CHAPTER 2

INTRODUCTION

Widespread deficiency of Zinc in major soil groups in our country is a matter of great concern as zinc plays a vital role in plant metabolism. (Takkar P.N (1986) Malewar G.U (1987). The general hypothesis for the role of micronutrients in plant metabolism is that they form stable complexes with naturally-occurring ligands to initiate and sustain biological activity (Price, 1968). It is very much applicable for zinc as it is reported to be a constituent of a large number of essential metalloenzymes required for plant growth (Price, 1970). There are several reports to show that zinc deficiency results in a sharp decrease in the levels of RNA and ribosome contents in the cells. (Kessler & Monselise 1959; Schneider & Price 1962; Wacker, 1962; Brown, Capellini and Price, 1988). Zinc deficiency results in lower synthesis of metalloenzymes such as dehydrogenases, proteinases and peptides in plant tissues (Vallee & Wacker, 1970). Zinc deficiency causes a decrease in the rate of terminal growth and stem length, accompanied by whorling of the leaves (Fertilizer Manual, IFDC, 1979). Thus the overall crop yield is affected by zinc deficiency. Human beings also require zinc. Insufficient zinc intake results in slowed growth, delayed wound
healing, poor appetite and mental lethargy. It also interferes with the immune response (Kirk & Othmer encyclopedia III ed Vol.24). The main function of zinc in human metabolism is enzymatic (Van Rij et al 1982). Assessing the needs of human beings for zinc, Van Rij et al have recommended the following dietary allowances of zinc.

- For adults - 15 mg/d
- For lactating women - 25 mg/d

We get the required dosage mainly from rice/wheat and cereals. It is therefore essential to supplement the requirement of the plant in order to:

1) Improve plant metabolism for increased grain production.
2) Ensure presence of enough zinc in the produce to furnish required level of nutrition for human beings.

Amelioration of zinc deficiency thus becomes highly imperative.

Zinc deficiency in soil is corrected by the application of zinc sulfate to the soil. But application of zinc sulphate entails some drawbacks. Being a highly water soluble salt, it dissolves quickly in the water standing
in the field and percolates into the deeper layers of the soil. Zinc available near the zone of the root system is therefore lower than the quantity applied and leads to its lower use efficiency.

Moreover, application of zinc sulfate by broadcast may not be uniform because of the relatively small quantity required which is of the order of 20 Kg/acre. The difference between the desirable level of application to soil and the level at which toxicity to the crop develops is fairly narrow so that non-uniform application of a concentrated material poses problems and use of straight and high analysis micronutrients may be wasteful and perhaps injurious. Thirdly, fertilizer grade zinc sulfate supplied by retailers frequently suffers from poor quality and adulteration. A strong need has therefore been felt by the fertilizer industry for a formulation containing low concentration of zinc in a suitable fertilizer carrier material for balanced nutrition, ideally as a homogenous formulation.

The Carrier for Zinc:

Giordano P.M and Mortvedt J.J (1972) suggest that micronutrient elements must also be present as minor
constituents in a fertilizer formulation of Primary nutrients in order to supply balanced nutrition to the growing crops. Biswas et al (1988) stress the need for a single fertilizer formulation containing both macro and micro nutrients without any interference between the constituents.

Even though one could conceivably combine micronutrients such as zinc with various available fertilizer formulations, such choice in practice would be restricted. When zinc goes into solution in soil moisture along with other constituents, its availability to the plant would be controlled by stability constants and solubility products of various Zinc compounds that are likely to form. In the presence of Phosphate, as with a NPK carrier, zinc precipitates completely as the solubility product of \((\text{Zn}_3\text{(PO}_4)_2\) is as low as \(9.1\times10^{-33}\). Therefore phosphate based complex fertilizers are unsuitable as carriers for zinc.

It has been observed in field trials that the use of nitrogen in conjunction with zinc increases the agronomic effectiveness by increasing the availability of \(N\) and in turn contributing to a better crop response. (Mortvedt J J and Giordano P.M (1988).
A positive synergistic interaction between Zn and N resulting in improved yield has been observed (Indulkar and Malewar (1990) and Yadhav et al 1972). Among nitrogenous fertilizers commercially available, Urea having the highest N content is being widely used. It is therefore useful to consider the feasibility of using urea as a better carrier for micronutrients.

Incorporation of Zinc:
A cheap and readily available zinc compound would be a desirable choice for making a fertilizer formulation with zinc on a commercial scale. Among various available zinc compounds, ZnSO4.7H2O and ZnO are the two chief sources of zinc for fertilizer application.

One way of incorporating these zinc compounds would be by physically coating them over urea prills but trials indicated that it did not guarantee uniform composition. For example, coating ZnO over urea prills results in segregation due to attrition of the coated ZnO layer during handling, transport and storage. Coating of pulverised zinc sulfate over urea results in the formation of an adduct during preparation and storage. Adduct formation takes place between urea and hydrated ZnSO4 when they are mixed together to yield
crystalline products such as ZnSO4.6CO(NH2)2 and ZnSO4.2CO(NH2)2.2H2O (Lehr 1972). Formation of these adducts is followed by the release of water of hydration from hydrated ZnSO4. Therefore the granular product would get caked up due to the released water making the product unsuitable for application.

ZnO which is commercially available in pure form was chosen as a source of Zn for the trials in preference to ZnSO4 for two reasons. They are:

1. Percentage Zn in ZnO is higher than in ZnSO4.7H2O and therefore it is enough to add less quantity of ZnO to get the formulation resulting in the marginal reduction of the Nitrogen content of Urea.

2. There is no release of water of hydration during formulation.

Further, incorporation of Zinc into Urea should be by some means other than coating, and should lead to a formulation with

i) Uniform composition

ii) Improved physical and chemical characteristics, and
iii) High use efficiency of the applied Zinc and Nitrogen.

The feasibility of incorporating ZnO in laboratory scale tests by dispersing it in molten urea was explored as molten urea is available in all urea plants and as the mixture could be granulated into uniform material in a commercially usable form.

When a portion of ZnO was added to molten urea, a vigorous reaction was noticed with evolution of NH₃. In a few minutes' time a clear solution, looking like molten urea itself, was obtained. Evolution of ammonia indicated a chemical reaction between ZnO and molten urea and became the starting point of the present research work which is pivotally based on the behaviour of Molten Urea as a non-aqueous solvent medium for certain inorganic compounds. In preliminary trials, some of the hydrated inorganic compounds of micronutrient value were also found going into the Molten Urea forming a homogeneous solution as ZnO did.

Thus the scope of the overall research work was made to cover the following four aspects:

1) Studying the dissolution of Zinc Oxide and also of other inorganic compounds of micronutrient value in molten urea.
ii) Characterising the product formed in the Urea-ZnO reaction.

iii) Defining the physico-chemical parameters associated with molten urea and ZnO interaction.

iv) Utilising the information gathered as above to design a pilot plant to prove viability of ultimate commercial production with the facilities and technology available in our country and also to obtain enough material to enable evaluation of the product in agronomic field trials.