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Slow-release lac-coated urea fertilizer

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ABSTRACT

Lac (shellac) was used as a coating material for producing a slow-release coated urea fertilizer. A suitable coating composition, based primarily on lac without using any solvent, a coating technique, a laboratory-scale coating equipment and a semi-pilot plant were designed, fabricated and commissioned into service.

Lac-coated urea fertilizer thus developed was found to have the following composition: urea 73.7%, resin 16.2% (lac : rosin=1 : 2), oil 3.3%, conditioner 2.9%, sealant 3.6% and microbicide 0.3%, i.e. total coating 26.3%. The product is uniformly coated, non-tacky, free-flowing and has good keeping quality. It has 34.2% total N and a daily dissolution rate of 0.6%. It was found to compare favourably with sulphur-coated urea fertilizer produced by the Tennessee Valley Authority.

Considerable losses of N from nitrogenous fertilizer like urea occur as a result of leaching, volatilization, decomposition or fixation and denitrification in the soil, with the result that plants do not get the nutrients when they need it (Powell, 1968). Research has therefore been in progress for developing slow-release N fertilizer.

Nitrification-inhibitors like 'N-serve' and 'AM' have been tried (Prasad *et al.*, 1966; Prasad and Bains, 1968; Prasad *et al.*, 1970) for reducing loss of N from applied fertilizers. Different indigenous materials were used (Bains *et al.*, 1971) to enhance the efficiency of N fertilizers in rice. The rate of mineralization of a few slow-release N fertilizers was found

to be slower than that of ordinary N fertilizers (Rajale and Prasad, 1970).

Various compounds of low solubility like urea-aldehyde condensation product have been reported (Powell, 1968), but the method of preparing them is expensive. Another method is to provide an insoluble coating on granules of fertilizer. A variety of coating materials (Powell, 1968) have been found suitable for coating. The most important of these are wax, polymers and sulphur.

Recently, the Tennessee Valley Authority (USA) developed (Rindt *et al.*, 1968) a slow-acting coated urea, which is prepared by coating urea granules with sulphur along with wax, coaltar and keiselguhr. This sulphur-coated urea was reported to cost, per unit N, 25-50% more than the uncoated product.

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In view of the need to have a slow-release urea fertilizer, we used lac in place of sulphur.

Shellac is a natural versatile resin having very fine film-forming properties. At the start a process of coating (Srivastava *et al.*, 1971) was developed by using lac-oil composition dissolved in a hydrocarbon solvent, followed by a coating of wax. Studies have shown that this coated product was only a quarter as hygroscopic as the uncoated urea. Ammonification was also found to be lower than from uncoated urea; but the dissolution rate was no better. The composition was modified by substituting linseed-oil by stearic acid, linseed-oil fatty acids, cashewnut-shell liquid and urea-formaldehyde resin. The products thus obtained were found unsuitable as they were all sticky and remained sticky even after exposure to air for many days. Again, only shellac resin was tried, but with no success.

Chakravarty (1967) used only shellac as a coating material by dusting it over oil-smearred granules, and reported that the quantity of oil and lac needed was not more than 2.5% of the fertilizer. The main objective of the work appeared to be to develop a free-flowing product and to stop the agglomeration of the fertilizer. No mention was made by the author about the dissolution rate, etc. This coating process was tried on urea, but no difference was found in dissolution rate between coated and uncoated urea.

Though a versatile resin, shellac possesses some defects like affinity towards moisture, as it has 5 hydroxyl groups in the molecule (Bose *et al.*, 1963). To minimize this defect, these hydroxyl groups of shellac should be blocked to produce a water-resistant coating. This can be done by reacting 1 part of shellac with 2 parts of rosin (ILRI, 1955). The resin thus obtained is an ester that can be used for coating, as 4 hydroxyl groups of shellac have been reacted.

Experiments have shown that only one coating of the resin powder could not cover fully the surface of urea granules. Multiple coating and some sealant coat was also necessary to seal such cracks and to

cover the portion left uncoated. As soil microbes are reported to be attracted more towards sealant like wax (Rindt *et al.*, 1968), the use of some microbicide would also be necessary.

In view of these findings, the following coating material, composition, process and equipment have been developed.

MATERIALS AND METHODS

A laboratory model (Fig. 1) suitable for coating about 200 g of urea prills at a time was designed and fabricated. On the same line (as mentioned below) a bigger machine (semi-pilot plant) was also designed, fabricated and commissioned (Fig. 2).

Principally it consists of a rotary pan (30 litres), attached to an axle of a reduction gear by a clamp arrangement. Urea granules are coated in this pan with resin and other material. A second pan may be used for giving a sealant coat. The semi-pilot plant can coat 5 kg of urea per charge. The pan is operated at an angle of 30° to the horizontal line at the rate of 36 rpm. It is driven by a single-phase motor of 1 hp and 1,440 rpm. The reduction of speed is 1:40. An alternate heating and cooling arrangement has been improvised by blowing hot air and air at room temperature from a separate unit (Fig. 3). Hot air is obtained by passing air through an electrically heated tunnel (1,000 W) at the rate of 3 m³/min. Heating can be controlled by an energy-regulator.

In an open stainless-steel cylindrical beaker of 6-litre capacity, fitted with a mechanical stirrer, 100 parts (2 kg) of rosin is heated. At 260°C, 50 parts (1 kg) of shellac is added frequently in small lots, while maintaining the temperature at 260±5°C. After the last addition (25 min), this temperature is maintained for 30 min and finally reacted resin (softening point 60°C, acid value 80, i.e. about 4-OH group of shellac has been reacted with —COOH of abietic acid of rosin), which is an ester of shellac and rosin, is poured through a 10-mesh sieve (so as to filter off any insoluble material) on a metal tray for cooling.

The cooled resin is crushed and

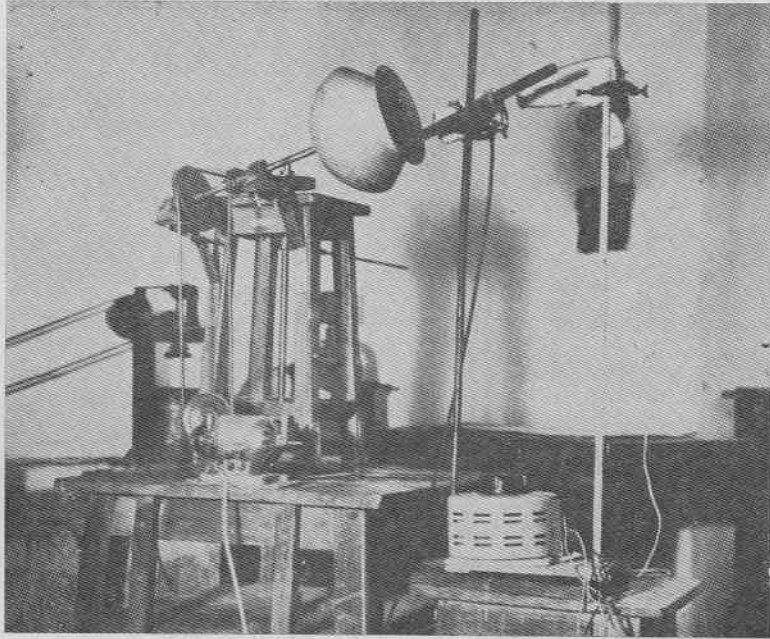


Fig. 1. Laboratory model of coating machine.

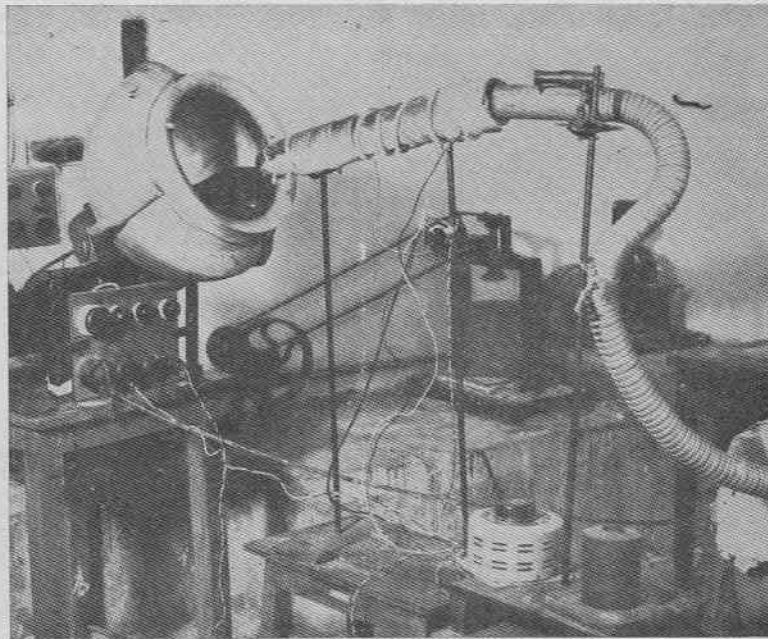


Fig. 2. Semi-pilot plant.

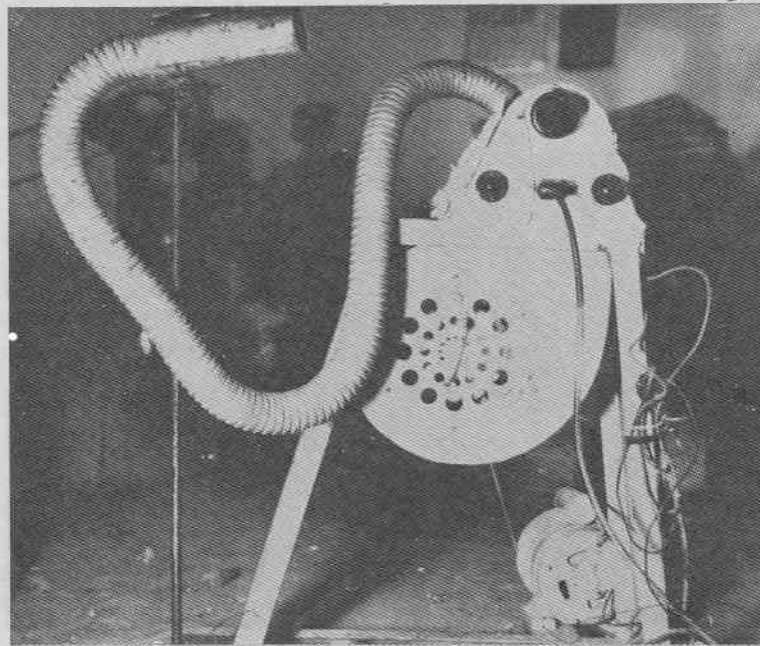


Fig. 3. Air-blowing machine.

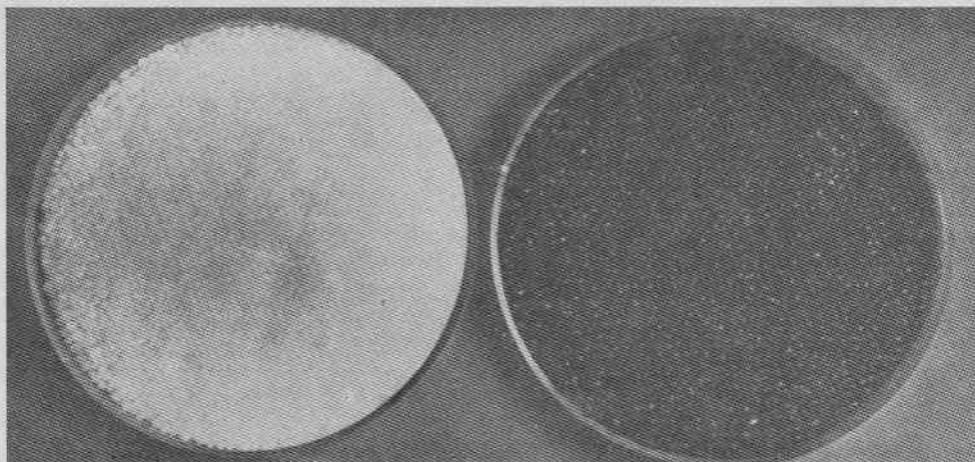


Fig. 4. Uncoated granules of urea fertilizers (*left*) and lac-coated slow-release granules of urea fertilizers (*right*).

powered in a Christi Norris Hammer-type disintegrator and sieved. This resin powder passing through 80-mesh sieve (British standard specification) is used for coating urea granules. The yield of the powder is 2.8 kg.

Coating composition

The coating composition used in the preparation of lac-coated urea is based on indigeneous materials.

Material	Specification	Proportion	Percentage
Urea (fertilizer)	Fertilizer grade (-10-mesh to + 20-mesh granules)	5 kg	73.7
Shellac-rosin ester (resin)	Shellac, fresh, handmade; rosin, WG grade	1100 g	16.2
Linseed-oil (oil)	Double-boiled (with 0.2% Co as cobalt naphthanate)	225 g	3.3
Soap stone (conditioner)	Commercial	200 g	2.9
Wax (sealant)	Commercial, hard, paraffin wax (melting point 60°C)	250 g	3.6
Coal-tar (microbicide)	Commercial (Shalimar tar products)	20 g	0.3

Total coating = 26.3%
Total yield = 6.75 kg

Coating process

Since uniform results were obtained in the laboratory plant, the coating procedure at semi-pilot plant level has been developed with the above coating composition. The details are given below.

Uncoated 5 kg of free-flowing dry urea fertilizer granules (prilled) is put into the tumbling pan and tumbled for 5 min at $58 \pm 2^\circ\text{C}$. Urea granules should first be made moisture-free before coating. After drying, 50 g of double-boiled linseed-oil (0.2% Co as drier) is added and tumbled to get uniform smearing of oil. This oil-smearred product is tumbled for 10 min at $58 \pm 2^\circ\text{C}$ by passing hot air into the tumbling machine. At this stage some stickiness will be observed which is necessary for anchorage of resin particles. The same process is again repeated with the same amount of oil. Then 600 g of resin powder is added slowly in a continuous and uniform stream over oil-smearred urea granules.

A temperature of $58 \pm 2^\circ\text{C}$ is maintained for 10 min. During this time the

resin softens or melts and spreads over the urea granules and forms a first coat. For the second coat, 75 g of the same oil is added in the same way over the resin-coated granules, and the smeared granules are dried for 5 min at this stage. Then 250 g of the same powder resin is added to the smeared product in the same manner; 100 g of soap-stone as a conditioner is added and $158 \pm 2^\circ$ is maintained for 10 min while tumbling. The resin will form a second coat. For the third coating the whole process with the same quantity of second coating is repeated. To the thrice-coated urea granules 20 g of coal-tar as microbicide is added and tumbled for 5 min at the same temperature. Over this coating, 250 g of hard paraffin-wax is added to seal the fine cracks or uncovered portion of the urea granules during resin-coating. This would also give a good water-repellency. A temperature of $58 \pm 2^\circ\text{C}$ is maintained for 10 min while tumbling. This product is allowed to cool to room temperature while the tumbling is continued. The

final product is taken out and spread over in metallic trays. The final product is free-flowing, non-tacky, dry and uniformly coated.

The above procedure is repeated several times to give a product having consistent characteristics.

Dissolution rate

The test for evaluating the coated urea is based on the degree of dissolution in water. The method is based on gravimetric determination of dissolved urea in water. The following procedure is followed.

In an Erlenmeyer ground-joint flask, 10 g of coated urea is taken and 50 cc of distilled water added. The weight of the flask containing urea and water is noted down. This flask is kept in an incubator at 30°C for 24 hr. After this period the flask is taken out and allowed to cool to room temperature. The flask is weighed again and the weight kept constant by adding distilled water if there is a loss in weight. This water containing coated urea is filtered through a filter-paper (Whatman No. 1). In a pre-weighed Petri-dish, 5 cc of filtered solution is taken out. This dish is kept in the air-oven at $100 \pm 2^\circ\text{C}$ and water is allowed to evaporate. The weight of the Petri-dish is again taken till the difference in weight is constant, and dissolution in 24 hr is thus calculated. The difference in dissolution between the first day and the fifth day is divided by 4 to get daily dissolution rate.

The total N is determined by the Tread-Well and Hall modification of Kjeldahl method (De, 1962).

DISCUSSION

The lac-coated urea (Fig. 4) thus prepared was found to be uniformly coated, non-tacky and free-flowing. The colour of the coating was blackish brown, depending upon the colour of the shellac used in the preparation of resin. The average thickness of the coating was 3.5 mil. The comparative characteristics of lac-coated and sulphur-coated urea are given below.

Total N of sulphur-coated urea (supplied by TVA) was 32.6%. In lac-coated urea it was 34.2%. This increase in N

is because of the percentage of coating material used in the formulation. The total coating material used was 29.65% in sulphur-coated urea and 25.92% in lac-coated urea. The dissolution in 5 days for sulphur-coated urea and lac-coated urea was 7.2% and 7.0% respectively. Thus, there was a close resemblance in this characteristic. But there was a slight difference in the daily dissolution rate, which was 0.7% in sulphur-coated urea and 0.6% in lac-coated urea.

Thus lac-coated urea compares favourably well with the sulphur-coated urea developed by Tennessee Valley Authority.

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