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Poly Vinyl Acetate Butyl Acrylate as an Effective Coating for Water Soluble Fertilizers: I- Dissolution Rate and Released Nutrients as a Function of Time.

El-Hady, O.A., Camilia, Y. El-Dewiny and Abd El-Kader, A.A.

Soils and Water Use Department, National Research Centre (NRC), Dokki, Cairo, Egypt.

Abstract: One of the main objectives of our research program is to produce slow and at the same time controlled release fertilizers using local and cheap coating materials . A complex fertilizer 20:20:20 was coated with the emulsified polymer (50% active material) polyvinyl acetate butyl acrylate. Four coating fertilizer ratios were examined namely ;0:100; 2.5 : 97.5 ; 5 : 95 and 7.5 : 92.5 . Dissolution rate and released N, P and K after soaking the fertilizer in deionized water for different periods up to 120 days under constant temperature (100°F i.e 37.8 °C) indicate the possibility of using such polymer to produce effective coatings for water soluble fertilizers. Coating thickness influences the release rate and longevity of the product. Costs of preparation are economically justified.

Key words: Controlled release fertilizers, Slow release fertilizers, Poly vinyl acetate, butyl acrylate-fertilizer coatings

INTRODUCTION

Application of regular soluble fertilizers -particularly to sandy soils that have very little ability to maintain soluble nutrient elements- is difficult to practice. Loss of fertilizers by leaching and deep percolation, frequent fertilizer applications; low crop use efficiency; pollution of ground water and eutrophication of natural surface waters besides increasing fertilization costs and labor expenses are expected. Therefore, specific fertility management practices will be required to grow crops on these sandy soils. Application of controlled release fertilizers (CRF) to release nutrients in small quantities over an extended period of time may solve most of the aforementioned problems. Numerous researches have demonstrated the superiority of slow release fertilizers in experiments with forage, grains, vegetables and fruit trees grown in field and green house. They reported that single application of slow release N fertilizer gave maximum yield production and seasonal distribution of growth similar to those obtained with the multiple (3-5) application of urea or ammonium nitrate. (Wen *et al.,* 2001; Jian Rong *et al.,* 2001; Junwei *et al.,* 2000; Paramasivam and Alva, 1997 a and b ;Wang and Alva, 1996; Ko *et al.,* 1996; Diez *et al.*, 1996 and Sharon, *et al.,* 1990).

In recent years, due to public demands for environmental protection and the need for increasing production efficiency, great efforts in developing and manufacturing slow and at the same time CRF became necessary. Resin coating technology has been adapted to produce CRF. With coating, the inner soluble nutrient elements will be released slowly to be taken by the growing plant as it is required (Wen *et al.,* 2001).

Producing CRF using local and cheep coating materials is of the main objectives of our research program. Of these is the emulsified polymer poly vinyl acetate butyl acrylate. Previous studies by the outhers using bitumen emulsions and polymerized or rubberized bitumen emulsions as coating materials El-Hady and Ghaly, 2000 and 2004 and El-Hady, *et al.,* 2003a encouraged us to continue the work with other coatings. That is the aim of the present study.

MATERIALS AND METHODS

Materials:

Fertilizer: A complex water-soluble fertilizer 20:20:20; that ordinary used in fertilization of new reclaimed sandy areas was used. It contains 20% of each of N,P_2O_5 and K_2O.

Corresponding Author: El-Hady, O.A., Soils and Water Use Department, National Research Centre (NRC), Dokki, Cairo, Egypt.

Coating Material:

The examined coating material was the emulsified polymer polyvinyl acetate butyl acrylate (50% active material). The polymer was prepared in the Polymer Pigments Department , NRC by emulsion polymerization of vinyl acetate + butyl acylate, (1:1). Polymerization conditions were : a) polymerization was carried out under nitrogen atmosphere i.e. in the absence of air . b) initiator used was the redox pair initiator system i.e. sodium bisulphate ($NaHSO_3$) and potassium persulphite ($K_2S_2O_8$) at the ratio of 1: 2.5. Initiator : monomer (w/w) was 0.5% polyvinyl alcohol having boiling point of 120 °C and Mol. Wt. 700000 and d) the temperature used and time of polymerization were 60 °C and 8 hr. with continuous stirring, respectively, (El-Hady and Abd El-Hady, 2001).

Methods:

Coating Process:

The prepared coating material was sprayed on the fertilizer using a modified horizontal rotary drum with pan granulator. It provides a homogenous (with respect to particle size), dense, mass of sized particles in random motion so that highly uniform coating can be applied to each particle. General, description of the apparatus was previously mentioned (El-Aila and Abou-Seada, 1996). Four different coating fertilizer ratios were examined i.e. 0:100, 2.5:97.5, 5:95 and 7.5:92.5.

Evaluation of the Prepared Fertilizers:

Dissolution Rate:

Uncoated and coated fertilizers were evaluated for their releasing rate as follows: A weight that contains five grams of the fertilizer was enclosed in a nylon screen bag. The bag was inserted vertically in a glass jar containing 25 ml deionized water. Jars were covered and placed in an incubator at 100 ^{0}F (37.8 ^{0}C) for the appropriate time interval. Dissolved fertilizer was determined by calculating the weight loss from each sample as a function of time. Data of the mean value of four replications were graphically plotted versus time.

Released Nutrients as a Function of Time:

Samples from the remained solutions were taken after 1, 2, 3, 5, 7, 14, 21, 28, 35, 42, 49, 56, 60, 90 and 120 days. Determination of N, P and K was carried out using methods described by Bremner and Mulvany (1982) for nitrogen and cottenie *et al*., (1982) for the other two nutrients.

RESULTS AND DISCUSSION

Dissolved amounts of the uncoated and coated fertilizers after immersing in deionized water for different periods up to four months (120 days) under constant temperature (100 ^{0}F) are illustrated in figure 1. It is worthy to note that each value is the mean of four replications. Released N, P and K are shown in figures 2, 3 and 4, respectively.

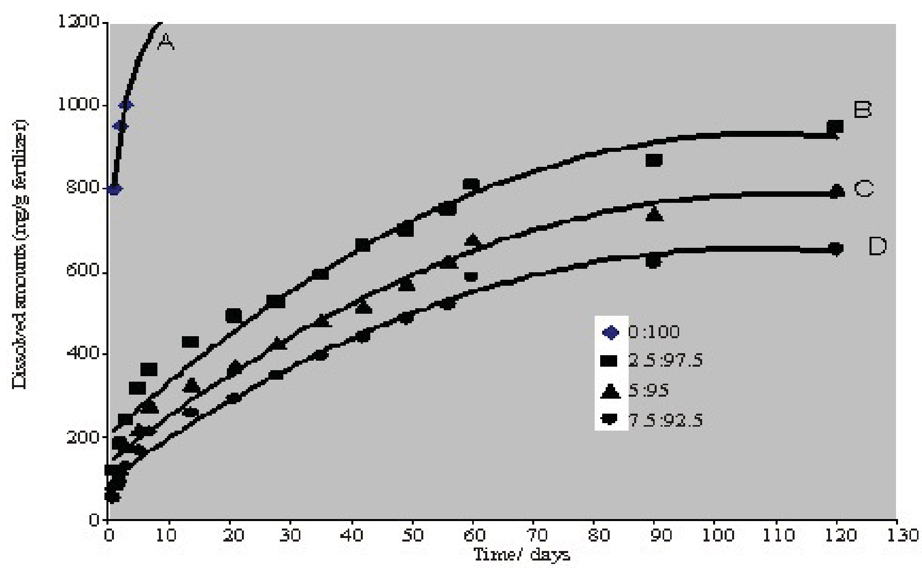

Fig. 1: Dissolved amounts (mg/g fertilizer).

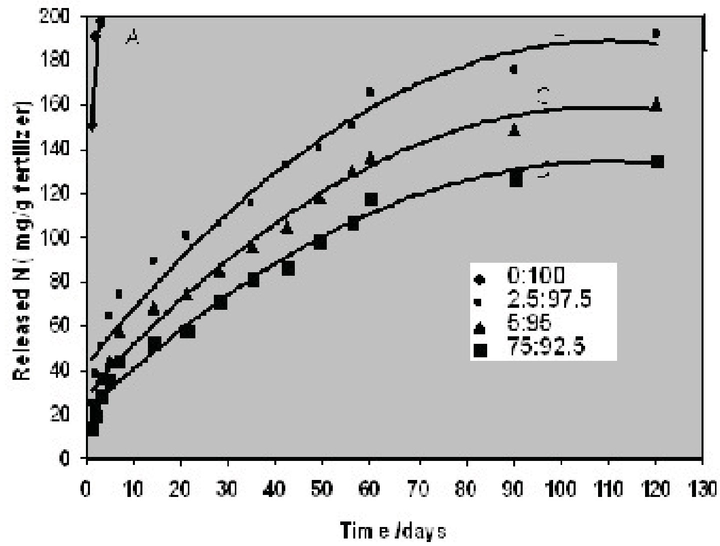

Fig. 2: Released N (mg/g fertilizer).

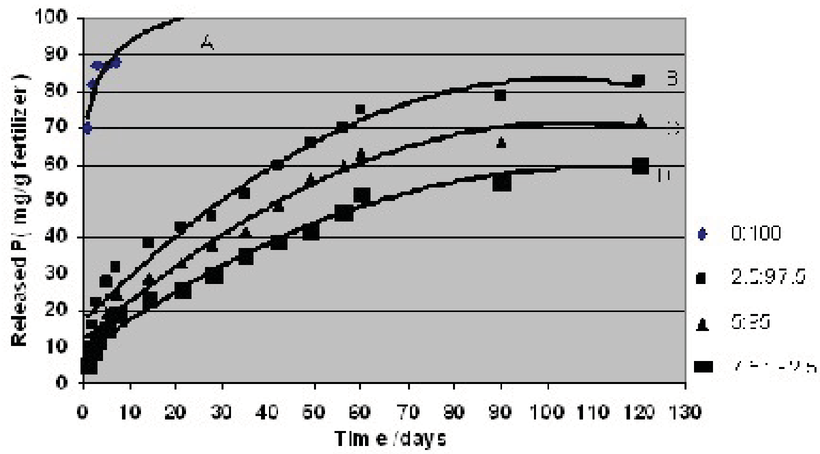

Fig. 3: Released P (mg/g fertilizer).

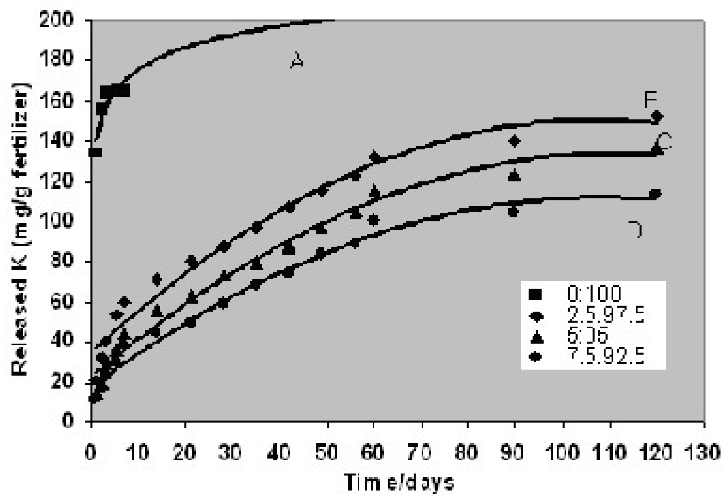

Fig. 4: Released K (mg/g fertilizer).

A considerable amount of the uncoated fertilizer was released in the first day to reach more than 75% of the fertilizer and its nutrients. The disappearance of undissolved fertilizer was observed at the third day. On the other hand, coated granules released their nutrients much more slowly. Considerable amounts of dissolved fertilizer and nutrients are still released. The higher the coating fertilizer ratio i.e. the thicker the coating is, the slower is the release of the fertilizer nutrients and the longer is the period of release, referring to the possibility of long duration of the fertilizer in the soil. The statistical relations between the percentages of dissolved fertilizer or released nutrients (y) and time in days (x(as affected by coating thickness are presented in Table 1. Regression equations and correlation coefficients denote highly significant relations. Taking these relations into consideration, the time in days required for the fertilizer to release different percentages of its inner content i.e. 25, 50 and 75% under the conditions of the study are shown in Table 2. Data indicate the aforementioned fact that coating thickness influences the release rate and longevity of the product.

In general, there are two release patterns for the coated fertilizer pellet to release soluble nutrient elements. An immediately and relatively rapid release through a few holes or many microscopic pores originally present in the coating and little release for an extended period of time (Ko *et al.,* 1996 and wen *et al.,* 2001). Therefore, controlling the thickness as well as using multiple coating techniques

Table 1: Statistical relations between the percentages of dissolved fertilizer or released nutrients (y) and time in days (x) as affected by coating thickness.

Coating : fertilizer	Regression Equations	Correlation coefficient r
	Dissolved fertilizer	
0:100	$y = 185.75LnX + 805.73$	r = 0.9950**
2.5:97.5	$y = -0.062X^2 + 13.49X + 207.65$	r = 0.9930**
5:95	$y = -0.052X^2 + 11.63X + 141.36$	r = 0.9950**
7.5:92.5	$y = -0.048X^2 + 11.09X + 93.96$	r = 0.9950**
	Released N	
0:100	(A) $y = 33.90LnX + 161.75$	r = 0.9879**
2.5:97.5	(B)$y=-0.0119X^2 + 2.617X + 44.139$	r = 0.9930**
5:95	(C)$y = -0.0113X^2 + 2.578X + 24.439$	r = 0.9935**
7.5:92.5	(D)$y = -0.0104X^2 + 2.213X + 17.475$	r = 0.9930**
	Released P	
0:100	A) $y = 11.50 \ln X + 68.701$	r=0.9643**
2.5:97.5	(B) $y = -0.007X^2 + 1.424X + 13.013$	r = 0.9599
5:95	C) $y = -0.006X^2 + 1.246X + 8.467$	r = 0.9940**
7.5:92.5	D) $y = -0.0049X^2 + 1.013X + 6.959$	r= 0.9925
	Released K	
0:100	A)$y = 16.93\ln X + 137.293$	r= 0.9628**
2.5:97.5	B)$y = -0.0117X^2 + 2.406X + 28.83$	r = 0.9849**
5:95	C)$y = -0.0107X^2 + 2.232X + 17.64$	r = 0.9930**
7.5:92.5	D)$y = -0.0084X^2 + 1.818X + 14.92$	r = 0.9915**

**highly significant at 1% level

Table 2: Time (days) required for the fertilizer to release 25%, 50% and 75% of its inner content under standard conditions (100 F^0 in water).

Coating : Fertilizer	% of release		
	25	50	75
		Dissolved fertilizer	
0:100	<1	<1	<1
2.5:97.5	3	25	54
5:95	10	37	85
7.5:92.5	16	50	>120
		Released N	
0:100	<1	<1	<1
2.5:97.5	3	24	54
5:95	9	36	81
7.5:92.5	15	50	>120
		Released P	
0:100	<1	<1	<1
2.5:97.5	4	23	50
5:95	10	34	73
7.5:92.5	16	50	>120
		Released K	
0:100	<1	<1	<1
2.5:97.5	3	25	56
5:95	10	36	80
7.5:92.5	15	48	>120

can control the rate of nutrient element release. Recent development in coating technology allows duration of nutrient elements from 20 to 700 days (measured in water at 25 ^{0}C). Nutrient element released from coated fertilizers could match crop uptake during the whole growing period, if a well designed mixture of coated fertilizers is used. This would allow coated fertilizers to have a higher crop use efficiency than that obtained from regular fertilizers. Researches comparing regular and coated fertilizers have demonstrated how coatings improve crop uptake efficiency. Garcia *et al.,* 1997 reported that poly-olefin or lignin-coated N fertilizers were particularly effective in minimizing N losses and enhancing N use efficiency in sandy soils. In the case of P, reduced contact between the fertilizer P and the soil extended the time that P was available to plants.

Nazyo et al., 1998 observed that P recovery rates were three to five times higher with polyolefin-coated double super phosphate and multi-super phosphate than with uncoated ones. In calcareous soils with high P-fixation capacity, where application of uncoated P fertilizers did not significantly increase soil available P, coated P fertilizer did. Coated trace nutritive elements such as Zn appeared superior to the regular ones. Polyolefin coated Zn increased Zn uptake in a Zn deficient soil resulting in a significant yield increase compared with that obtained using a soluble Zn form (Rico *et al.,* 1996).

Costs:

It is interesting to note that the main components of the examined coating are locally prepared. Producing one ton of this coating costs$\simeq$ 2000 L.E. (prices of 2007). With this respect, one ton of the regular soluble fertilizer (5000 L.E.) needs only $\simeq$ 51,105 and 162 L.E. for the coating material to produce CRF_S having the three coating fertilizer ratios, 2.5:97.5, 5:95 and 7.5:92.5,respectively. This will be economically justified if compared with other types of coatings.

Obtained results push us to continue the work with other coating formulations for soluble fertilizers having both macro and micro-nutrients at the same time.

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