Multiple Regressions Modeling of Urea Release from Briquettes

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Abstract**—Urea briquettes are extensively used in agricultural fields since loss of urea occurring is minimized. Large deviations observed in the case modeling urea release from uncoated briquettes by shrinking core and semi infinite models could be minimized by subjecting the same set of data to empirical modeling technique such as Multiple Regressions (MR). In this paper, MR model parameters were fitted for the experimental data on urea release from uncoated briquettes in three different types of soils viz loam, silty clay and silt loam. Input parameters considered are duration of release (t), moisture content (m), and clay content (C).Good fit was observed between experimental data and model predicted data for release of urea up to 70%. Clay content has higher effect on the rate of release and duration of release is weakly influencing the release.**

Keywords**—briquette, multiple regression model, release, soil, urea**

I. Introduction

Rice is the most important food crop in the developing countries of Asia, where population densities are very high and overall dietary levels are not adequate. In South and Southeast Asia, rain fed and irrigated transplanted rice occupies nearly two-thirds of the rice growing area and produces more than 80% of the paddy [1]. In these areas, prilled urea conventionally applied by farmers leads to serious losses (up to 60% of the applied N) via ammonia volatilization, denitrification, leaching and surface runoff [2]. In order to minimize N loss, especially due to denitrification, historically the Japanese have used different ways of deep placing nitrogenous fertilizer. In 1975, International Fertilizer Development Corporation proposed the use of large sized, cost effective briquetted form of urea which could achieve the same agronomic benefits as achieved through the Japanese concept of deep point placement of N fertilizer in transplanted rice fields [1].

The commercially available urea briquettes are commonly used in certain parts of Asia and these briquettes are known to reduce the loss of N and increase agricultural yield per unit weight of applied fertilizer [3]. Urea briquettes dissolve in about 8-10 hours in wet soil, producing high concentration of urea around the shrinking briquette [4].

Shrinkage and dissolution of uncoated briquettes in wet soil could be modeled using different approaches. Shrinking core model [5] focuses upon the reduction in size/weight of the briquettes and correlates the various soil/medium parameters with size/weight of briquettes and time/duration. Concentration of urea developed in the wet medium is ignored and resistance is assumed to exist in the core containing high concentration of urea surrounding the shrinking solid. Although a reasonably good prediction from this model can be obtained in case of low clay soils, in the case of high clay soils, large deviations can be observed. This is because of lack of free soil solution in the case of wet high clay soils. Semi infinite model [6] correlates the time dependent urea concentration developed from shrinking briquette in the wet soil with various soil parameters. However, large deviations (50% to 80%) can be observed between the experimental soil concentration and the model predicted soil concentration profile irrespective of type of soil [4]. Attributable reasons for the deviations could be the assumption of unchanging size of briquettes and experimental concentration measurement errors.

In this paper, data of unreleased urea vs. time, from experiments conducted in various soils and moisture contents, is modelled using the empirical model Multiple Regressions (MR).

II. MATERIALS AND METHODS

Urea concentration was measured in this study by the colorimetric method outlined by [7]. Urea concentration in wet soil as reported includes urea present in soil solution plus the quantity adsorbed on solid particles per gram of wet soil. Commercial urea briquettes are ellipsoidal in shape, weigh about 2.1g and have a urea content of about 98.5%. Three different soils were used in the study, viz. silty clay, loam and silt loam. These soils were characterized as per the Indian Standards [8]. Their properties are listed in Table 1.

TABLE 1
PROPERTIES OF VARIOUS SOILS

Characteristic	silty clay	loam	silt loam
Clay content, C,%	51	13	5
Saturation moisture, $\frac{g - moisture}{g - dry\ soils}$	0.55	0.40	0.40
pH	8.19	5.17	6.02
Organic carbon, %	0.582	0.323	0.0

The uncoated briquettes were subjected to release in wet soils. For uncoated briquettes, experiments were conducted in loam, silt loam and silty clay soils. Moisture contents (m, g-moisture/ g-dry soil) were 0.05, 0.10, 0.2, 0.3 and 0.4 for loam, 0.2, 0.3 and 0.4 for silt loam soil, while for the silty clay soil moisture contents were 0.2, 0.3, 0.4 and 0.55.

For a known quantity of dry soil, required quantity of water was added; equal quantity of the prepared wet soils soil was transferred to a series of plastic columns, covered by plastic film to prevent evaporation and incubated for 24 hours. One urea briquette was placed at a depth of 5 cm in each of the plastic column and allowed to dissolve and shrink. At regular intervals of time, shrunk briquette was withdrawn from different column and analysed for unreleased quantum of urea.

Uncoated briquettes shrank uniformly with time. At lower moisture contents, the differences in the urea release from the uncoated briquettes were almost independent of the type of soil; however at higher moisture contents, slower release was observed in the silty clay soil. Parameters affecting the urea release from the uncoated briquettes depended on time, moisture and clay content of the soils taken up.

III. RESULTS AND DISCUSSIONS

Consider the second order empirical model

$$Y = \beta_0 + \sum\beta_i X_i + \sum\beta_{ii} X_i^2 + \sum\sum\beta_{ij} X_i X_j \quad (1)$$

In equation (1), Y is the predicted output (fraction of urea released), X_i is independent input variable, β_o is intercept term, β_i linear coefficient, β_{ii} quadratic coefficient and β_{ij} is interaction (cross product) coefficient. The regression was carried out using Matlab2007b. Input parameters (X_i) were fixed by trial and error by minimizing RMSE.A combination of three different input parameters were found to give best result; they are time (t, hours), moisture content on dry basis (m, g-moisture/g-dry soil), and soil clay content. Release from uncoated briquettes is strongly dependent on time and soil moisture. Clay content (C) in soil has been observed to resist the dissolution of uncoated briquettes. In addition, unreleased urea was found to provide a better fit by the model in comparison with unreleased urea content.

Output (Released Urea Fraction=1 - Fractional Unreleased Urea) generated by the models were compared with experimental unreleased urea. Statistical parameters, such as Root Mean Square Error (RMSE), Mean Absolute Error and R^2 were determined. In all, 87 data points were utilized for modeling. About 40% of the data was used for training the model.The unreleased urea vs. time data required for the empirical modeling were obtained from our earlier study [9], for each of the moisture content.

The model output vs. the experimental output is plotted in Fig 1. Fitted equation is,

$$Y = -0.01013 + 0.0515\,t + 0.0852\,m + 1.1343C - 0.0012\,t^2 + 1.9254\,m^2 - 1.7541C^2 + 0.0496\,t\,m + 0.0035\,t\,C - 0.793\,m\,C \quad (2)$$

It can be observed from the equation (2) that the parameter time (t) has a weak influence on the output since the coefficients associated with all its term are very low in comparison with coefficients of the other parameters. Clay content has the most significant influence on the output Y, while moisture content has the intermediate effect on the output. Model output (fractional released urea) for the 87 different data points were obtained by substituting for the corresponding input parameters t, C and m in equation (2). Thus generated model output vs. the experimental data, with various statistical parameters is presented in Fig. 1.

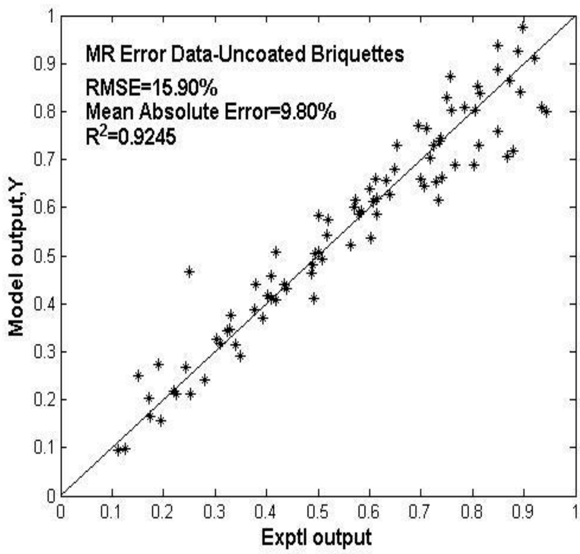

Fig. 1 Multiple regression model out vs. experimental output for uncoated data

It can be observed from Figure 1 that a relatively better match was observed with experimental outputs in the range of 0.1 to 0.70; whilst beyond 0.70 larger scatter was observed, probably due to the development of larger concentration gradients with time. This implies that a closer agreement between the model output and experimental data during the initial release periods when the released urea fractions are low.

IV. CONCLUSIONS

Multiple Regressions (MR) technique was employed to model the data of unreleased urea from the wet soil experiments conducted in various soils. In the case of urea release from uncoated briquettes, the MR model provided a good fit for the data in comparison with the reported semi infinite and shrinking core model.

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NOTATIONS

C	fractional clay content
m	moisture content on dry basis, g-moisture/ g-dry soil
MR	Multiple Regression
RMSE	root mean square error
t	time, h
X_i	independent input variable

Y	predicted output from MR model
β_i	linear coefficient
β_{ii}	quadratic coefficient
β_{ij}	interaction (cross product) coefficient
β_o	intercept term