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# Usage Rubber Coating Fertilizer as A Green Fertilizer and Studying Its Effects on Soil Fertility, Recovery and Agronomic Efficiencies of Some Crops

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## ABSTRACT

Cheap, environmentally friend, naturally, and biodegradables, these are the criteria to the optimum fertilizer in current age. The aim of this study was to prepare a naturally coated fertilizer by wrapping NPK fertilizer with a natural liquid rubber and to determine the effect of different treatments of NPK coated fertilizer on soil fertility and crop production compared to the traditional fertilizers. A field experiment was conducted for summer (2021) season followed by winter season (2021/2022) in a sandy soil at Ismailia Agriculture Research Station farm, Agric. Res. Center (ARC), Egypt. Maize and wheat crops were selected to deduce this search. The design of the experiment was a complete randomized block design with three replicates, slow release fertilizer (Rubber coating fertilizer-RCF) under investigations was applied directly at once through soil preparation at rates of 25%, 50% and 75% of recommended dose (RD) for both maize and wheat crops through the different seasons comparing to the uncoated fertilizer (traditional fertilizer –TF) which consider 100% of recommended dose. A parallel laboratory experiment was designed using soil columns to examine the releasing behavior of slow release fertilizer prepared by coating NPK fertilizer by natural rubber. The conducted column experiment showed that the cumulative amount of the different macronutrients (NPK) for traditional fertilizer at soil depth of 0-25 cm was about 100%, while the recorded value for the (RCF) was around 60%, i.e. the whole amount of added fertilizer was lost and about 40% of RCF still presented whereas at soil depth. The field application of RCF at different rates (25, 50 and 75% of recommended dose) has over showed its efficiency to reduce the release rate of fertilizer within soil and enhancing soil chemical properties such as EC, where the lowest value for EC recorded at RCF 25% of RD values during the two seasons. The enhanced soil properties and nutrients availability due to field application of RCF were reflected on crop productivities and nutrient contents in dry matter of both maize and wheat crops, whereas the highest values of these parameters were recorded for RCF treatment at level of (50% RD). The effect of RCF treatments on recovery efficiency percent (RE%) and agronomic efficiency (AE) for maize and wheat crops was estimated. The data obtained concluded that the highest RE% and AE results were observed for RCF at level of 50% of applied recommended doses while the lowest RE% and AE results were for RCF at levels of 25% and TF for N, P, and K for both maize and wheat crops, where the unit of nitrogen, phosphorus or potassium per fedden produces 52.33, 465.18, and 314.00 kg of maize grains, respectively in case of applying RCF at 50% of RD while the corresponding values for control (100% RD) were 29.01, 257.77, and 174.00 kg, respectively. Regarding to wheat crop, the unit of each of N, P, or k per fedden produced 29.00, 257.77 and 174 kg of wheat grains, respectively at the same level of RCF. Whereas the corresponding values for control (100% RD) were 17.25, 153.33 and 103.51 kg of wheat grains, respectively.

***Keywords:*** Rubber coating fertilizer, slow release fertilizer, wheat, maize, recovery, agronomic efficiency

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## 1. Introduction

Excessive and insufficient fertilization will have adverse effects on the environment and the growth and quality of crops (Pypers *et al.,* 2011). To match crop nutrient requirements, the ideal fertilizer should have this characteristic: the nutrient release matches the nutrient requirements of the crop throughout all of the plant growth stages. Fertilization directly affects soil quality and its productivity, while soil quality is the result of the comprehensive influence of many factors, such as soil nutrients, physical and chemical properties, soil structure and texture, etc. (Zhang *et al.,* 2008). Muhammad *et al.,* (2014) reported that about 50% of nitrogen applied to soil as urea is lost through volatilization and leaching. Pypers *et al.* (2011) concluded that the key to successful plant fertilization is the appropriate dosage and timing of fertilization. Fertilization is an effort to restore soil fertility that plays an important role in crop production. Thus, it contributes primarily and directly to the production costs. Slow release fertilizer (SRF) is the type of fertilizer that releases nutrient elements slowly and regularly, approaching the absorption patterns of plants. The nutrient elements contained in the fertilizers do not get carried away by the water (Hermida and Agustian, 2019). The use of SRF shows an advantage over ammonium nitrate and urea, and its relative performance varies with rainfall, fertilization level, and soil quality (Nelson, 2008). Trenkel (2010) revealed that compared with traditional fertilizers (TFs), slow-release fertilizers can maintain or even increase yields even with the same or reduced dosage. The synchronicity of the time and rate of the nutrient release of SRF can meet the nutrient requirements of plants and minimize the loss of fertilizer nutrients (Li, 2018). Although, compared with TF, the application of SRF in agricultural production is limited due to higher production costs, but the application of SRF reduces the input cost and the frequency of fertilization, and is a viable alternative method to avoid the excessive use of fertilizers (Gurusamy, 2017). In addition, soil nutrients are a key factor affecting crop quality (Wang *et al.,* 2019). Hartinee *et al.,* (2010) stated that the amount of fertilizer supplied to plants should be effective enough to increase the effective nutrients of the soil absorbed by the plants to increase yield and quality. Studies have shown that the nutrients in the soil, especially phosphorus (P) and potassium (K), have an important impact on yield and quality (Mohamed *et al.,* 2018). Giroto *et al.* (2017) showed that application of SRF can increase soil effective nutrient content and improve soil fertility. Jamil Khan *et al.* (2014) found that controlled-release fertilizers can dynamically release nutrients and meet the crop's changing nutrient demand throughout its growth cycle, maximize nutrient use efficiency, and minimize environmental risks. It is concluded that N supply should match N demand in time and space, not only for single crops but for a crop rotation as an integrated system (Spiertz, 2010). In the last decade, CRF/SRF has become an exciting topic for researchers in academia and industry (Jat *et al.,* 2012). On the hand and respect to the type of coating materials, the coatings are synthetic or natural organic compounds. The synthetic coatings are mostly petroleum derivatives, more expensive and with unknown degradability in soil (Calabi-Floody *et al.,* 2018). Natural organic coatings are biodegradable and totally release the encapsulated nutrients (Schneider *et al.,* 2016). The coating materials are a combination of the so-called slow-release and controlled-release materials and are also referred as environmentally friendly fertilizers (EFF) (Chalk *et al.,* 2015). The objective of this study was to develop an economically feasible and environmentally friendly coating NPK fertilizer (rubber coating fertilizer -RCF) using natural rubber material and studying its effect on soil nutrients, growth, quality, and crop production on both maize and wheat crops.

## 2. Materials and Methods

### 2.1. Field Experiment

A field experiment was conducted in summer (2021) season followed by winter season (2021/2022) in a sandy soil at Ismailia Agriculture Research Station farm, Agric. Res. Center (ARC), Egypt. The purpose of this study was to determine the effect of different treatments of NPK slow release fertilizer on soil fertility and crop production compared to the traditional fertilizers. Maize plants (Zea Mays L.) were planted during summer the season 2021 where wheat plants (*Triticum aestivum* L., CV. Giza 168) were cultivated during the winter season (2021/2022).

The design of experiment was a complete randomized block design with three replicates with 10.5 $m^2$ (3 X 3.5 m) plot area. Super phosphate (15.5 % $P_2O_5$) was added at 200 kg $fed^{-1}$ during soil preparation, urea (46 % N) was used as N fertilizer at application rate of 120 kg N $fed^{-1}$ applied in 3 equal doses after 21, 45 and 60 days of planting and potassium sulphate (48 % $K_2O$) at 50 kg/fed was added on two equal doses after 21 and 45 days of planting. These additions were applied to the control plots as traditional fertilizer and considered of 100% of recommended dose, while the slow release fertilizer (Rubber coating fertilizer) under investigations was applied directly at once through soil preparation at rates of 25%, 50% and 75% of recommended dose for both maize and wheat crops through the different seasons.

**2.2. Crops parameters**

At the end of field experiment some crop parameters are discussed according to Godebo *et al.* (2021) such as recovery efficiency percent (RE%) which defined as the quantity of nutrient absorbed per unit of nutrient applied.

$$RE\ \% = \frac{Un - Uo}{N} X100$$

Where; Un is nutrient uptake by plants under applied fertilizer, Uo is nutrient uptake by plants in unfertilized plot and N is the quantity of fertilizer applied.

Also agronomic Efficiency (AE) which defined as the economic productivity obtained per unit of nutrient applied.

$$AE\ (kg/kg) = \frac{Gf - Go}{N}$$

Where; $G_f$ is grain yield of fertilized plots, while $G_0$ is the grain yield of unfertilized plots, and N is the nutrient applied.

**2.3. Soil sampling**

Some physical and chemical soil properties of the experimental field were determined according to Page *et al.* (1982). Soil samples at 25, 50, 75 cm depth were collected from the experimental field as shown in Table (1) to determine their chemical and physical properties. All soil samples were air dried, crushed and sieved through 2mm sieved holes, then stored in plastic pages prior to analyses. Chemical and physical analyses of the soil are presented as shown in Table (1).

**Table 1:** Some physical and chemical properties of the soil under investigation.

| **Parameter** | **Value** | | |
|---|---|---|---|
| | **Sand** | **Silt** | **Clay** |
| **Textural class** | 90.11% | 5.00% | 4.89% |
| | Sandy soil | | |
| | **Soil depth (cm)** | | |
| | **0-25** | **25-50** | **50-75** |
| Bulk density($g/cm^3$) | 1.43 | 1.42 | 1.42 |
| pH(1:2.5) | 7.90 | 7.93 | 7.98 |
| ECe (dS $m^{-1}$) | 1.22 | 1.17 | 1.11 |
| Organic matter (%) | 0.33 | 0.31 | 0.28 |
| Total nitrogen(mg/kg) | 36.25 | 34.21 | 30.75 |
| Available P (mg/kg ) | 4.51 | 3.99 | 3.15 |
| Available K(mg/kg) | 85.14 | 80.58 | 78.35 |
| **Soluble cations and anions meq/L** | | | |
| $Ca^{2+}$ | 0.99 | 1.05 | 1.16 |
| $Mg^{2+}$ | 0.90 | 1.14 | 1.22 |
| $Na^{+}$ | 1.50 | 1.55 | 1.71 |
| $K^{+}$ | 0.44 | 0.48 | 0.49 |
| $CO_3^{2-}$ | 0.00 | 0.00 | 0.00 |
| $HCO_3^{-}$ | 1.41 | 1.44 | 1.56 |
| $Cl^{-}$ | 1.12 | 1.32 | 1.52 |
| $SO_4^{2-}$ | 1.30 | 1.46 | 1.50 |

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After harvest, disturbed soil samples have been collected from three layers 0-25, 25-50 and 50-75 cm for all plots. The soil samples were air-dried and analyzed for some chemical characteristics. Soil pH and organic matter were estimated according to the methods described by Page *et al.* (1982). The total soluble salts (EC) were determined in soil paste extract as $dSm^{-1}$ (Jackson, 1973). Particle size distribution was carried out by the pipette method described by Klute (1986). The contents of available macronutrients (N, P and K) in soil were determined according to the methods described by Cottenie *et al.* (1982).

**2.4. Plant analyses**

Samples of both maize and wheat grains were taken from each replicate and ground. A 0.5 g powder of grains of each sample was digested by a concentrated digestion mixture of $H_2SO_4/HClO_4$ acids (Sommers and Nelson, 1972). Nitrogen was determined by micro Keldahl, according to Cottenie *et al.* (1982). Phosphorus was determined by Spectrophotometric using ammonium molybdate/stannous chloride method (Chapman and Pratt, 1978). Potassium was determined by a flame photometer, according to Page *et al.* (1982).

**2.5. Preparation of rubber coating slow release fertilizer**

The preparation of fertilizer was performed according to Adlim *et al.* (2018).

Commercial liquid natural rubber latex (LNR) Malaysia origin Fig. (1) mixed with NPK fertilizer of composition (%) 10:5:5. The mixture composition was two portions of (LNR) to eight portions of NPK fertilizer. The whole mixture was stirred with a mixer to obtain relatively homogenously matrix then leaved to open air dry then crushed and kept in plastic bags for experimental treatments.


**Fig. 1:** Forms of materials which performed in preparation of slow release fertilizer; (a) natural rubber- (b) NPK fertilizer 10:5:5- (c) final product

**2.6. Studying the releasing behavior of the rubber coating fertilizer (RCF) under investigation**

A parallel laboratory experiment was design using soil columns to examine the releasing behavior of slow release fertilizer prepared by coating NPK fertilizer by natural rubber. A column experiment based on the modification of the displacement technique described by Cho *et al.* (1970) was applied. Firstly the soil under investigation was obtained from a local nursery and was sieved using a 2 mm sieve to remove debris and roots, followed by air drying. In two cylindrical plastic columns of internal diameter of 5.0 cm and height of 100 cm were backed by pre-equipped soil Fig. (2). The heights of the packed soil within the two columns were approximately 85 cm and about 15 cm of tip of each column leaved to fill by irrigation water then the masses of soil packed into each column were about 4 Kg. The bottom of each column was plugged by thick cotton layer to prevent the tested soil from getting out and also to get rid of the drainage water. To obtain leachate samples three slot pipes were punched at soil depths of 25, 50 and 75 cm of soil surfaces for each column. The slot pipe orifices were mounted by a layer of permeable nylon sheet prior to filling soil that due to prevent the packed soil particles from leaching out during irrigation processes. About two grams of each the traditional fertilizer (control sample) and RCF (treated sample) in the same contents of NPK placed on the soil surfaces of each column and another 50g soil was added and finally the two soils covered with Whatman filter paper to prevent soil dispersion when irrigation water stream is introduced. For

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nutrient releasing test the column soil were irrigated with distilled water (200 ml each time) for several times then the leachate samples were collected and transferred after each irrigation time to outer glass container and preserved to chemical analysis later and to determine the cumulative percent of each nutrient.


**Fig. 2:** The apparatus used in studying slow release fertilizer behavior compared to control

**Statistical analysis**

Analysis of Variance (ANOVA) of the obtained data was performed using a Randomized Completely Block Design (RCBD) procedure in SPSS version 22.0. The statistical differences among treatments means across traits were conducted using LSD test. Mean differences were considered significant at p = 0.05.

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## 3. Results and Discussion

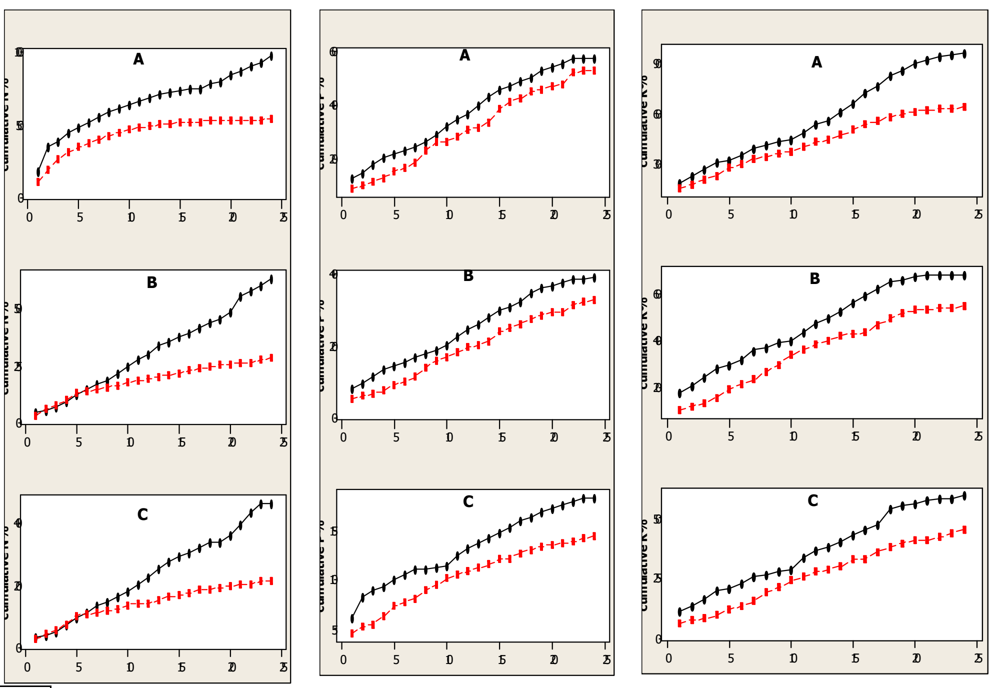
### 3.1. The releasing behaviour of the NPK nutrients of the slow releasing fertilizer -rubber coating fertilizer (RCF) - compared to traditional fertilizer (TF) through the conducted laboratory experiment

#### I-Cumulative nitrogen %

As shown in fig. (3), there were significant differences observed between the amount of nitrogen releasing from the rubber coated fertilizer compared to the non coated one which were observed in all soil depths (0-25, 25-50, 50-75 cm) of column experiment. The data recorded revealed that, at the end of experiment the cumulative nitrogen of traditional fertilizer (TF) at soil depth of 0-25cm was 100% while the recorded value for the RCF was 60%, i.e. the whole amount of added fertilizer was lost and about 40% of RCF still presented whereas at soil depth of 25-50 cm the cumulative nitrogen recorded 60% and 25% for TF and RCF respectively and at 50-75 soil depth the cumulative nitrogen were 45% and 15% for both TF and RCF respectively.

#### II-Cumulative phosphorus %

Respect to the cumulative P as in Fig. (3) the data showed that with increasing number of irrigation times the cumulative P% at soil depth of 0-25cm was 55% for TF where it was 51% for the RCF, whereas at soil depths of 25-50 cm the cumulative P were 37% and 30% for TF and RCF respectively and for 50-75cm soil depth the cumulative P% were 18%, 13% for TF and RCF respectively.




**◊ control**
**○ RCF**

**Fig. 3:** Cumulative percent for N, P, and K as affected by number of irrigation times at different soil depths.

The X axis in each graph represents the number of irrigation times. A: soil depth 0-25cm, B: soil depth 25-50cm, C: soil depth 50-75cm, RCF: Rubber coating fertilizer.

#### III-Cumulative potassium %

The data recorded in Fig. (3) also showed that the cumulative K at soil depth of 0-25cm was 91% for TF where it was 59% for the RCF, whereas at soil depths of 25-50 cm the cumulative K were

65% and 43% for TF and RCF, respectively, and for 50-75 soil depths the cumulative K were 57% and 42% for TF and RCF, respectively.

The sharp decreasing in cumulative P% values compared to the corresponding data for both N and K may be attributed to the chemisorptions processes of phosphate ions on soil particles. From the after mentioned data obtained from the column experiment it concluded that the RCF controlled the releasing of soil nutrients as much as possible and slow down them from leaching out to deep water compared to TF. The data agreed with Cheng *et al.* (2021) who found that the soil available N of slow release fertilizer in the harvest of Chinese chives was 63 % greater than that of the traditional fertilizer. The soil available P and available K of slow release fertilizer in the early stage of harvest were lower than those of the traditional fertilizer, but the soil available P and available K in the late stage of harvest were increased by 29 % and 38 % for slow release fertilizer. Slow release fertilizer can slow down the decomposition of N into ammonia, reduce the release rate of fertilizer N, synchronize N supply with crop N demand, and maintain a sustained and stable nutrient supply during the crop growing season, thereby improving the ability of plant dry matter synthesis and increasing its accumulation (Zhag *et al.,* 2020). Fageria (2005) and Raun *et al.* (2002) discussed that the frequent irrigation in vegetable production leads to a large amount of N leaching loss, denitrification, and volatilization in ordinary fertilizers, resulting in a low N recovery rate in the soil–plant system and insufficient N supply in the later stage of plant growth, which in turn leads to plant dry matter synthesis ability declines. However, slow release fertilizer can slow down the decomposition of N into ammonia, reduce the release rate of fertilizer N, synchronize N supply with crop N demand, and maintain a sustained and stable nutrient supply during the crop growing season, thereby improving the ability of plant dry matter synthesis and increasing its accumulation.

### 3.2. Conducted field experiment

The data discussed in Table (2) demonstrated that there were clear significant differences among EC values of different added rates of RCF compared to control where the mean values of EC for control possessed the highest value while the lowest one was for RCF at level of 25% of recommended dose during the two seasons. On the other hand, there were insignificant differences in pH values of different rates of RCF and control during the two seasons.

**Table 2:** The electrical conductivity and pH values of the soils treated by different rates of RCF during the two seasons compared to control.

| | **Maize** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **EC ($dSm^{-1}$)** | | | | **pH (1:2.5)** | | | |
| **Soil depth/cm** | **A** | **B** | **C** | **Mean** | **A** | **B** | **C** | **Mean** |
| **Control (100% RD)** | 1.29 | 1.33 | 1.37 | 1.33a | 7.95 | 7.94 | 7.98 | 7.96ns |
| **75 % RD Coated** | 1.28 | 1.30 | 1.32 | 1.30b | 7.94 | 7.95 | 7.96 | 7.95s |
| **50 % RD Coated** | 1.25 | 1.27 | 1.27 | 1.26bc | 7.96 | 7.96 | 7.97 | 7.96ns |
| **25 % RD Coated** | 1.22 | 1.25 | 1.26 | 1.24c | 7.93 | 7.94 | 7.94 | 7.94ns |
| **L.S.D (0.05)** | 0.028 | | | | 0.009 | | | |

**Table 2:** Cont.

| | **Wheat** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **EC ($dSm^{-1}$)** | | | | **pH (1:2.5)** | | | |
| **Soil depth/cm** | **A** | **B** | **C** | **Mean** | **A** | **B** | **C** | **Mean** |
| **Control (100% RD)** | 1.32 | 1.35 | 1.41 | 1.36a | 7.81 | 7.88 | 7.83 | 7.84ns |
| **75 % RD Coated** | 1.27 | 1.29 | 1.31 | 1.29b | 7.83 | 7.84 | 7.84 | 7.84ns |
| **50 % RD Coated** | 1.24 | 1.26 | 1.26 | 1.25c | 7.85 | 7.84 | 7.84 | 7.84ns |
| **25 % RD Coated** | 1.22 | 1.24 | 1.25 | 1.24c | 7.89 | 7.85 | 7.87 | 7.87ns |
| **L.S.D (0.05)** | 0.035 | | | | 0.007 | | | |

A: soil depth 0-25 cm, B: soil depth 25-50 cm, C: soil depth 50-75 cm, ns: non significant
RCF: Rubber coated fertilizer, RD: recommended dose

The clear decreasing in EC values due to adding different rates of RCF compared to control may be return to the lower amount of fertilizer added in case RCF and the slow releasing of coated nutrients. Cheng *et al.* (2021) declared that The soil total N content of slow release fertilizer (SRF) had significantly lower than traditional fertilizer in the early stage of Chinese chive harvest. This may be due to the fact that the SRF treatment reduced nutrients by 31% under the condition of balanced fertilization and appropriately increased the input of K. Frequent irrigation in vegetable production leads to a large amount of N leaching loss, denitrification, and volatilization in ordinary fertilizer however, SRF can slow down the decomposition of N into ammonia, reduce the release rate of fertilizer N, synchronize N supply with crop N demand, and maintain a sustained and stable nutrient supply during the crop growing season (Tian, 2018).

The data recorded in table (3) declared that the RCF reduced the releasing soil nutrients (NPK) around the plant root zoon compared to the control where the available macronutrients releasing concentrations of N, P and K respect to control (uncoated fertilizer-100% of recommended dose) exhibited the highest mean values concentrations for all soil depths, whereas the rubbery coated fertilizer at level of 25% of recommended doses recorded the lowest values during the two seasons. Generally, there were insignificant difference between the recommended doses 100% RD and rubbery coated fertilizer at level of 75 % of recommended dose for both maize and wheat crops. Also there were slightly significant differences in releasing concentrations values of N, P and K among RCF at 75 % and 50 % of levels of RD. Rafael *et al.* (2016) found that coated mono ammonium phosphate (MAP) fertilizer granules released P and ammonium cations to percolating water slower and in smaller amounts than the uncoated (MAP). Approximately 96 % of all the P was released from uncoated (MAP) by percolating water compared to the coated (MAP) which was 50 % releasing of the initial P. Lubkowski (2014) observed that the release of macro nutrients from uncoated NPK was six times faster than from oligochitosan-coated NPK. Noppakundilograt *et al.* (2015) evaluated the solubility of P in water from trilayer-coated NPK with poly (vinyl alcohol)/cross-Chitosan/poly (acrylic acid-co-acrylamide) and observed that only 12 % of P was released over 30 days, while conventional NPK released 100 % in 12 min.

**Table 3:** The available macronutrients (NPK) ppm of the soil during the two seasons as affected by the RCF treatments compared to control.

| | Maize | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | | | | P | | | | K | | | |
| **Soil depth/cm** | **A** | **B** | **C** | **Mean** | **A** | **B** | **C** | **Mean** | **A** | **B** | **C** | **Mean** |
| **Control (100% RD)** | 41.72 | 41.88 | 45.57 | 43.12a | 6.08 | 6.79 | 7.02 | 6.63a | 102.31 | 108.01 | 120.21 | 110.18a |
| **75 % RD Coated** | 42.5 | 40.78 | 38.25 | 40.51ab | 6.70 | 6.01 | 4.26 | 5.66a | 111.12 | 106.28 | 99.89 | 105.76b |
| **50 % RD Coated** | 39.15 | 37.25 | 34.58b | 36.99b | 6.11 | 5.02 | 3.25 | 4.79a | 96.12 | 94.58 | 90.21 | 93.64b |
| **25 % RD Coated** | 36.92 | 33.11 | 31.20 | 33.74c | 4.12 | 3.25 | 2.58 | 3.32b | 77.54 | 75.36 | 71.85 | 74.92c |
| **L.S.D (0.05)** | 3.55 | | | | 0.95 | | | | 4.12 | | | |

**Table 3:** cont.

| | Wheat | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | | | | P | | | | K | | | |
| **Soil depth/cm** | **A** | **B** | **C** | **Mean** | **A** | **B** | **C** | **Mean** | **A** | **B** | **C** | **Mean** |
| **Control (100% RD)** | 38.72 | 38.87 | 42.38 | 39.99a | 5.86 | 6.53 | 6.57 | 6.38a | 93.27 | 98.35 | 109.32 | 100.28a |
| **75 % RD Coated** | 39.43 | 37.87 | 35.56 | 37.62a | 6.45 | 5.8 | 4.14 | 5.46a | 101.13 | 96.81 | 91.1 | 96.35ab |
| **50 % RD Coated** | 36.38 | 34.65 | 32.21 | 34.41b | 5.89 | 4.86 | 3.17 | 4.64b | 87.73 | 86.35 | 82.44 | 85.51b |
| **25 % RD Coated** | 34.35 | 30.87 | 29.13 | 31.45c | 4 | 3.17 | 2.53 | 3.23c | 71.08 | 69.12 | 65.96 | 68.72c |
| **L.S.D (0.05)** | 2.48 | | | | 1.17 | | | | 3.93 | | | |

A A: soil depth 0-25 cm, B: soil depth 25-50 cm, C: soil depth 50-75 cm, ns: non significant
RCF: Rubber coated fertilizer, RD: recommended dose

The data showed in table (4) declared that in spite of the slowing down of releasing of NPK nutrient due to adding different rates of RCF to soil, the plant nutrient uptake was not affected which was reflected on N, P, and K contents in seeds for both maize and wheat crops. Where there were nearly insignificant differences between control treatments (100% RD) and RCF treatments at (75% RD) in N, P, and K percentages for maize and wheat crops. While there were clear significant differences among RCF treatments at levels of (50%, 25% of RD) when compared to control (100% RD) where the RCF treatments at (25%RD) recorded the lowest values for N, P, and K contents for maize and wheat crop seeds. Similar trend with Cheng *et al*. (2021) who found that the slow release of N, P, and K nutrients met the physiological requirements of Chinese chives in different growth periods, thereby improving their nutritional quality. Also his study showed that slow release fertilizer increased the effective nutrient content of the soil moreover SRF increased the content of soil total N, total P, and available N during the harvest of Chinese chives and maintained a high supply capacity of soil available P and available K in the middle and later stages of harvest.

**Table 4:** Macronutrients percentages in maize and wheat seeds as affected by the RCF treatments compared to control.

| Treatments | Maize | | | Wheat | | |
|---|---|---|---|---|---|---|
| | N% | P% | K% | N% | P% | K% |
| Control (100% RD) | 2.53 a | 0.37 a | 2.18 a | 2.22a | 0.39a | 1.57a |
| 75 % RD Coated | 2.49 a | 0.35 ab | 2.15 a | 2.20a | 0.36ab | 1.53a |
| 50 % RD Coated | 2.43b | 0.32 b | 2.08 b | 2.15b | 0.33b | 1.47b |
| 25 % RD Coated | 2.14 c | 0.26 c | 1.82 c | 1.89c | 0.25c | 1.26c |
| L.S.D (0.05) | 0.05 | 0.03 | 0.06 | 0.04 | 0.03 | 0.05 |

RD: recommended dose, RCF: Rubber coated fertilizer

In discussion the effect of RCF treatments on some crop specifications, the data presented in table (5) indicated that there were insignificant differences among 50%, 75% and control 100% of RD treatments in grain and straw yields to both maize and wheat crops, whereas the treatments of RCF at level of 25% RD recorded the lowest results in both crops. Where the highest result of grain yield of maize crop was recorded for control (100% RD) which was 4.43 ton/fed while the lowest value grain yield was 1.79 ton/fed for RCF treatment at level of (25% RD). Whereas the corresponding values for wheat crop were 2.90, 1.25 ton/fed for both control (100% RD) and RCF treatment at level of (25% RD). Carreres *et al.* (2003) found that SRF could promote the root development and nutrient absorption capacity of crops. Similarly, Liu *et al.* (2016) and Zhou *et al.* (2016) reported positive effects of matrix-based fertilizer on grain yield in wheat and agronomical efficiency in maize. Ushna *et al.* (2022) found that the slow release fertilizers application also facilitated the increase of plants dry biomass than control plants whereas the Zn-bulk fertilizers (coated fertilizers) improved plants dry weight than control.

**Table 5:** Productivity of both maize and wheat as affected by RCF treatments compared to control.

| Treatments | Maize | | | Wheat | | |
|---|---|---|---|---|---|---|
| | Yield (ton.fed$^{-1}$) | | Weight of 100 seeds (g) | Yield (ton.fed$^{-1}$) | | Weight of 100 seeds (g) |
| | Grain | Straw | | Grain | Straw | |
| Control (100% RD) | 4.43 a | 3.08 a | 33.20 a | 2.90a | 3.82a | 43.61a |
| 75 % RD Coated | 4.19 a | 3.12 a | 33.27 a | 2.66a | 3.55a | 43.67a |
| 50 % RD Coated | 4.09 a | 3.05 ab | 32.68 b | 2.57a | 3.60a | 43.48a |
| 25 % RD Coated | 1.79 b | 1.41 c | 27.58 c | 1.25b | 2.11b | 37.11b |
| L.S.D (0.05) | 0.25 | 0.0.7 | 0.29 | 0.26 | 0.31 | 0.23 |

RD: recommended dose, RCF: Rubber coated fertilizer

### 3.3. The effect of RCF treatments on nutrients uptake efficiency

Studding the effect of RCF treatments on recovery efficiency percent (RE%) and agronomic efficiency (AE) for maize and wheat crops the data as in table (6) showed that the highest RE% and

AE results were observed for RCF at level of 50% of applied recommended doses while the lowest RE% and AE results were for RCF at levels of 25% for N, P, and K for both maize and wheat crops compared to controls. In addition there were significant differences in RE% and AE values between RCF at level of 50% and 100% of RD (control), which indicated that the recovery of soil nutrient by plant roots increased with applying coated fertilizer than in un coated one, also the amount of grains produced per unit of nutrient were higher in case of applying coated fertilizer than in un coated one.

**Table 6:** Total dry matter (ton/fed), crop recovery percent and agronomic efficiency, affected by different rates of RCF compared to control

| Nutrient treatment | Maize | | | | Wheat | | | |
|---|---|---|---|---|---|---|---|---|
| **N** | **TDM (ton/fed)** | **N (%)** | **RE (%)** | **AE (kg/Kg)** | **TDM (ton/fed)** | **N (%)** | **RE (%)** | **AE (kg/Kg)** |
| **Control (100% RD)** | 7.51 | 0.84a | 44.42b | 29.01b | 6.72 | 0.74a | 34.64b | 17.25b |
| **75 % RD Coated** | 7.31 | 0.83a | 56.31b | 36.05b | 6.21 | 0.73a | 41.30b | 20.33b |
| **50 % RD Coated** | 7.14 | 0.81a | 79.72a | 52.33a | 6.17 | 0.71a | 59.41a | 29.00a |
| **25 % RD Coated** | 2.58 | 0.67b | 38.13c | 24.02c | 2.55 | 0.60b | 23.77c | 14.00c |
| **Non fertilized** | 2.40 | 0.42c | ---- | ----- | 2.33 | 0.35c | --- | ---- |
| **L.S.D (0.05)** | --- | 0.11 | 15.47 | 12.51 | --- | 0.09 | 11.42 | 3.35 |
| **P** | **TDM (ton/fed)** | **P (%)** | **RE (%)** | **AE (kg/Kg)** | **TDM** | **P (%)** | **RE (%)** | **AE (kg/Kg)** |
| **Control (100% RD)** | 7.51 | 0.12a | 60.14b | 257.77b | 6.72 | 0.11a | 49.51b | 153.33b |
| **75 % RD Coated** | 7.31 | 0.12a | 72.29b | 320.01b | 6.21 | 0.10a | 52.15b | 180.74b |
| **50 % RD Coated** | 7.14 | 0.11a | 95.11a | 465.18a | 6.17 | 0.10a | 77.62a | 257.77a |
| **25 % RD Coated** | 3.20 | 0.07b | 46.50c | 109.62c | 3.36 | 0.07b | 41.48c | 124.44c |
| **Non fertilized** | 2.40 | 0.05c | --- | ---- | 2.33 | 0.04c | --- | --- |
| **L.S.D (0.05)** | --- | 0.01 | 13.36 | 130.85 | --- | 0.02 | 6.58 | 29.96 |
| **K** | **TDM (ton/fed)** | **K (%)** | **RE (%)** | **AE (kg/Kg)** | **TDM (ton/fed)** | **K (%)** | **RE (%)** | **AE (kg/Kg)** |
| **Control (100% RD)** | 7.51 | 0.22a | 61.45b | 174.00c | 6.72 | 0.21a | 56.86b | 103.51b |
| **75 % RD Coated** | 7.31 | 0.22a | 77.62b | 216.00b | 6.21 | 0.19a | 59.99b | 122.01b |
| **50 % RD Coated** | 7.14 | 0.21a | 98.01a | 314.00a | 6.17 | 0.18a | 83.06a | 174.01a |
| **25 % RD Coated** | 3.20 | 0.18b | 34.81c | 74.00d | 3.36 | 0.16b | 51.52b | 84.00c |
| **Non fertilized** | 2.40 | 0.17b | --- | --- | 2.33 | 0.12c | --- | --- |
| **L.S.D (0.05)** | --- | 0.02 | 16.93 | 40.15 | ---- | 0.03 | 15.57 | 19.14 |

TDM: total dry matter (grain plus straw yield), RE%: recovery efficiency, AE: agronomic efficiency, RD: recommended dose, RCF: Rubber coated fertilizer

The agronomic efficiency indices consider the most important indicator that reflect the efficiency of agricultural fertilization systems. From the above discussed results, it is clear that the unit of nitrogen, phosphorus or potassium per fedden produces 52.33, 465.18, and 314.00 kg of maize grains, respectively in case of applying RCF at 50% of RD, while the corresponding values for control (100%RD) were 29.01, 257.77, and 174.00, respectively. Regarding to wheat crop the unit of each of N, P, or k per fedden produced 29.00, 257.77 and 174 kg of wheat grains respectively at the same level of RCF whereas the corresponding values for control (100% RD) were 17.25, 153.33 and 103.51 kg of wheat grain respectively. The results in line with Muhammad 2014 who found that the agrotain coated urea increased N use efficiency and ultimately increased plant heights and length of ear. Zaman *et al.* (2009) also reported that encapsulating of urea with inhibitors improved N availability and increased the crop yield. Enhanced crop yield by coated urea was also reported by few other scientists during conducting trials on application of Agrotain coated urea (Mattain *et al.,* 2008). Sun *et al.* (2019) showed that a single application of polymer coated urea that reduced the amount of fertilization could increase yield by 6.0–21.0 % compared with the application of urea as it is.

Some researchers proposed decreasing the application rate of slow-release fertilizer, so as to produce the same grain yield while reducing the cost of slow-release fertilizer (Geng *et al.,* 2015; Liu *et al.,* 2016). The control release fertilizer product with excellent slow release capacity, being easy to get at a low price and environment-friendly, could be especially useful in agricultural application (Dong *et al.,* 2016).

## 4. Conclusion

The rubber coated fertilizer (RCF) was prepared to supply NPK nutrients to the plant at a controlled release rate and to increase the NPK fertilizer use efficiency (FUE) under sandy soil condition. The results concluded that, the prepared RCF fertilizer could be considered as slow-release for deliver NPK to the plant for longer time compared with traditional NPK fertilizer. The conducted column experiment showed that the cumulative amount of the different macronutrients (NPK) for traditional fertilizer at soil depth of 0-25cm was about 100% while the recorded value for the (RCF) was around 60%, i.e. the whole amount of added fertilizer was lost and about 40% of RCF still presented whereas at soil depth. The field application of RCF at different rates (25, 50 and 75% of recommended dose) has over showed its efficiency to reduce the release rate of fertilizer within soil and enhancing soil chemical properties such as EC where the lowest value for EC observed at RCF 25% of RD values during the two seasons. The enhanced soil properties an and nutrients availability due to field application of RCF were reflected on crop productivities and nutrient percent in dry matter of both maize and wheat crops whereas the highest values of these parameters recorded for RCF treatment at level of (50% RD). Studding the effect of RCF treatments on recovery efficiency percent (RE%) and agronomic efficiency (AE) for maize and wheat crops the data obtained concluded that the highest RE% and AE results were observed for RCF at level of 50% of applied recommended doses while the lowest RE% and AE results were for RCF at levels of 25% and TF for N, P, and K for both maize and wheat crops.

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