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Effect of Two Urea Forms and Organic Fertilizer Derived from Expired Milk Products on Dynamic of NH_3 Emissions and Growth of Williams Banana

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Abstract: Sustainable agricultural development depends mainly on the recycling of organic wastes to reduce environmental pollution, as well as to reduce the use of mineral fertilizers. Expired milk products are rich in organic carbon and nitrogen, so they are good raw materials for making organic fertilizers. In this study, expired milk products were converted to organic fertilizer (EDPF) by gravity and thermal treatments. The extracted EDPF was used in the nutrition of Williams banana plants under field conditions for two growing seasons. The field experiment consisted of four treatments including: C = control without N fertilization, U = traditional urea, SRU = slow-release urea, and EDPF. EDPF significantly ($p < 0.05$) improved the growth and yield of Williams banana in comparison to U and SRU. EDPF significantly minimized the soil pH and increased the soil organic-C and cation exchange capacity compared to the other treatments. EDPF increased the total yield of bunches by 20% and 17% in the first and second years, respectively, above U and SRU. EDPF surpassed the traditional and slow-release urea in its ability to supply the banana plants with nitrogen. NH_3 -N loss from U, SRU, and EDPF reached 172, 132, and 100 kg N ha⁻¹, respectively, which accounted for 34%, 26%, and 20% of the total added nitrogen. Nitrogen loss from the investigated treatments was in the order: U > SRU > EDPF > C. EDPF significantly reduced the ammonia volatilization compared to U and SRU by reducing the soil pH and increasing the soil organic matter. The dynamic of NH_3 emissions not only depends on the nitrogen form but also on climatic conditions and concentrations of NH_4^+ in the soil solution. Protecting the ecosystem and maximizing the benefits of wastes utilization can be done through the recycling of expired dairy products to organic fertilizers.

Keywords: recycling; dairy products; ammonia volatilization; Elovich equation; banana quality



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1. Introduction

Banana (*Musa* spp.) is the queen of tropical fruits and it is a major food due to its high nutritional value, moreover, it has special importance in the diets of millions of people around the world [1]. It is a cash crop and has great economic importance in Egypt, where the total cultivated area is 33,553 ha⁻¹ which produces 1,314,177 tons with an average of 39 tons ha⁻¹ according to Ministry for Agriculture and Land Reclamation of Egypt (M.A.L.R.) [2]. Fertilization practices are the main limiting factor for the maximum growth and yield of bananas [3]. Banana plants have a long growth period in the field and remove large amounts of nutrients, consequently, plants need high fertilization rates, which causes an increase in the cost of production and environmental pollution [4].

Nitrogen (N), as an essential plant nutrient, is one of the elements that plants need in large quantities [4]. Nitrogen is vital for optimum vegetative growth, it is the main

element in the composition of proteins and other compounds in plant tissues, thus it affects vital processes such as respiration and photosynthesis [5]. Banana growers tend to add high rates of nitrogen fertilizers to obtain high yields, but this increases the costs of production due to the high price of manufactured nitrogen fertilizers [6]. Besides, the application of excessive chemical fertilizers causes air, soil, and water pollution [7]. Urea is the famous and traditional form of nitrogen used in the nitrogen nutrition of plants, it represents more than 50% of the fertilizers used by farmers in the world [8]. A large part of the nitrogen is lost when urea is added to the alkaline soils, especially under high-temperature conditions [7,9]. Ammonia volatilization is the main mechanism of nitrogen loss from urea which accounted for 40% of the total applied nitrogen [10,11]. Controlled release urea is a good method to increase nitrogen efficiency and reduce the loss through coordinating N release that matches plant requirement and thereby minimizing the hazards of environmental pollution [9]. Although the high cost of slow-release nitrogen fertilizers, they are effective tools to reduce ammonia loss and increase nitrogen use efficiency [9–11].

Milk products must have more interest in our studies due to their importance as human foods. A large portion of dairy products lose their validity before use causing an environmental problem in disposing of these large quantities [12,13]. In most cases, expired milk products are disposed of due to the safety and health of the environment and humans [14,15]. Dairy factories deal with expired milk products in several ways, including disposal at landfills of municipal wastes, transferring to solid and liquid waste stations, or adding them directly to agricultural soils [16]. The expired dairy products contain high levels of microbial content and are rich in soluble organic compounds, and this may encourage the growth of some unfavorable microbes and thus cause harm to growing plants [12,13,15,17]. The second problem with adding these wastes directly to the soil is their high fat content (up to 8%), which does not decompose easily in the soil and reduces the soil quality characteristics. [18,19]. The expired dairy products contain high levels of nutrients and organic carbon, therefore, they should be recycled and used in agricultural production instead of being disposed of and adding more burdens to the ecosystem [12,13,19].

The basic idea of this research paper is based on extracting the protein compounds from expired dairy products and then drying them thermally. Our study aims to evaluate the efficiency of the extracted compounds compared to traditional and slow-release urea in the nutrition of Williams banana under field conditions. The study also investigates the dynamic of NH_3 emissions from the newly discovered fertilizer compared to traditional and slow-release urea in alkaline soils under arid conditions.

2. Material and Methods

2.1. Converting Expired Milk Products to Organic Fertilizer

The protein compounds were extracted from three types of expired dairy products including yogurt, milk, and cheese. The expired products were mixed with water at a rate of 1: 3 (expired products: water). The aforementioned dairy products expired for human consumption a month ago. The expired products were left for 24 h on a bench at 20 °C without stirring. After 24 h, the above fatty layer of the mixture was removed, then the protein layer was extracted by a clean fine cloth. The extracted protein compounds were oven-dried (70 °C) and ground to pass through a 2 mm sieve.

The pH of the extracted fertilizer was measured directly in 1:2 dry product to water suspension, while the EC was measured in 1: 5 water extract. Total organic carbon was determined by the dichromate oxidation method as described by Wakley and Black [20]. The content of N, P, and K in the dry powder was measured after the digestion of 2 g by H_2O_2 and H_2SO_4 based on the method of Parkinson and Allen [21]. Total N, P, and K were analyzed by standard methods of Burt [20].

2.2. Field Experiments

This study was conducted during two successive growing seasons: 2017 and 2018. Williams banana plants are grown in silty loam soil under a flood irrigation system in a private banana orchard located at El-Wasta village, Assiut Governorate at Upper Egypt. The soil of the experimental site is classified as Entisol: Typic Torripsamments [22] and Table 1 shows the main characteristics of the studied soil. Plant spacing was 3×4 m apart and selecting three suckers/holes with a population density of 2500 plant ha⁻¹. The field experiment consisted of four treatments including: C = control without N fertilization, U = traditional urea, SRU = slow-release urea, and EDPF = expired dairy products fertilizer. The treatments were arranged in a randomized complete block design and repeated in the same experimental units in the two growing seasons. All the treatments received the same amount of N, P, and K. The resin-coated urea (42% N), traditional urea (46% N), superphosphate (6.8% P), and potassium sulfate (40% K) were used. The rate of nitrogen, phosphorus, and potassium additions were 500, 150, and 350 kg ha⁻¹ of N, P, and K [1,6]. These rates were added each year in nine equal doses from March to November during each season. The climatic conditions of the field experiment were as follow: maximum and minimum temperature of 18–30 and 7–18 °C, relative humidity of 40–50%, and no rainfall during the experimental periods. All agricultural operations, including irrigation and service, from planting to harvesting, were carried out according to the instructions of the Egyptian Ministry of Agriculture. The service operations that were performed were irrigation, hoeing, and weed control. Weed control and hoeing were done manually. As for irrigation, it was done when the soil moisture reached 70% of the field capacity. The growth parameters were recorded after inflorescence emergence. The total yield of bunches was recorded when the fingers reached maturity, which was in December.

Table 1. Basic soil properties before cultivation.

Soil Characteristics	Value
Texture	Silty loam
pH	8.36 ± 0.00
Cation exchange capacity	16 ± 0 cmol kg ⁻¹
Organic-C	11,400 ± 0.2 mg kg ⁻¹
Total N	278 ± 12 mg kg ⁻¹
Total P	520 ± 0.10 mg kg ⁻¹
Total K	12,000 ± 2 mg kg ⁻¹
Available N (NH ₄ + NO ₃)	80 ± 6 mg kg ⁻¹
Available Olsen P	4.9 ± 0.2 mg kg ⁻¹
Available-K	400 ± 14 mg kg ⁻¹

2.3. Analysis of Soil Samples

Composite soil samples (0–20 cm) were collected in the first season and air-dried. The dried samples were crushed and sieved to pass through a 2-mm sieve. The physiochemical characteristics of soil were measured according to Burt [20]. The digital pH meter was used to measure the soil pH in 1:2 soil to water suspension. The soil salinity in the soil samples was measured by the electrical conductivity (EC) of the 1:2 soil to water. The total nitrogen in the soil was determined by the micro-kjeldahl method [20]. A closed chamber (40 × 20 cm) and portable ammonia detector (PAD) were used to measure the ammonia volatilization under the field conditions. The ammonia volatilization was recorded two times every day during the fertilization program from March to November each year. The detection limit of the portable detector is 0.30 µg N. The method of ammonia volatilization measurement is described in detail in Yang et al. [23]. The soil pH and the concentrations of NH₄⁺ were measured daily in the soil samples collected from the upper soil layer (0–20 cm). The dynamic of NH₃ emission was fitted by the Elovich equation by using the SigmaPlot program [11]. The equation is: $qt = a + blnt$. The value of q represents the cumulative ammonia loss during time (t) in days, while a and b are parameters of the equation.

2.4. Analysis of Fruit Quality and Plant Samples

The juice of banana fruits was freshly prepared by bender and was used for measuring the total soluble solids and total sugars determination as described by Official Methods of Analysis [24]. The artificial ripening for bunches was carried out, then the fruit quality was evaluated. Finger weight (g) and pulp % were recorded. Composite leaf samples were collected from the upper top leaf of banana plants after inflorescence emergence. Each sample consists of three plants by collecting 10 × 10 cm from the middle part of the leaf blade. The leaf samples were used to determine the nitrogen (N), phosphorus (P), and potassium (K) content of banana plants. The determination of the total N, P, and K in plant samples was done after the digestion by H₂O₂ and concentrated H₂SO₄ [21]. N, P, and K in the digest of plant samples were determined according to Burt [20]. Chlorophyll was extracted from the fresh Williams banana leaves by acetone and then measured spectrophotometrically at 663 and 645 nm [25]. Chlorophyll a and b concentrations were calculated according to the following two equations:

$$[\text{Chl a}] = 12.25 \cdot \text{Absorbance at 663.6} - 2.55 \cdot \text{Absorbance at 646.6}$$

$$[\text{Chl b}] = 20.31 \cdot \text{Absorbance at 646.6} - 4.91 \cdot \text{Absorbance at 663.6}$$

2.5. Data Analysis

The experimental design of the field trials was laid out in a randomized complete block design with five replicates. Kolmogorov-Smirnov was used to check the normality of data. The significance of the differences between the treatments was tested by the analysis of variance (ANOVA) and Duncan multiple range tests ($p \leq 0.05$). Kinetics of ammonia volatilization was fitted by SigmaPlot software, version 12.5 (SPSS, Chicago, IL, USA). Pearson correlation analysis was run to test the relationships between temperature, soil pH, and concentrations of NH₄⁺ and ammonia emissions. All the statistical analyses were run by SPSS, version 15 (Systat Software, San Jose, CA, USA).

3. Results

3.1. Characteristics of the Extracted Organic Fertilizer (EDPF)

The data in Table 2 show the chemical properties of the extracted organic fertilizer. The extracted organic fertilizer contains 5, 1.5, and 4% of N, P, and K, while the pH (1:5) is 4.50 and the total organic carbon is 45%. The extracted organic fertilizer is rich with organic matter and contains 5% of N and 4% of K. The traditional (U) and slow-release urea (SRU) contain 42% and 46% of N. The rate of nitrogen fertilization was 500 kg ha^{−1}, thus the application rate of EDPF, traditional urea (U), and slow-release urea (SRU) were 10,000, 1190, and 1087 kg ha^{−1}, respectively.

Table 2. Characteristics of the extracted organic fertilizer.

% Nitrogen	% Phosphorus	% Potassium	pH	% Organic Carbon
5	1.50	4.0	4.50	45

3.2. Effect of Nitrogen Forms on the Growth of Williams Banana

Expired dairy products fertilizer (EDPF), traditional (U), and slow-release urea (SRU) were added to banana plants cultivated on silty loam soil under two-year field trials. Table 3 shows the response of Williams banana plants to the tested fertilization treatments. The height of the pseudostem, leaf area, and chlorophyll affected significantly ($p < 0.05$) by the different forms of nitrogen compared to the untreated soil. EDPF improved the growth of Williams banana compared to U and SRU. The highest growth parameters in the two growing seasons were obtained from the plants fertilized with EDPF. Chlorophyll a and chlorophyll b were determined in the leaves of Williams banana and the data are illustrated

in Table 3. Chlorophyll a and b in the plants fertilized with EDPF were significantly higher than U and SRU in the two growing seasons.

Table 3. Effect of nitrogen forms on the growth of Williams banana.

Treatments	Pseudo Stem Height (cm)	Leaf Area (m ² Plant ⁻¹)	Bunch Weight (kg)	Finger Weight (g)	Chlorophyll a (mg g ⁻¹ Fresh Weight)	Chlorophyll b (mg g ⁻¹ Fresh Weight)
First growing season (2017)						
C	2.55 ± 0.21 ^c	16 ± 2 ^c	18 ± 1 ^c	80 ± 3 ^c	1.02 ± 0.07 ^c	0.75 ± 0.04 ^d
U	3.18 ± 0.17 ^b	21 ± 2 ^b	24 ± 1 ^c	103 ± 3 ^b	2.08 ± 0.02 ^b	1.02 ± 0.01 ^c
SRU	3.22 ± 0.25 ^b	20 ± 3 ^b	25 ± 2 ^b	105 ± 5 ^b	2.07 ± 0.03 ^b	1.45 ± 0.08 ^b
EDPF	3.84 ± 0.12 ^a	24 ± 2 ^a	30 ± 3 ^a	122 ± 4 ^a	3.00 ± 0.06 ^a	2.00 ± 0.05 ^a
Second growing season (2018)						
C	2.47 ± 0.08 ^c	14 ± 1 ^d	17 ± 1 ^c	82 ± 3 ^c	1.15 ± 0.04 ^c	0.82 ± 0.02 ^c
U	3.40 ± 0.09 ^b	19 ± 2 ^c	24 ± 2 ^b	110 ± 6 ^b	2.02 ± 0.07 ^b	1.36 ± 0.04 ^b
SRU	3.46 ± 0.06 ^b	22 ± 1 ^b	25 ± 2 ^b	115 ± 5 ^b	2.12 ± 0.08 ^b	1.22 ± 0.05 ^b
EDPF	3.70 ± 0.18 ^a	25 ± 2 ^a	28 ± 3 ^a	126 ± 12 ^a	3.13 ± 0.01 ^a	2.14 ± 0.06 ^a

C = control, U = urea, SRU = slow release urea, and EDPF = expired dairy products fertilizer. Means (± standard deviation, *n* = 5) in the same column with different letters show significance based on Duncan's test at *p* < 0.01.

3.3. Effect of Nitrogen Forms on the Yield and Quality of Williams Banana

Fertilization of Williams banana plants with EDPF gave a higher bunch yield than U and SRU (Figure 1). EDPF significantly enhanced the bunch weight over U and SRU in the first and second years (Table 3). In the same trend, the addition of EDPF caused increases in the total yield of bunches above U and SRU. The total bunch weight ranged between 42 and 75 ton ha⁻¹, the highest significant value was obtained from the plants fertilized with EDPF, while the lowest value was obtained from C. The fruit quality of banana fingers was evaluated and the results are shown in Figure 2 and Table 3. The finger weight, % pulp, % total soluble solids, and % total sugar significantly increased as a result of EDPF, U, and SRU addition. The finger weight of the plants fertilized with EDPF was significantly higher than that fertilized with U and SRU. All the tested fertilizers led to increases in the quality characteristics compared to control.

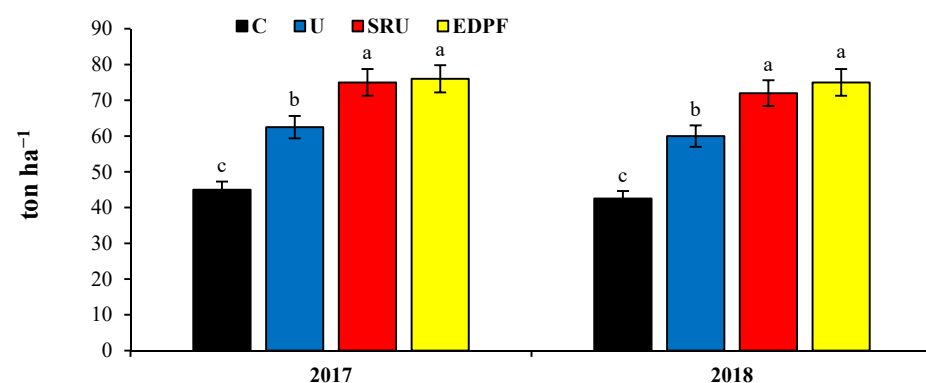


Figure 1. Effect of nitrogen forms on the total banana yield during the two growing seasons (ton ha⁻¹). C = control, U = urea, SRU = slow-release urea, and EDPF = expired dairy products fertilizer. Means (± standard deviation, *n* = 5) in the same column with different letters show significance based on Duncan's test at *p* < 0.01.

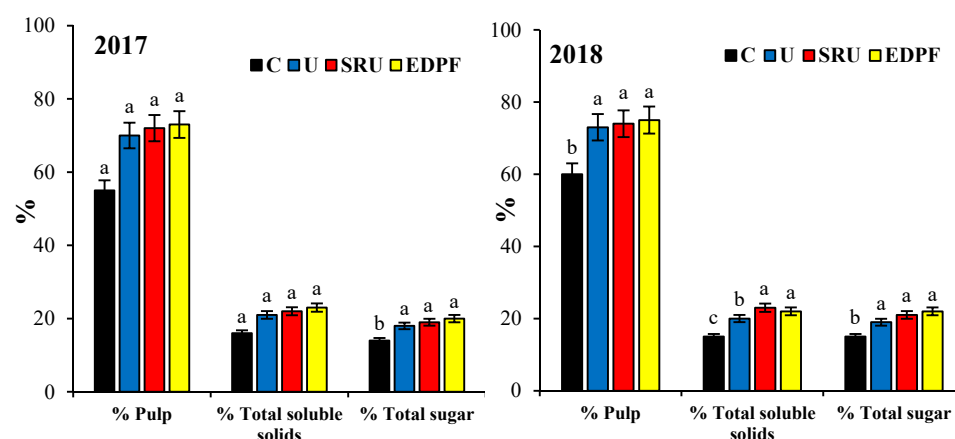


Figure 2. Effect of nitrogen forms on the fruit quality of banana fingers. C = control, U = urea, SRU = slow-release urea, and EDPF = expired dairy products fertilizer. Means ($\pm$ standard deviation, $n = 5$) in the same column with different letters show significance based on Duncan's test at $p < 0.01$.

3.4. Effect of Nitrogen Forms on Chemical Properties of Soil and Nutrients Uptake

The effects of U, SRU, and EDPF on the availability and uptake of N, P, and K were studied and the results are shown in Table 4 and Figure 3. The addition of EDPF, U, and SRU significantly enhanced the nutrients uptake compared to C. The addition of EDPF increased the availability of P by 48 and 67%, respectively, compared to SRU and U. EDPF significantly increased P uptake by 29 and 23%, respectively, compared to U and SRU (means of the two growing season). The uptake of N, P, and K can be arranged in descending order: EDPF > SRU > U > C. Although EDPF gave the highest values of N and K availability and uptake, there were no significant differences compared to U and SRU.

Table 4. Effect of nitrogen forms on nutrients availability and some chemical properties of soil.

Treatments	Nitrogen (mg kg ⁻¹)	Phosphorus (mg kg ⁻¹)	Potassium (mg kg ⁻¹)	pH	Organic-C (g kg ⁻¹)	CEC (cmol kg ⁻¹)
C	30 $\pm$ 3 ^b	13.5 $\pm$ 1.2 ^b	550 $\pm$ 16 ^a	8.13 $\pm$ 0.05 ^b	11.4 $\pm$ 0.3 ^b	16 $\pm$ 1 ^b
U	250 $\pm$ 10 ^a	12.2 $\pm$ 2.0 ^b	540 $\pm$ 20 ^a	8.26 $\pm$ 0.10 ^b	11.6 $\pm$ 0.2 ^b	16 $\pm$ 1 ^b
SRU	240 $\pm$ 17 ^a	13.7 $\pm$ 2.2 ^b	550 $\pm$ 12 ^a	8.12 $\pm$ 0.08 ^b	11.5 $\pm$ 0.4 ^b	16 $\pm$ 1 ^b
EDPF	260 $\pm$ 12 ^a	20.4 $\pm$ 3.1 ^a	560 $\pm$ 17 ^a	7.42 $\pm$ 0.12 ^a	13.0 $\pm$ 0.2 ^a	18 $\pm$ 1 ^a

The soil samples were collected at the end of the second growing season. C = control, U = urea, SRU = slow-release urea, and EDPF = expired dairy products fertilizer. Means ($\pm$ standard deviation, $n = 5$) in the same column with different letters show significance based on Duncan's test at $p < 0.01$.

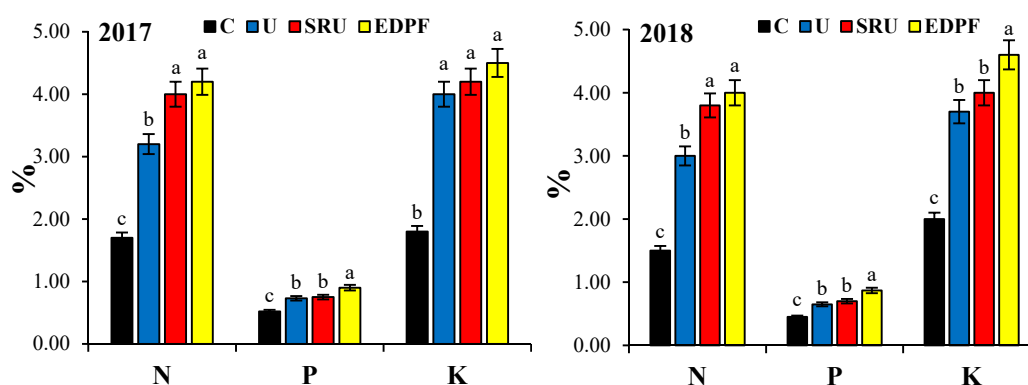


Figure 3. Effect of nitrogen forms on nutrients concentrations in banana leaves (% dry weight basis). C = control, U = urea, SRU = slow-release urea, and EDPF = expired dairy products fertilizer. Means ($\pm$ standard deviation, $n = 5$) in the same column with different letters show significance based on Duncan's test at $p < 0.01$.

EDPF caused remarkable improvement in the characteristics of silty loam soil (Table 4). The values of the soil pH reduced significantly as a result of EDPF addition. The initial value of the soil pH was 8.36 and it reduced to 7.42 when the soil was amended with EDPF. The cation exchange capacity (CEC) and the soil organic carbon were significantly improved as a result of EDPF addition. EDPF increased the soil organic-C and CEC by 12 and 13% compared to U and SRU.

3.5. Effect of Nitrogen Forms on the Dynamics of Ammonia Volatilization

The cumulative $\text{NH}_3\text{-N}$ volatilization was affected significantly by the different fertilization treatments (Figure 4). The highest significant values of the ammonia loss were found in the traditional urea in both growing seasons. The cumulative $\text{NH}_3\text{-N}$ volatilization from U treatment reached 172 kg N ha^{-1} which accounted for 34% of the total added nitrogen. The total ammonia loss from EDPF reached 100 kg N ha^{-1} which accounted for 20% of the applied N. Ammonia volatilization can be arranged in the descending order: $\text{U} > \text{SRU} > \text{EDPF} > \text{C}$. EDPF significantly reduced the ammonia volatilization compared to U and SRU. The loss of nitrogen to the total applied fertilizer was 34%, 26%, and 20%, respectively, for U, SRU, and EDPF.

The correlations between NH_3 fluxes and air temperature, soil pH, and NH_4^+ concentration were studied and the results are shown in Table 5. The correlations between NH_3 emission and the air temperature, soil pH, and NH_4^+ concentration were positive and significant in all the tested fertilization treatments. The relationship between the time and the NH_3 fluxes was fitted by the Elovich equation and the results are shown in Table 6. The Elovich equation described the relation between time and the NH_3 fluxes adequately in all the fertilization treatments. The highest value of b , which is the regression coefficient of the fitted equation, was recorded in U, while the lowest one was found in EDPF.

Table 5. Correlation between NH_3 fluxes and air temperature, soil pH, and NH_4^+ concentration.

Treatments	Air Temperature	Soil pH	NH_4^+ Concentration
C	0.72 **	0.81 **	0.92 ***
U	0.95 ***	0.94 ***	0.94 ***
SRU	0.89 **	0.93 **	0.97 ***
EDPF	0.93 ***	0.96 ***	0.76 **

** $p < 0.01$, *** $p < 0.001$.

Table 6. Release kinetic of NH_3 volatilization under different fertilization treatments.

Treatments	a	b	R^2	RMSE
C	−7.520	3.860	0.66 *	4.790
U	−3.387	18.607	0.90 ***	7.527
SRU	−6.964	10.874	0.94 ***	5.293
EDPF	−4.707	5.752	0.96 **	4.292

The results of NH_3 volatilization of the two growing seasons were fitted by the Elovich equation: $qt = a + b \ln t$. C = control, U = urea, SRU = slow-release urea, and EDPF = expired dairy products fertilizer. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

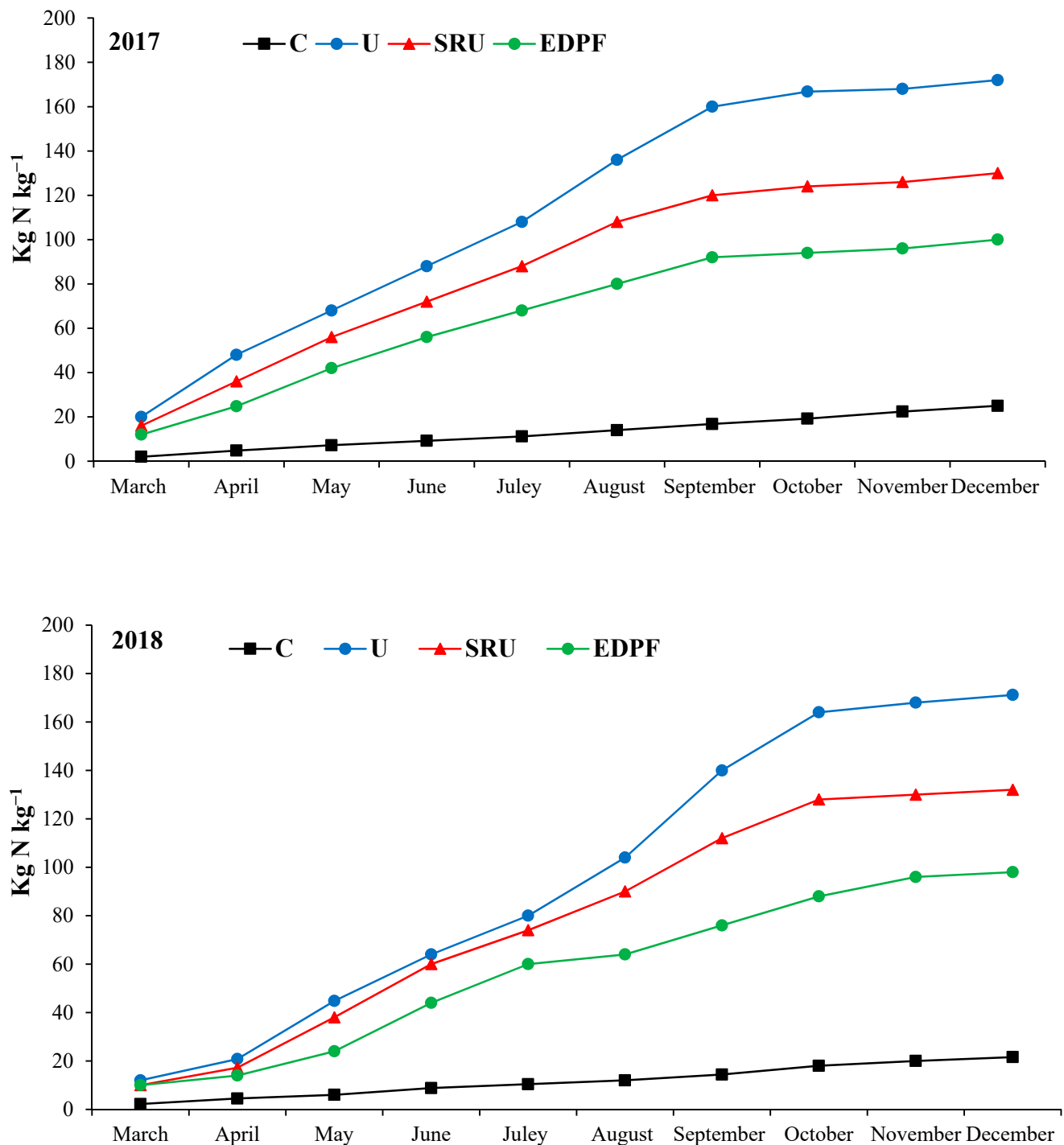


Figure 4. Effect of nitrogen forms on cumulative $\text{NH}_3\text{-N}$ volatilization. C = control, U = urea, SRU = slow-release urea, and EDPF = expired dairy products fertilizer.

4. Discussion

One of the most important characteristics of banana plants is that they are voracious for fertilization, especially nitrogen since it is included in the composition of most of the vital components [4,5]. Banana farmers tend to add high rates of nitrogen fertilization to achieve more yields and in the hope of more profit [6]. Increasing the rates of nitrogen fertilization increases the costs of production due to the high price of manufactured nitrogen fertilizers, consequently, it causes lower profits and an increase in environmental pollution due to nitrogen gas emissions [7]. In the current study, an organic fertilizer (EDPF) was

extracted from the dairy wastes for the nitrogen nutrition of Williams banana plants in comparison with the traditional (U) and slow-release urea (SRU). EDPF increased the total yield of bunches by 20 and 17% in the first and second years, respectively, above U and SRU. EDPF was more able to improve the properties of the soil, as its addition led to: (i) an increase in the soil organic carbon by about 12%, (ii) increase the cation exchange capacity by 13%, and (iii) reduce the soil pH compared to U and SRU. Banana plants are better able to absorb nutrients when soil properties are improved, thus increasing growth and yield [12,13,19,26–29]. EDPF minimized the soil pH from an initial value of 8.36 to 7.42, while the U and SRU failed to reduce the soil pH. Soil pH plays an important role in nutrients availability and root growth [30–34]. Provide ideal conditions for the growth of roots and increase the absorption of nutrients lead to an increase in the photosynthesis process and thus increase growth and yield [19,35–39]. The findings of the current study confirmed the increases in the chlorophyll in the leaves of Williams banana plants as a result of EDPF application. Similar results were found in the case of zucchini (*Cucurbita pepo* L.) and wheat (*Triticum aestivum* L.) [13,19].

The results of the current two-year field study revealed that the ammonia loss from the soil is increased by increasing the soil pH and the NH_4^+ -N concentrations, moreover, the higher temperature encourages ammonia volatilization. The main factors controlling the ammonia flux from the soil are soil pH, temperature, and the concentration of NH_4^+ in the soil solution [7,9,10,34]. Based on the kinetics study of the NH_3 volatilization, the extracted organic fertilizer (EDPF) gave the lowest value of the regression coefficient of the fitted equation. Ammonia loss from the added traditional urea accounted for 34% which equals 172 kg N ha^{-1} . EDPF reduced the NH_3 flux compared to the traditional urea and the slow-release urea. The superiority of EDPF in reducing the emission of NH_3 is due to reducing the soil pH and increasing the soil organic carbon. The increase of soil organic carbon and the reduction of soil pH inhibits NH_3 volatilization [7].

The organic fertilizer which used in this study has a pH value of 4.50 and the total organic carbon is 45%. Most of the organic compounds in this fertilizer are amino acids with acid pH values. The rate of application of the organic fertilizer is 10 ton ha^{-1} for two consecutive seasons with a total amount of 20 ton ha^{-1} . Adding this huge amount of acid material (pH = 4.5) reduced the soil pH. Moreover, during the decomposition of the organic materials, several organic acids are released, thus reducing the soil pH. Several researchers obtained similar results especially in alkaline soils [39–43]. Benefits of the organic fertilizers in reducing the pH of alkaline soil are due to the release of organic acids and carbon dioxide (CO_2) into the soil during the decomposition of the organic compounds [41–43]. Aboukila et al. [43] found that adding organic fertilizers to alkaline soils reduced the soil pH from 8.37 to 7.51.

5. Conclusions

The response of William banana plants to three forms of nitrogen was investigated in two-year field experiments. The traditional and slow-release urea were compared with an organic fertilizer extracted from expired milk products. The extracted organic fertilizer was able to supply William banana plants with its N-requirements. The organic fertilizer led to an increase in the bunch yield by 20 and 17% in the first and second growing seasons. Ammonia loss from the applied nitrogen was 34% in the case of traditional urea compared to 26% from the slow-release urea. The extracted organic fertilizer reduced the ammonia emission from soil to less than 20% of the added nitrogen. Reducing the soil pH of the alkaline soil and increasing the soil organic carbon are good strategies to reduce ammonia loss from banana fields, moreover, the ammonia concentration in the soil solution must also be maintained in line with the growth stage. Traditional urea is one of the fertilizers that its use in banana fields may cause high rates of ammonia emissions, especially at high temperatures in arid and semi-arid regions. The current study presents a new and simple method for extracting nitrogen-rich organic fertilizer from expired milk products. The method of extracting the organic fertilizer depends on separating protein compounds

using gravity, then drying them with heat and grinding them. This method is inexpensive as it provides an opportunity to recycle expired milk products and reduce environmental pollution. The extracted organic fertilizer should be tested under different environmental conditions, and economic studies are required to determine its efficiency compared to mineral fertilizers.

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