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Improving the dissolution and releasing characteristics of potassium nitrate and urea fertilizers by their coating with some organic and inorganic materials

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ABSTRACT

This work describes the method of producing physically prepared slow – release fertilizers to provide an insoluble coating on granules of water – soluble fertilizers. The fertilizers chosen are potassium nitrate and urea. Stearic acid, calcium hydroxide, paraffin was, fatty acid and talk are the materials used to prepare four types of coating varying in their composition. These types of coating are referred to by a number of examples : Ex_1, Ex_2, Ex_3 and Ex_4. The granules of coated fertilizers were tested for their dissolution in water at 20 and 40 °C. It was found that coated potassium nitrate has lower dissolution than coated urea. As the temperature was raised from 20 to 40 °C, the dissolution rate increased for both fertilizers. The treatments Ex_3 and Ex_2 have the best (lowest) dissolution rate, respectively. The Ex_4 treatment recorded the worst values due to that the strength of the granules was quite poor. Releasing rate of potassium nitrate and urea fertilizers in sandy soil at 25 and 50 °C and field capacity 20 and 40 % was tested. Increasing temperature increased the releasing rate. Moisture content had lower effect. Potassium nitrate fertilizer recorded lower values of releasing than urea. Among the treatments, coating of both fertilizers decreased their releasing rate in the following order, $Ex_3 > Ex_2 > Ex_1 > Ex_4$ and finally the uncoated treatment.

KEYWORDS

Slow – release fertilizers;
Dissolution rate;
Releasing rate;
Potassium nitrate;
Urea;
Sandy soil.

INTRODUCTION

It is a well known fact that no fertilizer, of whatever composition, is ever utilized by the crop with a complete efficiency. This occurs particularly with nitrogen – based fertilizers, although it is encountered also with all water – soluble fertilizers. The main reason for this deficiency is the rapid dissolution of the fertilizer in the soil where only a part thereof is actually utilized, the balance being lost in the draining of rain or irrigation water. The main solution suggested to overcome this disadvantage was the use of physically prepared slow – release fertilizers, by coating the fertilizer granules with sulfur, wax or synthetic polymers[1-3].

Among the factors influencing the fertilizer release from coating material are environmental effects. Increasing either temperature or moisture content of the soil increases the release of potassium nitrate from the coating film[4-6]. Dissolution doubles for every 10 °C rise in temperature[7,8]. Nitrogen is released from the coated fertilizer when water moves into the granules by osmotic potential; the resulting pressure causes the fertilizer to diffuse out through the coating[9,10].

The object of the present work is to provide a method for manufacture of physically prepared slow – release fertilizers, by coating the fertilizer granules with some materials and study the effect of coating, moisture and temperature on the dissolution and releasing rates.

MATERIALS AND METHODS

The fertilizer to be coated according to the present work, is selected from the well – known water soluble fertilizers such as: potassium nitrate and urea. Whereas the coating constituents are quite inert material. Specifications of the original potassium nitrate (Chemicoke product) and commercial urea fertilizer prills are cited in (TABLE 1).

TABLE 1 : Potassium nitrate and urea specifications

Fertilizers	Total N Content (%)	Solubility in water (%)	Bulk Density, g/cm^3	Particle Size, (mm)
Potassium nitrate	33.3	100	0.85	1.5-2.0
Urea	46.0	100	0.75	1.6-2.30

Coating process

The work will be hereafter illustrated by a number of Examples (Ex) being clearly understood that no limitation should be understood, since many variations could be conceived, without being outside the scope of the present work.

Example 1

An amount of 100 g. of each fertilizer was introduced in a laboratory rotating pam and heated to about 75 °C. To the prills of the fertilizer an amount of 5.3 grams of stearic acid was added together with an amount of 20 g. of calcium hydroxide. After the entire amount of stearic acid was consumed, by its reaction with the calcium hydroxide, free flowing granules were obtained consisting of the fertilizer coated by calcium stearate, formed in – situ from the two reagents. To the coated granules in the pam granulator, an amount of 4 g. of paraffin wax was added together with a small quantity (about 2 g.) of calcium hydroxide (as inert constituent) and the pam granulator continued to operate until all the paraffin wax was consumed. After cooling, the granules were taken out from the granulator, the composition of the coating being as follows:

22 g. of calcium hydroxide
5.3 g. of steartic acid, and
4 g. of paraffin wax.

Example 2

The experiment as described in Example 1 was repeated, but in this case the calcium hydroxide used as the inert material in the step of the coating with paraffin, was replaced by 15 g. of talc. Also, the stearic acid was replaced by 6.6 g. of fatty acids (EDENOR UKD 3510, Trade Mark produced by Henkel, Germany). The composition of the coating was as follows:-

6.6 g. of fatty acid
20 g. of calcium hydroxide.
4 g. of paraffin wax and
15 g. of talc.

Example 3

The same equipment as in the previous Examples was utilized, but in this case the coating consisted of 3 layers. In each layer, the coating contained:

2.2 g. of fatty acid
6.6 g. of calcium hydroxide.
1.3 g. of paraffin, and
5 g. of talc.

The granules obtained were treated again in a similar manner, with two separate additional portions, of the above four reagents, one after the other resulting the granules coated by three layers.

Example 4

A comparative experiment as described in Example 1 was performed, with the same pam laboratory granulator as in the previous Examples, the fertilizer being also 100 g. but the reagent used for the coating was calcium stearate i.e. the already formed salt. Into the granulator containing the resulted coating an amount of 4 g. paraffin was added together with 2 g. of calcium hydroxide (as inert constituent) The composition of coating was as follows:

22 g. of calcium hydroxide.
5.3 g. of stearic acid, and
4 g. of paraffin wax.

Dissolution of fertilizers in water

Fifty g. of each of potassium nitrate and urea fertilizers for each Example 1,2,3,4 and control were held in sealed flasks containing 100 ml. pf distilled water at 20 and 40 °C for 7 weeks. The refractive index of the solution was measured as a function of time; the fertilizer dissolved in water (%) was calculated from the following equation:

$$\%\ \text{Dissolution} = \frac{(n_D^{20} - 1.3322)[744000\ (n_D^{20} - 1.3322)] + 141000}{100 - \%\ \text{total coating}}$$

Where n_D^{20} is the refractive index[11].

Fertilizers release in sandy soil

3 g. from each of potassium nitrate and urea fertilizers for each Example were enclosed in a nylon screen rectangular bag. The bag was inserted vertically in 300 g. dried soil (sieved by 1.00 mm. screen) that was incubated in a wide mouth pot 7 cm. diameter and 9 cm. height (Figure 1). Tap water was added to each pot to bring the moisture content of the soil to approximately 20 and 40 % of field capacity. The pots were incubated at 25 and 50 °C for 7 weeks. All combinations of the variables were replicated 3 times. Both fertilizers release rates were determined by calculating the weight loss from each sample as a function of time.

All data were statistically analyzed according to Snedecor and Cochran, 1967[12].

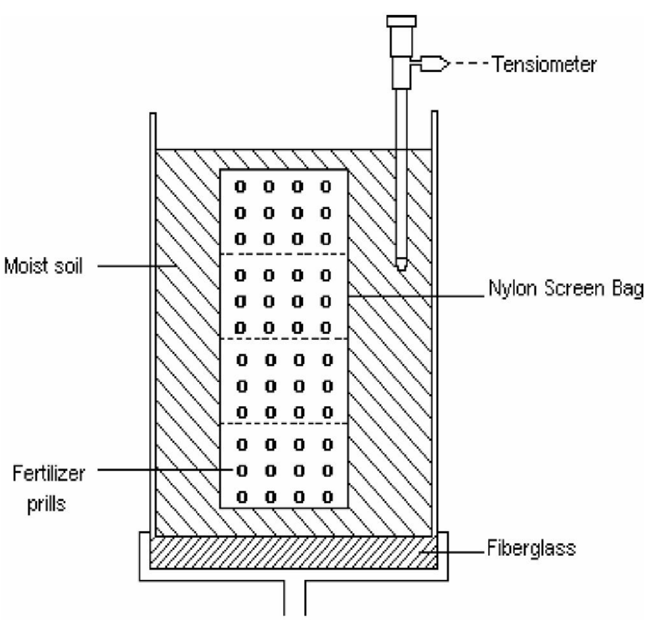


Figure 1 : Schematic diagram of the system used for measuring Potassium nitrate and urea release in sandy soil

RESULTS AND DISCUSSION

The release of fertilizer from coated fertilizer prills depends on many factors such as the quality of coating film, incubation media, temperature, water content and method of application[6,11,13,14]. The contribution of these factors to potassium nitrate and urea release from different Examples of coatings is discussed below.

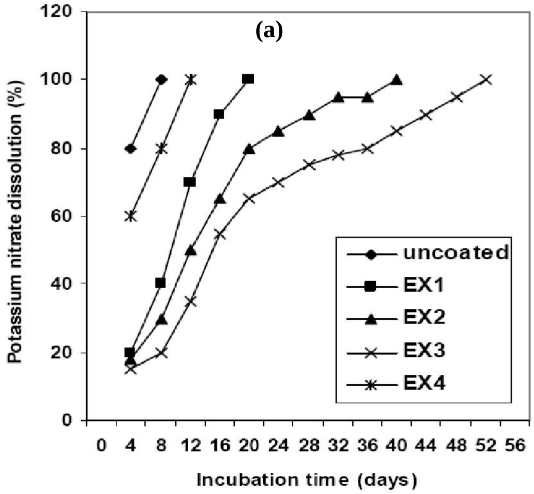
Dissolution of potassium nitrate and urea in water

Dissolution of Potassium Nitrate and Urea from Ex_1, Ex_2, Ex_3, and Ex_4 coatings at 20 and 40 °C for 7 weeks is illustrated on Figures 2, 3, respectively. Coating each fertilizer decreased the dissolution rate compared with the uncoated (control) treatment. Among the Examples (Ex_1, Ex_2, Ex_3, and Ex_4) for both fertilizers, Ex_3 and Ex_2 have the best (lowest) dissolution rates, respectively regardless the temperature and there was a significant difference between them. Treating both fertilizers with 3 layers (Ex_3 treatment) reduced the dissolution rate compared with the unlayered treatment Ex_2. This is in agreement with Heikal and Khalil[6]. The Ex_4 treatment recorded the worst values, it achieved 100 % dissolution in water after only 12 and 8 days at 20 and 40 °C, respectively for the two fertilizers compared with 52, 28 and 44, 24 days in the best treatment (Ex_3) for potassium nitrate and urea, respectively. This is due to that; the granules obtained possess indeed a smooth surface, due to the paraffin coating, but their strength was quite poor[15].

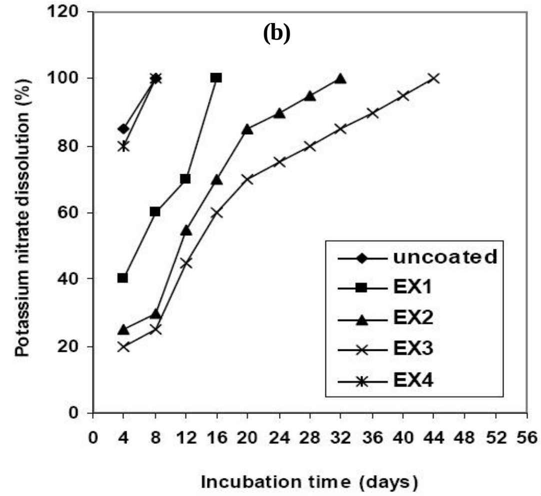
Comparison between the two fertilizers, reveals that coated potassium nitrate has lower dissolution rate than coated urea at 20 and 40 °C (Figure 4). Higher urea dissolution is due to increase of solubility and diffusion coefficient of the fertilizer[16-18]. As temperature was raised from 20 to 40 °C the dissolution rate of both coated urea and potassium nitrate increased (Figure 5).

Potassium nitrate and urea release in sandy soil

Potassium nitrate and urea release from Ex_1, Ex_2, Ex_3, and Ex_4 coatings at 25 and 50 °C and field capacity 20 and 40 % is shown on Figures 6, 7, 8, and 9, respectively. Comparison between the different examples; Ex_1, Ex_2, Ex_3, Ex_4 and uncoated treatment reveals that, coating of potassium nitrate and urea fertilizers decreased their releasing rate in the following order, $Ex_3 > Ex_2 > Ex_1 > Ex_4$ and then the uncoated regardless the temperature and moisture content of soil, and there was

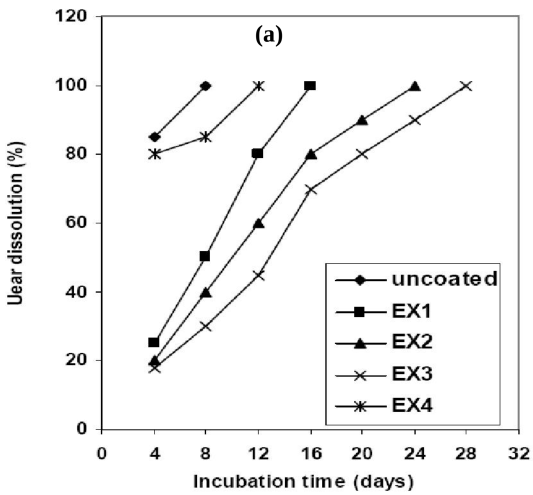


a) at 20 °C

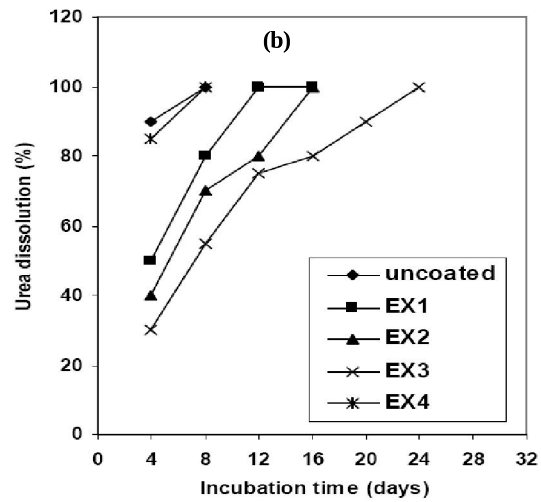


b) at 40 °C

Figure 2 : Dissolution rate of uncoated and coated potassium nitrate in water

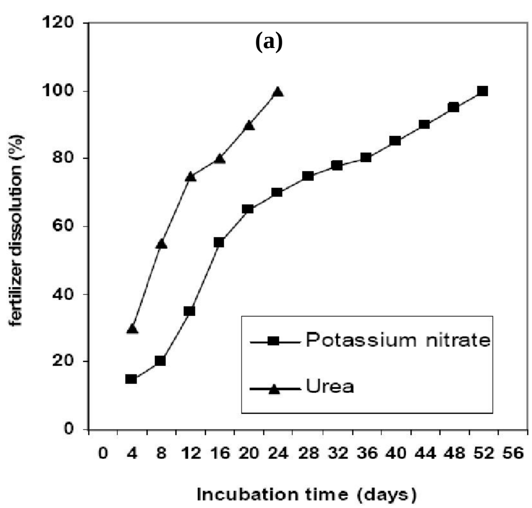


a) at 20 °C

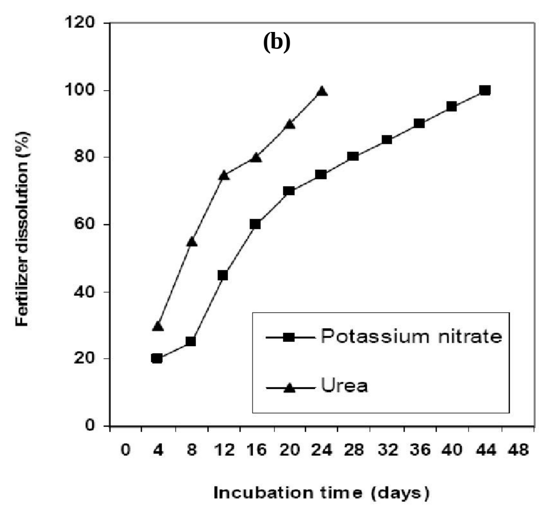


b) at 40 °C

Figure 3 : Dissolution rate of uncoated and coated urea in water

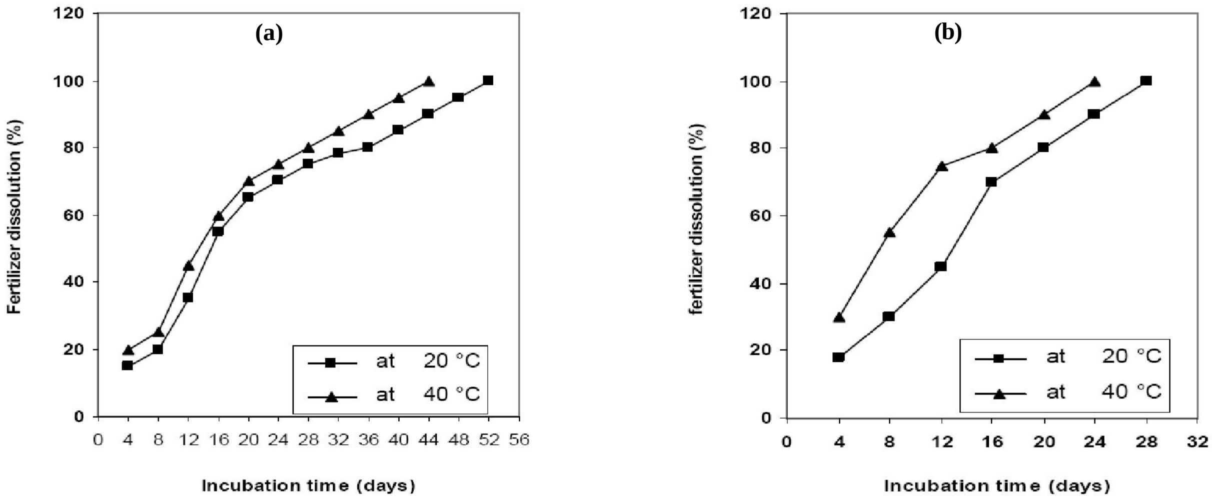


a) at 20 °C



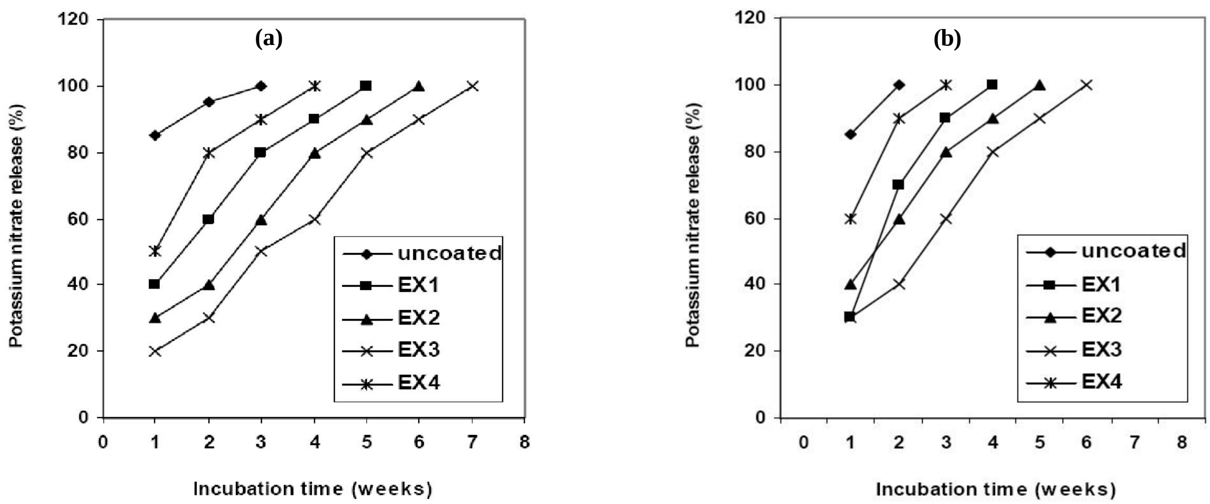
b) at 40 °C

Figure 4 : Comparison between dissolution rates of potassium nitrate and urea fertilizers having the same treatment Ex_3.



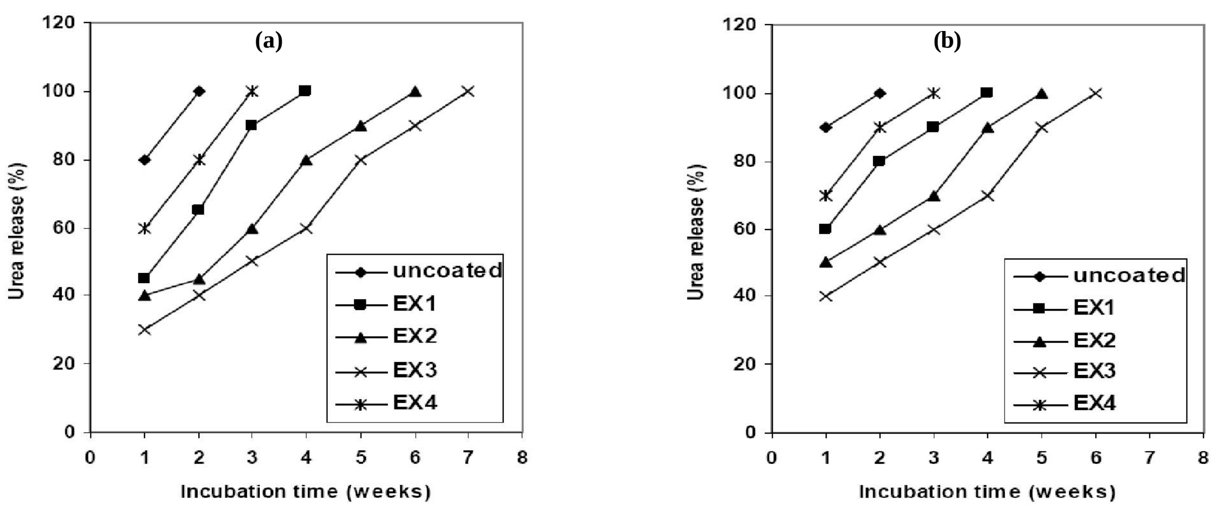
a) Potassium nitrate b) Urea

Figure 5 : Effect of temperature on dissolution for potassium nitrate and urea fertilizer having the same treatment Ex_3.



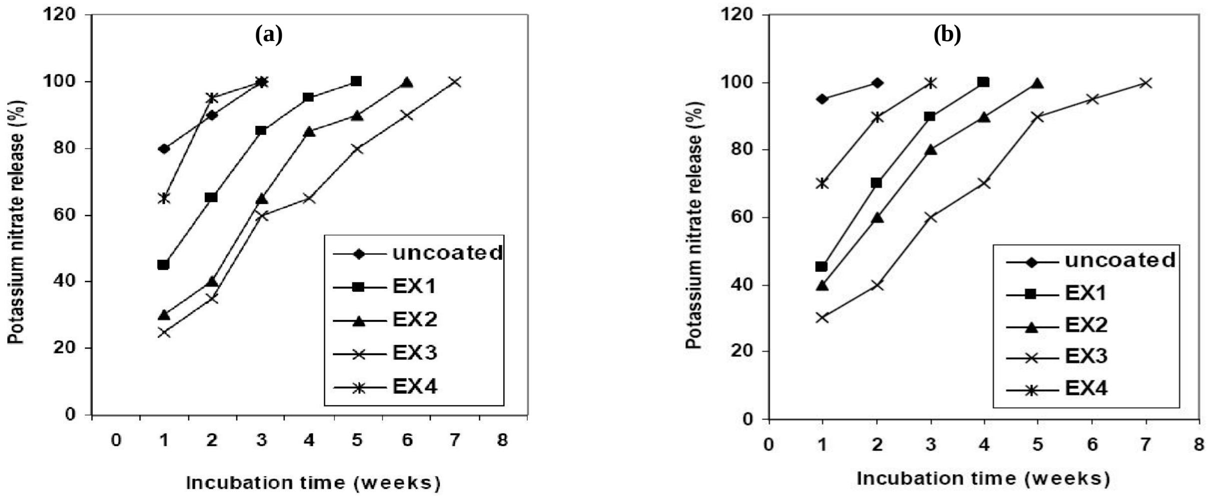
a) at 25 °C b) at 50 °C

Figure 6 : Releasing rate (%) of uncoated and coated potassium nitrate in sandy soil at 20 % field capacity



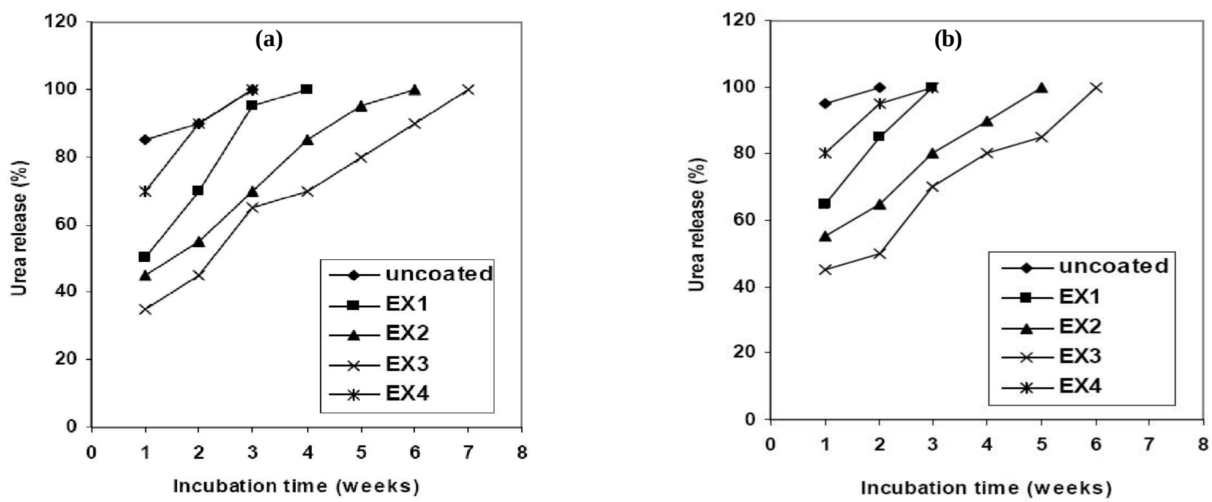
a) at 25 °C b) at 50 °C

Figure 7 : Releasing rate (%) of uncoated and coated urea in sandy soil at 20 % field capacity



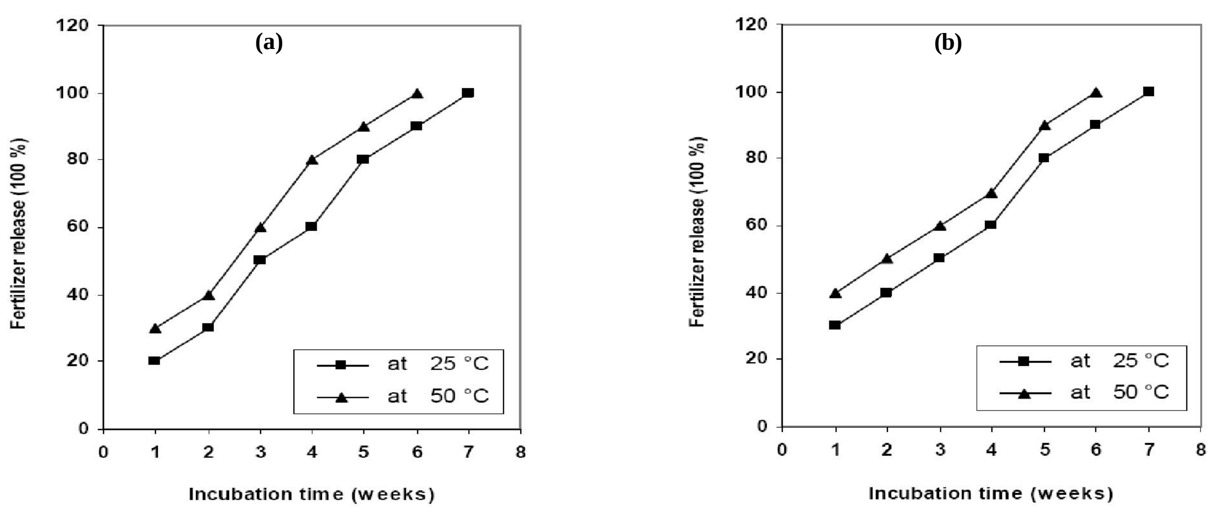
a) at 25 °C b) at 50 °C

Figure 8 : Releasing rate of uncoated and coated potassium nitrate in sandy soil at 40 % field capacity



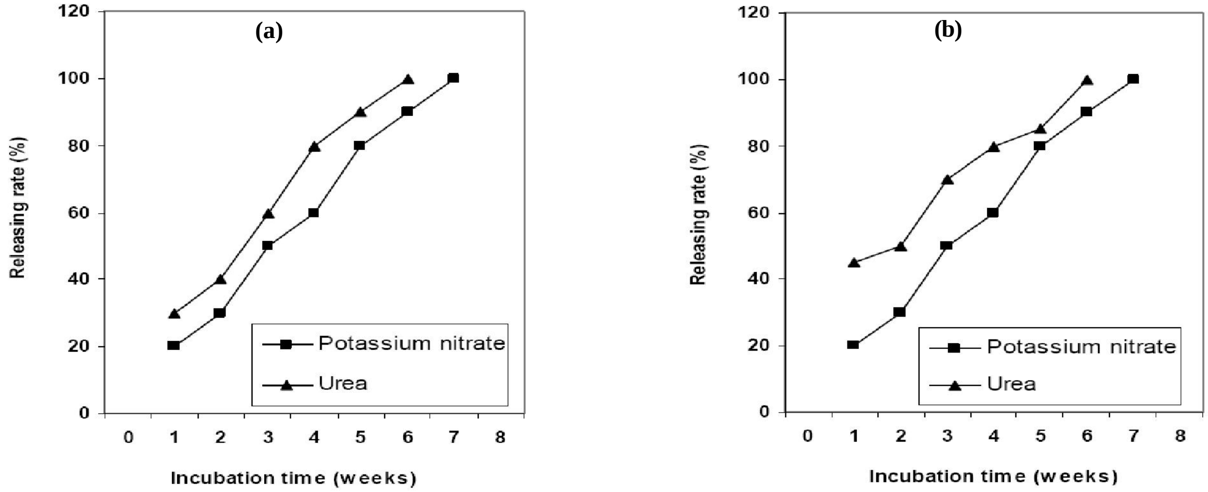
a) at 25 °C b) at 50 °C

Figure 9 : Releasing rate of uncoated and coated urea in sandy soil at 40 % field capacity



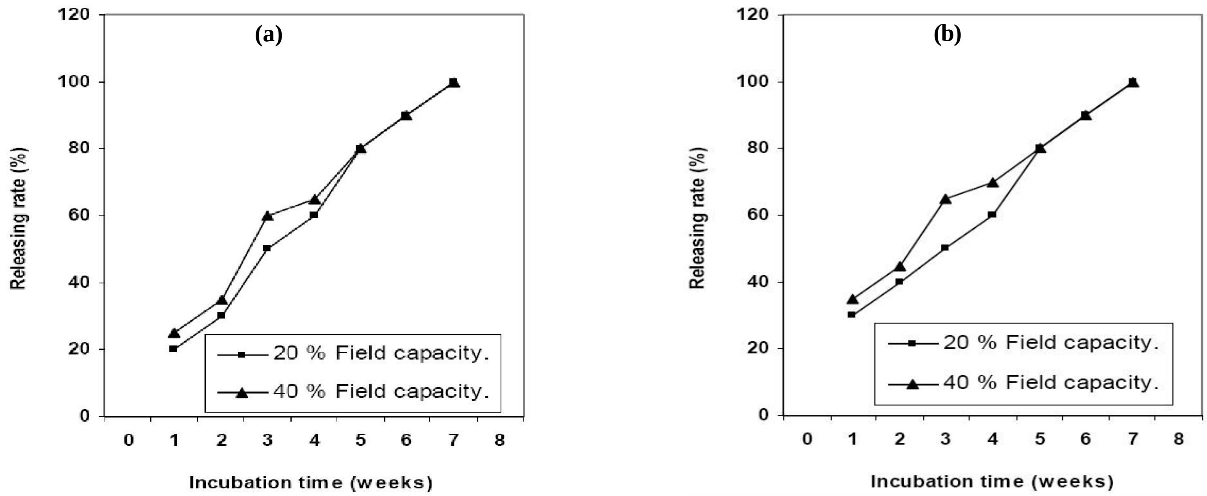
a) Potassium nitrate b) Urea

Figure 10 : Effect of temperature on the releasing rate for potassium nitrate and urea fertilizers having the same treatment Ex_3 at field capacity 20 %



a) 20 % field capacity b) 40 % field capacity

Figure 11 : Comparison between the releasing rates of potassium nitrate and urea fertilizers having the same treatment Ex_3 at 25 °C



a) Potassium nitrate b) Urea

Figure 12 : Effect of moisture content on the releasing rate for potassium nitrate and urea fertilizers having the same treatment Ex_3

a significant difference between them.

The release rate of coated potassium nitrate and urea fertilizers increased with increasing temperature. Raising temperature from 25 to 50 °C increased the releasing rate of potassium nitrate by about 50 % at the first week of incubation. This percentage decreased to 11 % at the sixth week. On the other hand, for urea fertilizer, the releasing rate increased by around 33 % at the first week, and decreased to 11 % at the sixth week (Figure 10).

As in the same manner for the dissolution in water, the release of coated urea in sandy soil was higher than coated potassium nitrate. The difference percentage was higher at the beginning of incubation (50-100 %) and decreased to 11 % by the end of incubation (Figure 11).

The moisture content has a lower effect on the releasing rate than temperature as shown from (Figure 12). Thus, it can be concluded that increasing temperature increases the degradation rate of the coating film. On the other hand, increasing the soil moisture content does not have the same effect on the degradation of the coating film. This is in agreement with liu etal. 2004, and Liang and liu, 2006[19,20].

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