	3.62

* PU = Prilled Urea

** NCU = Nimin Coated Urea

* Chitra, 1992