Zinc Sulfate Controlled Release Fertilizer with Fly Ash as Inert Matrix

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Abstract: - The paper presents controlled release of Zinc sulphate fertilizer made with fly ash as inert matrix. Pellets were made from the mixture and the release rate of zinc sulphate with time was studied. The parameters covered are fractional zinc sulphate, fractional cement and fractional sand and diameter of the inert particle size, diameter of the pellet. The parameters also measured with Naphthalene coating pellets and compared. The study is useful to identify the controlled release of zinc sulphate fertilizer and also to predict the release rate at any instant of time.

Key- words:- Controlled release, Release rate, Fertilizer, Inert matrix, binding agent.

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1. Introduction

Nutrient losses due to leaching, volatilization and fixation and the activated risk of nitrate leaching after fertilizer addition to the soil may be reduced through the use of controlled release fertilizers. Conventional fertilizers commonly used as nitrogen sources, such as urea and ammonia salts, have very high water solubility, thus causing pollution of underground and surface aquifers with nitrates, whose harmful effects are well known. Controlled release fertilizers under development attempt to improve this situation.

Polymer-coated controlled-release fertilizers are used to overcome and improve current low nutrient use efficiency, and the potential economic and environmental benefits. Controlled release of the active agent is important not only for attaining the most effective use of the agent but also for the prevention of pollution. Controlled release fertilizers are made to release their nutrient contents gradually and if possible, to with the nutrient requirement of a plant. A number of Controlled release fertilizers have been developed during the past decades. There are three types of these fertilizers: (a) matrix-type formulations constitute the first major category of controlled release fertilizers due to their simple fabrication (b) Application of thin film coating to fertilizer particles like sulfur coated urea and (c) Chemically altered fertilizer or any other such method that makes the fertilizer available over an extended period of time like guanyl urea sulfate (GUS) and guanyl urea phosphate (GUP), Crotonylidene diurea (CDU), iso butylidene diurea (IBDU) are some among them.

Several techniques or methods have been practiced and proposed in India but failed to produce a reasonably low cost fertilizer preparation technique viable for practice. Application of manure, castor seed meal, meat meal, neem meal, bone meal etc., comes under this has been in use. Super phosphate can also be classified under this category fertilizer. Practice of coating of asphaltic tar to urea embedded in neem cake was once recommended and practiced by farmers but failed to continue due to its inherent difficulties.

There are some materials available in nature that decays slowly and the nutrient content in that material may be available for a long time. Fly ash is one such material which can be considered as a controlled release fertilizer and have been used in farm practices and its benefits have been realized from time immemorial. Fly ash is selected as barrier matrix since it is cheap and easily available for farmers makes it suitable for the matrix material. Several binding agents were visualized for the study like as cement, tar, plaster of paris, sodium silicate, lime is prominent. But lime has been selected for the present study as binding material. Zinc Sulfate is highly soluble and readily dissociate in water and it is liable for loss with water either by seepage or by drainage. Hence Zinc Sulfate has been selected for the development of controlled release fertilizer with Fly ash matrix as major ingredient of the controlled release fertilizer. Two types of combinations were chosen in the preparation controlled release fertilizer.

1) Zinc sulfate fertilizer with fly ash as barrier for diffusion and Lime as binder.

2) Zinc sulfate fertilizer with fly ash as barrier for diffusion and Lime as binder with Naphthalene coating.

The fertilizers so prepared were tested in laboratory for their sustained release rates.

In the present study matrix type of controlled release fertilizer is envisaged with fly ash matrix as it is available with no cost and has some binding capability on its own with lime as add mixture. Pellets were made zinc sulfate, fly ash together with lime with varying composition. Variables covered in the study together with their ranges are presented in table 1. Pellets may out of fly ash–lime $ZnSO_4$ system was tested for their release pattern.

$ZnSO_4$ content was varied from 5 to 15%, it's percentage beyond 15% the pellets were broken because of egress of $ZnSO_4$ dissolution. The release data was encouraging from the experimental results. Further, advantage of system was enhanced by coating with sparingly soluble naphthalene. The coated pellets with all the above parameters were studied for their release. The release was sustained up 6 days without coating while that maintained up to 15 days with naphthalene coating.

The data was analyzed to determine release rate constants. The system followed nearly zero order with marginal value of exponent. The rate constants were and presented in table 2, together with their composition.

A model was developed for the release rate using Fick`s second law of diffusion for controlled release fertilizer with matrix system. The system followed two prominent regions namely initial region and latter region separate models were presented. These models were compared with the experimental data and found good agreement. The results are highly useful for the development of controlled release fertilizer and to predict release pattern.

The developed equations are as follows:
Fertilizer pellets with naphthalene coating

$$g_t = \frac{3}{\rho_s r}\left[\frac{D.t}{\varepsilon .l}(c_2 - c_1) - \frac{l}{6}\right] \qquad t < Y$$

$$1 - g_t = \frac{c_s}{\rho_s}\exp\left(-\frac{3D}{r\,l\,\varepsilon}\,t\right) \qquad t > Y$$

The derived equations highly useful for the prediction of release data and in the design of tailor made control release fertilizers.

2. MATERIALS AND METHODS

Proper soil management is required when using fertilizers to avoid contamination of surface and groundwater. Plant nutrient requirements can be met either inorganic or organic fertilizers. Inorganic materials may be used separately or blended form. Micronutrients are group of nutrients which are essential for plant growth that are required by plants in small quantities. Intensive farming depletes nutrients. Micronutrients are not an exception to this norm. Therefore, selective use of micronutrients is necessary for increasing agricultural production. Iron, zinc, manganese, copper, boron, molybdenum and chlorine fall under this category. The following micronutrients namely zinc Sulphate, monohydrate & heptahydrate of manganese Sulphate, borax, copper Sulphate, ferrous Sulphate, ammonium molybdate, chelated zinc, and chelated iron have been used for the supplementation. The list of micro nutrients under practice can see from Table 2.

The materials used in the present study for the preparation of controlled release fertilizers are:

- Zinc Sulfate (fertilizer)
- Fly ash (inert material)
- Lime (binding agent)

Fly ash and lime were mixed in several proportions with Zinc Sulfate as active fertilizer ingredient.

2.1 Zinc Sulfate

Zinc (Zn) is an essential nutrient required fertilizer for crop production. While some soils are capable of supplying adequate amounts, addition of zinc fertilizers is needed for others. Zn may be needed in fertilizer programs for production of corn, sweet corn, and edible beans. Zinc, however, is needed in very small amounts. Plant uptake of this nutrient is very small. Therefore, Zn is classified as a micronutrient.

Physical and Chemical Properties

Appearance: Colorless crystals or granules.
Odor: Odorless.
Solubility: Soluble in water.
Specific Gravity: 1.97
pH: ca. 4.5 Aqueous solution
% Volatiles by volume @ 21C (70F): 0
Boiling Point: > 500C (> 932F) Decomposes.
Melting Point: 100C (212F) Loses all water at 280C.

2.2 Fly ash

Fly ash is a fine powder recovered from the flue gases of thermal power plants. These micron-sized earth elements consist primarily of silica, alumina and iron. Fly ash occurs as very fine particles. The composition of fly ash varies depending on the quality or the source of the coal used and the operating conditions of the Thermal Power Stations. Fly ash consists of practically all the elements present in soil (except organic carbon and nitrogen), so it was found that this material could be used safely as it is derived from the earth. For the present study, the fly ash particle size of 75 and 150µm was taken. In India most of the fly ash produced is alkaline in nature. Hence the application of fly ash to agricultural soil increases the soil pH. The crops grown under fly ash based treatment were observed to be resistant to disease, insect, and pest infestation as compared to the crops grown without fly ash. Although, fly ash has many benefits as an input material for agriculture applications, there may be some precautions (due to the presence of some amounts of heavy and toxic elements and its natural radioactivity) have to be taken while using fly ash in agriculture.

Fly ash obtained from Simhadri Power Plant (NTPC) was used in the study to make pellet matrix in the preparation of controlled released fertilizer. For the present study, the fly ash particle size of 75 and 150µm was taken.

2.3 Lime

Several binding agents were visualized for the study. Among them sodium silicate, tar, cement, lime and hemi hydrate of calcium sulphate are prominent. But lime has natural affinity to fly ash to form aggregate and also a nutrient for the plant uptake. Lime is selected for the study as it does not pollute the environment. The application of lime for agricultural or engineering purposes is a well established practice. Addition of lime to soil is intended to maintain a neutral soil pH. Different formulations of lime are available for agricultural and engineering use; both have different chemical and physical properties. Agricultural lime is usually ground dolamitic lime unless the soil is calcium deficiency. The sparingly soluble lime remains inert in soil, slowly dissolving in available water.

After preparing the pellets from the above materials, the release of Zinc Sulfate from the pellet in the water was determined

by volumetric analysis. The chemical used in the volumetric analysis are as follows.
EDTA : Analytical grade from Merck
Erochrome Black –T : Analytical grade from Merck
Ammonia Buffer: Analytical grade from Merck

2.4 Preparation of Zinc Sulfate Pellets

Controlled release zinc sulfate pellets were prepared with fly ash and lime. Lime was chosen as binder because of its low cost and availability. The percent of Zinc sulfate in the pellets was varied as 5, 10, and 15 percent. The binder and inert materials contribute to remaining percentage. Binder composition was varied as 3, 4 and 5 percent. The balance is fly ash inert. The Particle size of inert material was not varied as it alters the porosity of the pellet which not affects the diffusion rate. Less than 250µm size fly ash particles were used in the preparation of pellets. The range of variables covered in the present study was presented as table 1.

In the present study, the pellets of Zinc Sulphate pellets ($ZnSO_4$, fly ash & lime system) were prepared by mixing Zinc Sulphate with fly ash-lime matrix in the ratios of 5:95, 10:90, and 15:85. The inert composition was also varied to obtain varied strength to the pellets. The proportions of the fly ash-lime- fertilizer ratios are maintained as 92:8, 86:14 and 80:20. The entire experiment was carried out using less than 250µm size fly ash particles.

The mixtures so prepared were taken separately, sufficient amount of water was added to it and made into paste. The paste was then moulded into spherical pellets of diameters 1cm to 1.8cm. The pellets thus prepared were kept in cool and dark place for curing and subsequently used in the experimentation.The following solutions were prepared for the estimation of zinc content in the leached solution.

2.5 Preparation of EDTA solution

To prepare 0.1 M EDTA solution 37.23g is dissolved in distilled water and made up to 1 liter with distilled water in volumetric flask.

2.6 Preparation of Erichrome black-T indicator

Dissolved 0.2g of the dye stuff in 15ml of try ethanolamine and 5ml of absolute ethanol.

2.7 Preparation of Buffer solution (pH=10)

Add 142ml of concentrated ammonia solution (sp.gr. 0.88-.090) to 17.5gms of A.R. Ammonium chloride and dilute to 250ml with distilled water.

3. EXPERIMENTAL PROCEDURE

To estimate the release rate of zinc from the zinc sulfate pellets the following experimental work was carried out. A 500mL beaker was taken. The pellet was kept in the beaker and 200ml of water was added to it. The beaker was continuously stirred. The zinc sulfate from the pellet releases slowly into the water. The samples of the leachant were collected at various time intervals and analyzed for its content using EDTA method.

3.1Analysis of leachant:

1ml of the leachant was transferred into a conical flask and 10ml of distilled water is added to it. 2-3 drops of Eriochrome Black – T indicator was added, 10ml Ammonia buffer was also added to maintain the pH at 10. The liquor is analyzed for its zinc content using volumetric analysis. 0.1N EDTA solution is used for titration purpose. Endpoint is wine red color to blue. The data of time versus concentration of zinc in the leach liquor was obtained which is used for subsequent mathematical analysis.

3.2 Porosity measurement

Sample pellet was taken and weighed for its initial weight (W_1). The sample was then placed in a petre dish and was saturated with water excess amount of was wiped out with filter paper. The pellet was again weighed its value is (W_2). Difference in weight was noted and was equivalent to weight of water adsorbed.

Then volume of water absorbed was determined by the following equation

$$V = \frac{\Delta W}{\rho}$$

Where ΔW is weight of water adsorbed by the pellet. (gm)

ρ is density of water. (gm/m^3)

Porosity ε = volume of water adsorbed/volume of the pellet.

Volume of the pellet was calculated from measured diameter which was measured using a sensitive micrometer gauge.

4. RESULTS & DISCUSSIONS

Pellets of controlled release fertilizer with $ZnSO_4$ active ingredient were made with 5-15% $ZnSO_4$. As the high percentage of active ingredient is mandatory for cost effective fertilizer, an attempt is made to produce pellets with higher percentage of $ZnSO_4$ but yield to the force of dissolution. The range of variables covered in the study was presented as table 4.

The data was analyzed in terms of C_A Vs Time and X_A Vs Time

Where C_A is concentration of $ZnSO_4$ in the leachant.

Mole fraction of $ZnSO_4$ retained in the pellet

is, $X_A = \frac{N_{A0} - N_A}{N_{A0}}$

A graph is drawn for X_A Vs time and shown as fig 5.3 and fig 5.4. The figure reveals two zones, the initial zone or Zone A, when the release is rapid and the later zone or zone B, where, retarded release was common. The initial zone was found to last about 15-20 hours, where the release is rapid and ranges from 15 to 40% depending upon the composition of the pellet. The remaining fraction of fertilizer released Slowly over a period of 7 to 14 days which is called later zone or zone B depending upon the pellet composition and or coating. For the data of figure 5.1 and figure 5.2, XA was computed and XA versus time was drawn and shown as figure 5.3 and figure 5.4. Similar observation could be seen. As initial fraction of $ZnSO_4$ in the preparation of pellet increases the initial period and quantity released were also higher. For the development of controlled/slow release fertilizer lower initial fraction of $ZnSO_4$ is favored but cost of the fertilizer increases.

Release kinetics of controlled release fertilizers is important to predict the release pattern. An attempt is made to identify the release order and rate of the active ingredient. X_A versus time data were computed and their relationships were established for each pellet using polynomial regression analysis of the type.

$$X_A = b_0+b_1 t +b_2 t^2 +b_3 t^3+b_4 t^4$$

For these relationship very high value of r^2 (i.e. >0.99) indicated the accuracy of polynomial. b_0, b_1, b_2, b_3, b_4 are constants. These constant together with r^2 are tabulated in table 5. The rate of release was calculated using the following equation

$$-r_A = 1/A\ (dX_A/dt) = k\ (X_A)^n$$

Now graphs are drawn as $-r_A$ versus X_A. All these figures indicating the release follow nearly zero order. From regression of data for each curve the rate constants were computed. The value of k together with r^2 were tabulated in table-5.

The data indicates the physical parameters of pellet like composition and diameter are key parameters which control the release. By a careful selection of this parameter one can design the required controlled release of fertilizer.

$$k=\phi(f_{znso4},\ f_{fly\ ash},\ f_{lime},\ d_p)$$

The data was analyzed in terms of k and other pertinent parameters.Pellets of different compositions are made and tested for their release rates. The components of the pellets have strong influence on the release pattern. The study is directed to maximize zinc sulphate and to minimize inert matter. Influence of each parameter can be analyzed as fallows.

4.1 Effect of zinc sulphate

Effective if active ingredient on zinc sulphate is very much important in the design of controlled release fertilizer. To know its effect, a graph is drawn as X_A versus time, and shown as Fig 5.3 and figure 5.4.

X_A is fractional zinc sulphate in the pellet at any instant of time. The figure reveals that X_A is decreasing with time. The decrease is rapid initial period while that is tapered of as time lapses. A district zone is found in the latter period when the release is relatively slow. The point at which the two zones intersect each other is called critical point. At critical point the release pattern changes its course and depends on the initial composition of zinc sulphate.

For lower initial zinc sulphate, the fractional release in the initial region also low. The values varied from 17% to 50%. At critical point, larger the initial fraction greater the cumulative release. In the later region, the release decreases with increase in fraction of zinc sulphate and fallowed by decrease. It can be ascertained from the above observations that 10% fertilizer is better.

4.2 Effect of Binder

Binder has strong influence on release of nutrient because of inert matrix binder interaction resulting in aggregation by bonding and decreases in porosity resulting lower release rate in Fig 5.5 and figure 5.6 indicates that 4% lime has better interaction leading to strong bond. The figure reveals increase in binder decrease the release fallowed by an increases with increase in binder.

4.3 Effect of Inert

Fractional inert material has little effect on X_A, for it fraction is maintained nearly constant at about 80 to 85%. The effect is shown in fig 5.7 and fig 5.8.

4.4 Effect of Pellet Diameter

The effect can be seen for the pellets without coating in fig 5.9 and the same effect can be seen in fig 5.10 for the pellets with coating. The figures reveal that X_A decreases with time. The two regions can be seen in both the figures. As the diameter of the pellet increases zinc sulfate retention in the pellet increases at any time. This is in general agreement with the earlier observations (37, 38).

4.5 Effect of Particle Size of the Fly Ash

Particle size of Fly ash has marginal effect. It is shown in fig 5.11 and 5.12. As size of the particle increases porosity of the pellet increases, hence so the release rate. $X_{critical}$ values were also found varying.

5.CONCLUSIONS

1) The zinc sulfate controlled release fertilizer made of zinc sulfate, lime and fly ash is readily available at low cost.
2) The release rate increased with increase in fractional zinc sulphate.
3) The increase in diameter of the pellet decreased the fractional release rates.
4) The rate of release decreased with increase in binder percentage.
5) As the inert particle size increased the porosity increased and hence the release of zinc sulfate increased.
6) For the pellet without coating the zinc sulfate release was up to a period of seven days. Initially the release rate was high and after 12 hrs the release rate decreased.
7) The Naphthalene coated pellets extended the release of zinc sulfate from 7 days to 14 days with a slow release in the initial period followed by gradual increase.
8) The rate of release of fertilizer is related to fractional zinc sulphate at any instant of time in following format. $-r_A = k (X_A)^n$.
9) The developed mathematical equations for nutrient release are as

follows and the results were shown in figures 5.13 and 5.14:

$$g_t = \frac{3}{\rho_s r}\left[\frac{D(t-t^1)}{\varepsilon l}(c_2 - c_1) - \frac{l}{6}\right] \qquad t < Y$$

$$g_t = 1 - \frac{c_s}{\rho_s}\exp\left(-\frac{3D}{r\, l\, \varepsilon}\, t\right) \qquad t > Y$$

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Figures:

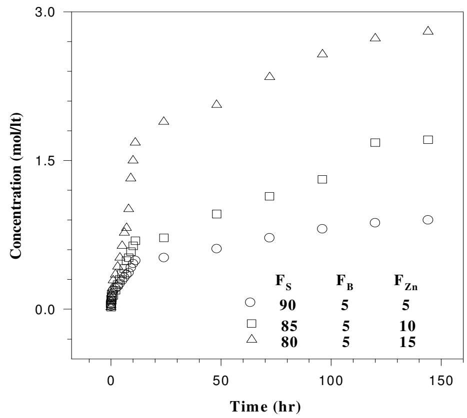

Fig.5.1 Variation of concentration with time(without coating)

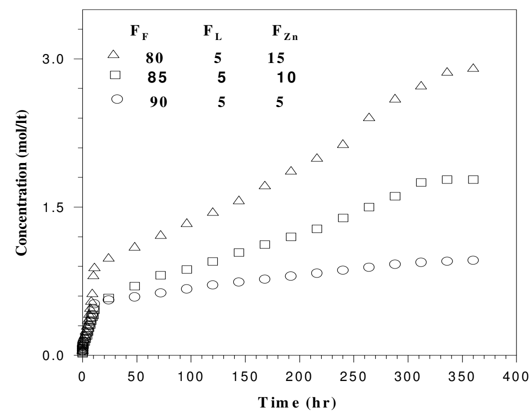

Fig.5.2 Variation of concentration with time(napthalene coating)

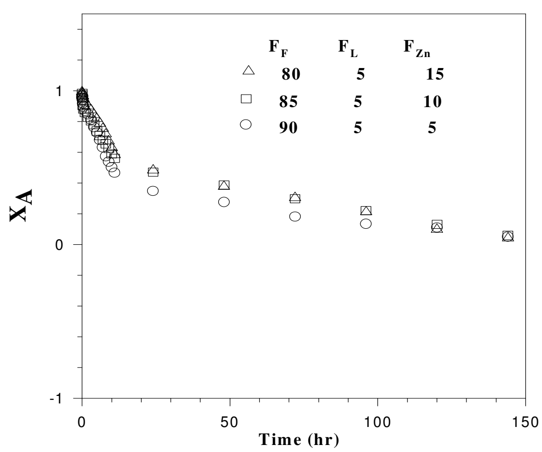

Fig.5.3 Variation of X_A with time(without coating)

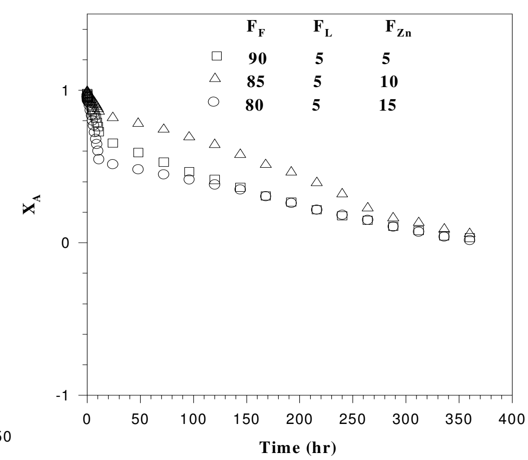

Fig.5.4 Variation of X_A with time(napthalene coating)

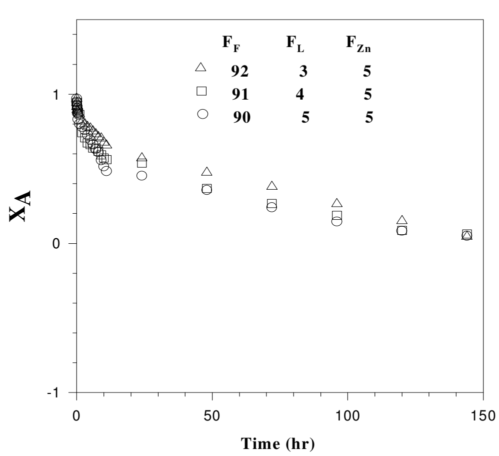

Fig. 5.5 Variation of X_A with time(without coating)

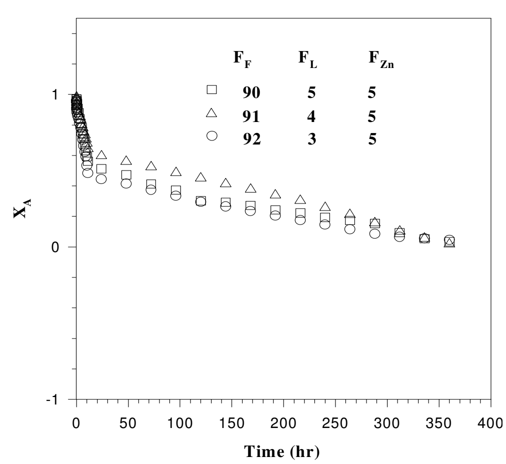

Fig.5.6 Variation of X_A with time(naphthalene coating)

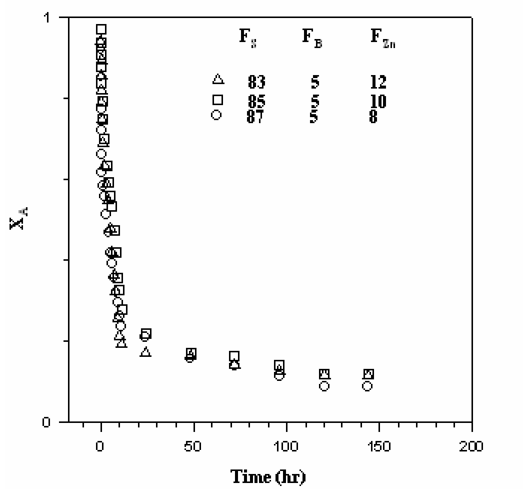

Fig 5.7 Variation of XA with time (without coating)

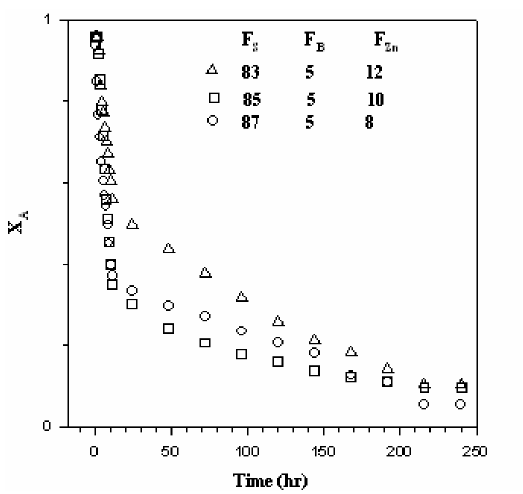

Fig 5.8 Variation of XA with time (with coating)

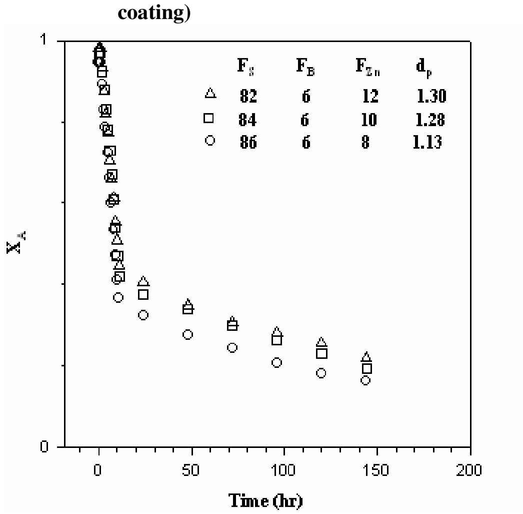

Fig 5.9 Variation of X_A with time (without coating)

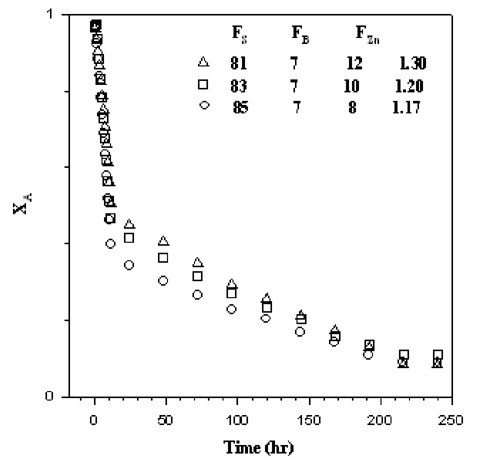

Fig 5.10 Variation of X_A with time (with coating)

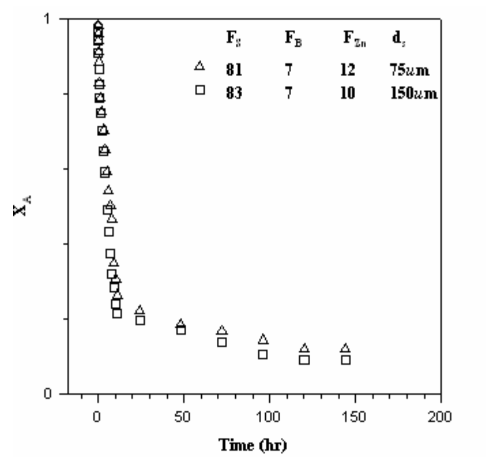

Fig 5.11 Variation of X_A with time (without coating)

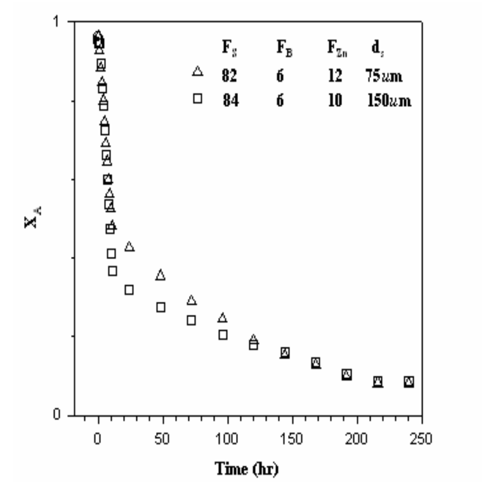

Fig 5.12 Variation of X_A with time (with coating)

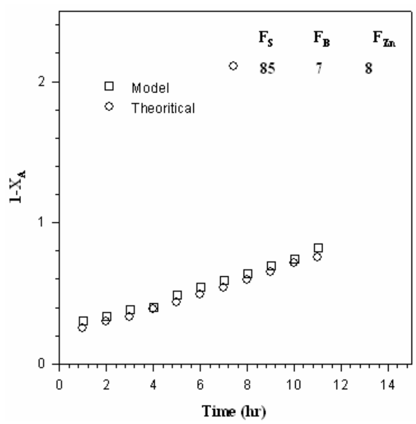

Fig 5.13 Variation of 1-X_A with time

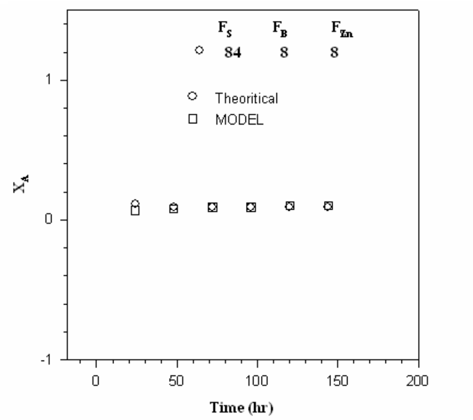

Fig 5.14 Variation of X_A with time

Tables:

Table-1. Range of variables studied

Diameter of the pellet (d_s cm)	Fractional Zinc Sulfate (f_{Zn})	Fractional fly ash (f_f)	Fractional lime (f_l)
1-1.5	0.5	0.92-0.90	0.03-0.05
1-1.5	0.10	0.87-0.85	0.03-0.05
1-1.5	0.15	0.82-0.80	0.03-0.05

Table 2 - Nutrient Contents of Micronutrient Fertilizers

SI. No	Name	Formula	Element/Forms	Contents(%)
1.	Zinc Sulphate	$ZnSO_4.7H_2O$	Zn	21.0
2.	Manganese Sulphate	$MnSO_4$	Mn	30.5
3.	Ammonium Molybdate	$(NH_4)_5$ $Mo_7)_{24}4H_2O$	Mo	52.0
4.	Borax(for soil application)	$Na_2B_4O_7.5H_2O$	B	10.5
5.	Solubor(foilar spray)	$Na_2B_4O_7.5H_2O$ + $Na_2B_{10}O_{16}.10H_2O$	B	19.0
6.	Copper Sulphate	$CuSO_4.5H_2O$	Cu	24.0
7.	Ferrous Sulphate	$FeSO_4.7H_2O$	Fe	19.5
8.	Chelated Zn	as Zn-EDTA	Zn	12.0
9.	Chelated Fe	as Fe-EDTA	Fe	12.0
10.	Zinc Sulphate monohydrate	$ZnSO_4.H_2O$	Zn	33.0

Table-3 Physical and Chemical Characteristics Fly ash and Soil:

Properties	**Fly ash**	**Soil**
BD (g cm^{-1})	<1.0	1.33
W.H.C. (%)	35-40	<20
Porosity (%)	50-60	<25
P (%)	0.004-0.8	0.005-0.2
K (%)	0.19-3.0	0.04-3.0
S (%)	0.1-1.5	0.01-0.2
Fe (%)	36-1333	10-300
Zn (ppm)	14-1000	2-100
Cu (ppm)	1-26	0.7-400
Mn (ppm)	100-3000	100-4000
B (ppm)	46-618	0.1-40

Table: 4

S.No	Variables	range
1	Fractional Zinc sulphate	5 to 15%
2	Fractional inert matrix	80 to 92%
3	Particle size of the inert	75-150µm
4	Fractional binder	3,4,5
5	Diameter of the pellet	1 to 1.8 cm

Table:5

d_p	f_{zn}	f_b	f_I	b_0	b_1	b_2	b_3	b_4	b_5	r^2
1.148	8	8	84	0.9834	-0.0372	7.954e-4	-7.489e-6	3.099e-8	-4.655e-11	0.9721
1.182	10	8	82	0.9702	-0.0390	8.404e-4	-7.899e-6	3.256e-8	-4.873e-11	0.9844
1.157	12	8	80	0.9484	-0.0413	9.210e-4	-8.807e-6	3.680e-8	-5.570e-11	0.97803
1.186	10	6	84	0.9760	-0.0476	1.068e-3	-1.004e-5	4.141e-8	-6.204e-11	0.9730
1.216	12	6	82	0.9717	-0.0486	1.087e-3	-1.026e-5	4.236e-8	-6.356e-11	0.9708
1.294	8	6	86	0.9428	-0.0525	1.186e-3	-1.122e-5	4.652e-8	-7.011e-11	0.9658
1.305	8	7	85	0.9501	-0.0425	9.557e-4	-9.065e-6	3.746e-8	-5.614e-11	0.9764
1.245	10	7	83	0.9747	-0.0406	8.863e-4	-8.358e-6	3.456e-8	-5.190e-11	0.9791
1.163	12	7	81	0.9488	-0.0466	1.060e-3	-1.006e-5	4.170e-8	-6.268e-11	0.9701
1.236	8	9	83	0.9721	-0.0458	1.013e-3	-9.566e-6	3.960e-8	-5.958e-11	0.9744
1.238	10	9	81	0.9751	-0.0547	1.243e-3	-1.184e-5	4.939e-8	-7.479e-11	0.96461
1.196	12	9	79	0.9454	-0.0478	1.090e-3	-1.036e-5	4.303e-8	-6.484e-11	0.9692
1.132	8	5	87	0.9475	-0.0364	7.930e-4	-7.539e-6	3.1417e-8	-4.747e-11	0.9833
1.263	10	5	85	0.8882	-0.0516	1.216e-3	-1.173e-5	4.9107e-8	-7.437e-11	0.9541

1.236	12	5	83	0.9549	-0.0561	1.269e-3	-1.202e-5	4.999e-8	-7.556e-11	0.9631
1.294	8	6	86	0.9752	-0.0428	9.333e-4	-8.777e-6	3.632e-8	-5.466e-11	0.9772
1.182	10	6	84	0.9542	-0.0455	1.006e-3	-9.512e-6	3.9460e-8	-5.949e-11	0.9747
1.117	12	6	82	0.9479	-0.0438	9.692e-4	-9.232e-6	3.8580e-8	-5.848e-11	0.9784
1.241	8	7	85	0.9528	-0.0501	1.124e-3	-1.061e-5	4.388e-8	-6.596e-11	0.9742
1.316	10	7	83	0.9423	-0.0437	9.426e-4	-8.722e-6	3.5634e-8	-5.310e-11	0.9804
1.232	12	7	81	0.9922	-0.0436	8.774e-4	-7.778e-6	3.0864e-8	-4.503e-11	0.9806
1.163	8	8	84	0.9620	-0.04058	8.823e-4	-8.271e-6	3.4030e-8	-5.090e-11	0.9813
1.183	10	8	82	0.9415	-0.0472	1.088e-3	-1.048e-5	4.3887e-8	-6.641e-11	0.9745
1.185	12	8	80	0.9707	-0.0475	1.036e-3	-9.632e-6	3.9453e-8	-5.893e-11	0.9751
With Out coating										
1.243	8	9	83	0.8654	-0.0765	2.797e-3	-4.414e-5	3.069e-7	-7.752e-10	0.9819
1.281	10	9	81	0.8346	-0.0840	3.051e-3	-4.756e-5	3.284e-7	-8.271e-10	0.9814
1.387	12	9	79	0.6013	-0.0703	2.798e-3	-4.556e-5	3.222e-7	-8.235e-10	0.8677
1.126	8	8	84	0.8574	-0.0850	3.353e-3	-5.445e-5	3.848e-7	-9.831e-10	0.9628
1.165	10	8	82	0.8261	-0.0860	3.308e-3	-5.289e-5	3.707e-7	-9.429e-10	0.9625
1.287	12	8	80	0.8745	-0.0832	3.109e-3	-4.890e-5	3.386e-7	-8.533e-10	0.9766
1.092	8	6	86	0.8883	-0.0804	2.906e-3	-4.507e-5	3.100e-7	-7.788e-10	0.9818
1.263	10	6	84	0.8668	-0.0862	3.196e-3	-5.005e-5	3.459e-7	-8.716e-10	0.9769
1.268	12	6	82	0.8815	-0.0800	2.935e-3	-4.571e-5	3.144e-7	-7.881e-10	0.9773
1.204	8	7	85	0.8732	-0.0783	2.853e-3	-4.447e-5	3.066e-7	-7.704e-10	0.9816
1.406	10	7	83	0.8796	-0.0793	2.828e-3	-4.338e-5	2.961e-7	-7.396e-10	0.9736
1.462	12	7	81	0.8634	-0.0837	3.148e-3	-5.002e-5	3.490e-7	-8.846e-10	0.9770
1.162	8	5	87	0.8334	-0.0864	3.305e-3	-5.256e-5	3.667e-7	-9.297e-10	0.9726
1.206	10	5	85	0.8783	-0.0765	2.740e-3	-4.206e-5	2.871e-7	-7.169e-10	0.9794
1.236	12	5	83	0.7360	-0.0696	2.653e-3	-4.239e-5	2.967e-7	-7.539e-10	0.9336
1.128	8	6	86	0.8726	-0.0644	2.277e-3	-3.508e-5	2.398e-7	-5.988e-10	0.9808
1.172	10	6	84	0.8790	-0.0825	2.942e-3	-4.552e-5	3.137e-7	-7.906e-10	0.9788
1.242	12	6	82	0.8338	-0.0955	3.619e-3	-5.732e-5	3.995e-7	-1.012e-9	0.9586
1.126	8	7	85	0.9209	-0.0811	2.900e-3	-4.441e-5	3.020e-7	-7.516e-10	0.9825
1.139	10	7	83	0.8816	-0.0907	3.493e-3	-5.593e-5	3.919e-7	-9.958e-10	0.9765
1.234	12	7	81	0.8512	-0.0895	3.565e-3	-5.646e-5	3.894e-7	-9.561e-10	0.9554
1.184	8	8	84	0.8729	-0.0836	3.031e-3	-4.689e-5	3.216e-7	-8.055e-10	0.9792
1.213	10	8	82	0.8608	-0.0756	2.768e-3	-4.342e-5	3.012e-7	-7.612e-10	0.9775
1.316	12	8	80	0.8600	-0.0856	3.271e-3	-5.215e-5	3.642e-7	-9.231e-10	0.9718