neglect in sections in which the head of the museum is not much interested. A geologist for instance will hardly take an interest in ethnology or an archaeologist in zoology and vice versa. It is here that the services, if available, of honorary workers, who are experts and keen on the subject, should be enlisted. Perhaps it would be better policy for one man to curate a certain section in two or more museums.

Another point which needs development in local museums are libraries, laboratories and research collections, which should be available to the public. There might also be an Inspector-General of Museums whose duty it would be to go round giving advice and suggestions.

Visits of the staff to other museums should be encouraged, as it may be useful in suggesting new ideas, and it should be open even to junior members of the staff as well as to directors and curators. Museum publications should be encouraged even if they do not profit the museum.

Lastly the man appointed to a museum should be an enthusiast and keen on this subject, and the keener he is the more the museum will improve unless his energies are damped by those above him or by financial stringency.

SCIENTIFIC CORRESPONDENCE

Use of mint essential oil as an agrichemical: Control of N-loss in crop fields by using mint essential oil-coated urea as fertilizer

Indian agriculture aims at competitive production of higher level of food grains, vegetables and fruits and industrial raw materials from the existing arable land, through innovative research and development applications. The land holdings with Indian farmers are small, not amenable to the mechanized agricultural practices responsible for high crop yields, such as obtained in North America, Europe and Australia. Productivity of Indian agriculture per unit area and time is largely dependent on provision of fertilizers and irrigation in ample measure for the adequate expression of genetic potential of improved varieties of food grain, horticultural and industrial crops.

Fertilizers are one of the costly inputs in the agriculture of the developing countries. Agricultural production in these areas could be improved, if fertilizers could be used in larger quantities. Urea is the widely used nitrogenous fertilizer. Indian agriculture presently consumes over 10 million tonnes of urea. However, it appears that benefits from such large levels of urea fertilizer use in Indian agriculture can be expanded by increasing the effectiveness of fertilization. Average estimates indicate that the recovery of applied urea by summer season *kharif* crops in India is 30 to 50% and it can be ≤ 20% in lowland rice crops[1]. In the soil, the applied urea is hydrolysed by the enzyme urease of rhizosphere microbes to ammonium (NH_4) and nitrate (NO_3), which are prone to losses through volatilization, and denitrification and leaching, respectively. Arrest of N-loss in the crop fields can help increase N utilization/beneficiation per unit area. This, if achieved, will provide several advantages: decrease the cost of agricultural production and increase profits to farmers, expand the use of urea in optimal amounts over larger cultivated area and contain N-pollution that results from inefficient use of urea[2].

Control of urea transformation reactions that occur in soil for better utilization of its N by crops has been an active R&D area. Several classes of compounds, including phosphorodiamidates and triamidates, sulphahydryl reagents, hydroquinones, catechol, *p*-benzoquinones, dihydric phenols and aminocresols have been found to restrict hydrolysis of urea in soil. Ammonium polyphosphate and phosphoric, boric and nitric acid have been found to reduce volatilization of ammonia generated from urea[3]. Urea–thiourea mixtures placed in either bands or pellets have been used to retard the transformation of urea in the soil[4]. Rapid nitrification or oxidation of ammonium to nitrate in soil catalysed by microbes has been found to be inhibited by nitrapyrin (2-chloro-6-trichloro methyl pyridine), BHC, sodium azide, sodium chlorate, dicyandiamide (DCD), thiourea, AM (2-amino-4-chloro, 6-methyl pyridine), ATC (4 amino-1,2,4-triazole), N-serve and certain other compounds[4–6]. Besides, certain natural products like Karanjin from Karanj tree (*Pongamia glabra*), tea waste tannins, neem tree (*Azadirachta indica*) oil cake have also been found to retard hydrolysis of urea and nitrification to various degrees[7]. However, the high costs of these materials and/or large-scale unavailability have constrained the commercial use of urea treated with such protectants of N-loss.

There are a number of challenges to be met by Indian agriculture, in the post-green revolution era. In the case of most of the food grain crops, the yields per unit area have stabilized at a lower level than those obtained in the developed countries. Since the cost of cropping has gone up, the farmers are demanding higher than international prices for their produce. Full-scale application of World Trade Organization (WTO) regime may permit large-scale imports of commodities produced abroad, at comparatively lower prices. These kinds of development are expected to negatively affect the interest of local farmers in the cropping of food grains and jeopardize national food security. Thus one of the major concerns of Indian R&D effort in the area of agriculture must be to develop technologies whose deployment will allow high levels of income to farmers, while sustaining their interest in food grain crops.

In recent years, in the Indo-Gangetic plains, considered as the bread-basket of India, adoption of new rotations such as rice/pigeon pea – wheat/Bengal gram/*Brassica*/potato–mint in place of the conventional rice–wheat rotation, permitted by the availability of the early maturing variety of mint like 'Kosi', etc. has almost doubled the per unit area income of farmers, without impacting food grain production, in about one hundred thousand hectares of land[8,9]. The post-harvest processing of mint herbage into menthol mint essential oil, menthol crystals and fractionated minor terpenes has created new employment opportunities in the area[9]. Of the world requirement of about 20,000 tonnes of menthol mint essential oil, 75% is currently being met with by India[8]. In order to further spread the benefits of new mint-related agrotechnologies, there is a need to find new, large-scale technical uses of mint oils.

The whole mint essential oils of *M. arvensis* and *M. spicata* and their fractions rich in specific terpenes and semi-synthetic products of individual terpenes of these oils have been found to possess a variety of antimicrobial, pesticidal and anticancer activities, on which new uses of mint oils are expected to be based[10]. Recently the *M. spicata* whole essential oil (MSO) and the *M. arvensis* dementholated essential oil (DMO) have been found to possess urease and nitrification inhibitory activities, as potent as that of diacyandiamide (DCD), under laboratory, greenhouse and field conditions[11]. With the use of MSO- or DMO-coated urea, it was observed that nitrification decreased by 25–35% and N-utilization efficiency increased by 15–40% under different conditions[11].

In view of the possibility of producing mint oils in larger quantities, need to increase the efficiency of urea utilization in Indian fields and mint essential oils being relatively cheaper than synthetic compounds possessing comparable activity and their biodegradable nature, the efficacy of urea treated with mint essential oil was tested in large-scale experiments carried out in the farmers' field in the Indo-Gangetic plains. Here we compare the yields of wheat and rice crops grown in field plots applied with mint-treated urea on one hand and plain urea on the other. The experiments were conducted in cooperation with farmers in their fields during June/July to October 2000 *kharif* season in relation to rice crop and October/November 2000 to April 2001 *rabi* season in relation to wheat crop. During each season, 0.2 ha of land of each concerned farmer was employed. Thirty farmers, drawn from two villages each of Barabanki, Lucknow and Sitapur districts of Uttar Pradesh were involved (Table 1). To prepare DMO-coated urea, urea granules were first thoroughly mixed with castor oil and air-dried for 24 h and subsequently with 0.5% v/w of DMO. The field plots were applied with 60 kg P_2O_5 and 60 kg K_2O/ha at the time of land preparation, prior to planting of rice or sowing of wheat. Rice seedlings were planted in July 2000. The treatments were coated urea at the rate of 80 kg N/ha and plain urea at the rate of 120 kg N/ha. Each urea treatment was applied in three splits: 21 days after planting, 40 days after planting and at pre-flowering stages. Crops were harvested during October–November 2000. Wheat was sown during the second week of November 2000. The treatments were coated urea at 80 and 120 kg N/ha and plain urea at 120 and 160 kg N/ha. Each urea treatment was applied in three splits; at pre-sowing, crown root initiation and dough stages. Crops were harvested during 20 March to 1 April 2001. In both the crops, weeding and intercultural operations were done and irrigation was given as and when required. Yield-related observations were recorded at the harvest time.

It will be seen from the results summarized in Table 2 that the rice crops fertilized with 80 kg/ha of DMO-coated urea gave about 5% more grain yield than crops fertilized with 120 kg/ha of plain urea. This means a saving of one-third amount of urea, presumably because of higher N utilization efficiency when urea had been coated with DMO. This level of effectiveness of DMO coating of urea is the same as that reported for DMO-coated urea under greenhouse conditions and also for DCD-coated urea under greenhouse and field conditions[12]. Since it is known that fertilizer N in waterlogged rice fields is lost by leaching and denitrification, these processes must be controlled by DMO when urea coated with DMO had been used[11]. The saving in N must have

Table 1. Districts and villages where the effect of essential oil-coated urea and plain urea on the yields of rice and wheat crops was studied in the farmers' field

Crop	District	Village*
Rice	Barabanki	Moradabad
		Bhaggapurva
	Lucknow	Jainabad
		Murlipurva
	Sitapur	Manpur
		Gurepara
Wheat	Barabanki	Nargis Mau
		Bhaggapurva
	Lucknow	Jainabad
		Murlipurva
	Sitapur	Pipra
		Bahtootpur

*Five farmers were included in the study in each village; 0.2 ha of land of each farmer was used.

Table 2. Effect of different doses of DMO-coated and plain urea on yield of rice and wheat in farmers' field in the Indo-Gangetic plains

	Grain yield (t/ha) obtained from farmers' field			
Crop/treatment	Lucknow	Barabanki	Sitapur	Mean
Rice				
C80	4.30[a]	4.20[b]	4.51[c]	4.34
NC120	4.16[a]	4.05[b]	4.28[c]	4.16
LSD (p = 0.05)	0.25			
Wheat				
C80	4.06[de]	5.43[f]	6.14[g]	5.21
C120	5.15[e]	6.46[f]	7.18[g]	6.26
NC120	3.77[d]	5.62[f]	6.16[g]	5.18
NC160	3.98[de]	5.80[f]	6.48[g]	5.41
LSD (p = 0.05)	1.21			

All values are mean of ten observations (farmers); C, Coated; NC, Noncoated (plain urea). Values having the same superscript are statistically not different.

Table 3. Comparison of dementholated *Mentha arvensis* essential oil with some commonly used synthetic and natural urea coating materials in terms of the relative cost, availability and agro-ecological safety

Urea coating material	Cost of coating material/ tonne urea (Rs)	Quantity of material required (%)	Resource of coating material	Resource sustainability/ availability	Ecological safety	Reference(s)
Dicyandiamide	> 4000	1–20	Chemical synthesis	Unlimited	Persistent	7, 13, 14
Neem cake	> 1000	10–60	Plantation	Limited	Biodegradable	15
Other neem products	1000	1–5	Plantation	Limited	Biodegradable	16
Karanj (oil and other products)	> 1000	20–30	Plantation	Limited	Biodegradable	17
Dementholated mint oil	700	0.5–1.0	Seasonal crops	As desired	Biodegradable	11

resulted from delay in the conversion of urea-N into NO_3. It will also be seen from Table 2 that wheat yield obtained with DMO-coated fertilizer urea used at the rate of 80 kg/ha was about the same as that obtained with plain urea used at the rate of 120 and 160 kg ha^{-1}. Thus on an average basis, DMO-coated urea gave a saving of 25–40% over plain urea. The estimate of N use efficiency in terms of yield was in line with the studies being conducted in the experimental field at CIMAP with mint, wheat and mustard as the test crops[12]. It will be seen from the comparison of DMO and urea coating materials in vogue given in Table 3 that DMO is less costly, eco-friendly and easier to produce locally in abundant quantities, without detriment to food production. The amount of DMO required to coat one tonne of urea is 5 to 10 kg. If the technology is used in commercial scale in coating about 50% of the total fertilizer urea currently consumed (10 m tonnes), there will be an additional requirement of 25,000–50,000 tonnes of mint oil, which is double to four times the current production. The most notable point is that the by-product DMO can be used after extraction of menthol, the primary and remunerative component of the oil, which can be marketed. Besides meeting the domestic requirement, this will certainly enhance the export market.

A large fraction of mint farmers in the Indo-Gangetic plains have already adopted the crop rotation: rice/pigeon pea–wheat/Bengal gram/*Brassica*/potato–mint, which permits profitable mint oil production while continuing the food grain production in both *rabi* and *kharif* seasons. The adoption of DMO-treated urea fertilizer technology will allow extension of high-profit food grain–mint agriculture to a wider sphere of the farming community in the Indo-Gangetic plains and other areas having similar agro-climatic conditions.

The present investigation in farmers' field has confirmed the results obtained in greenhouse and research field, that lower amount of DMO-treated urea gives the same advantages as 30–50% higher level of plain urea in wheat, rice and mint crops[12]. The present observations, therefore, open the way for large-scale use of DMO-coated urea in Indian agriculture to obtain the following advantages: (1) higher income for more farmers by use of *kharif* grain–*rabi* grain–*zaid* mint rotations; (2) new employment opportunities as the cultivation and processing of mint are highly labour-intensive; (3) saving on fertilizer consumption (the fertilizer thus saved could be used for covering more areas which are under sub-optimal supply of the costly input, thereby increasing food productivity); (4) relief from environmental hazards due to fertilizer – wastage related menace; and (5) opening of new vistas in fertilizer industry by production of slow-release N-fertilizers.

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