# INTED 2021

15th International Technology, Education and Development Conference

8-9 March, 2021

# CONFERENCE PROCEEDINGS

Sharing the Passion for Learning

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# TEACHING CROP FERTILIZER REQUIREMENTS WITH THE NUTRIENT RECOMMENDATION MODEL FERTILICALC

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## Abstract

The development of software that facilitates the application of theoretical concepts to solve problems in specific case studies designed by the student may have a major role in the teaching-learning process in science and engineering. Fertilizer recommendation is a crucial task in managing sustainable agricultural systems that look for an efficient use of resources and a minimum environmental impact. However, selecting the best management alternatives of fertilizers, either organic or mineral, is a complex task, as it requires integrating knowledge on crops, soils and nutrient cycling tailored to a particular crop rotation. The aim of this study was to describe the potential application of the Windows software FertiliCalc to teach fertilizer management in Bachelor and Master degrees related to agriculture. The software is developed in up to 87 languages, freely available and provides a manual and bibliographic material in which the program is based. The effect of FertiliCalc as a learning tool was assessed by mean of a pre-test-post-test design applied to a group of 24 students of Agriculture Engineering. A knowledge survey that contained 20 questions was answered by the students before and after practicing with FertiliCalc. The mean pre-test score of the students was 41% and the median 36%, whereas for the post-test score the mean and the median were 54%. The post-test score was significantly higher ($p>0.001$) than the pre-test. Overall, 18 students increased their scores, 3 had the same and 3 slightly lower score. The graphical representation showed that students that already had a basic knowledge were able to increase more their learning. FertiliCalc showed high potential as a teaching tool since it helps understanding the rationale behind fertilizer management, and it may also allow students to learn the technical terminology in foreign languages.

Keywords: Agriculture, Agronomy, Decision tools, Pre-Test-Post-Test assessment, Virtual lab.

## 1 INTRODUCTION

Fertilizer recommendation is a crucial task in managing sustainable agricultural systems looking for an efficient use of resources and a minimum environmental impact [1]. Crops respond to fertilizer application by increasing yield or product quality, so nutrient application with either organic or mineral fertilizers is a common practice all around the world. In addition, excessive application of certain nutrients, i.e. nitrogen (N) and phosphorus (P), not only implies an economic cost for the farmers but also increase the risk of environmental pollution. Particularly, N losses may contribute to climate change by boosting greenhouse gas emissions and to environmental pollution by increasing N concentration in soil and water [2]. A crucial strategy for reducing nutrient losses while maintaining economic profitability is adjusting nutrient application to accurately meet crop requirements. Because of that, all University degrees related to agricultural sciences and engineering include courses in which guiding fertilization and training the students to sustainable manage nutrients are the main goals.

However, selecting the best management alternatives of fertilizers, either organic or mineral, is a complex task, as it requires integrating knowledge on crops, soils, agricultural practices and nutrient cycling. This information is available for many crops and soils but it is frequently hard to compile as it is dispersed in different literature sources. In addition, all this knowledge needs to be tailored to a particular crop rotation and soil and management conditions and so multiple combinations appear. The time available in the academic courses is usually limited and only allows covering a few study cases that serve as example for a practical application of the concepts studied in theoretical seminars. Because of that, there is a need for pedagogical tools that allow the teacher to analyze different case studies and the students to design their own crop rotations and play with different combinations of soil conditions and agricultural practices to better understand their effect on nutrient cycling and management.


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FertiliCalc is a software that calculates the required seasonal nutrients for a crop rotation. It includes a dataset with a large number of crops from which the user can pick as many as needed to create a crop rotation [3]. The relevant information of these crops for nutrient cycling is gathered in the dataset and has been collected from different sources [4, 5, 6]. The user introduces the yield for each crop and can customize the crop data or use that existing in the dataset. Soil characteristics can be easily introduced by the user as well as some common agricultural practices. A more detailed description of the software will be provided in the Material and Methods section, but what is relevant is that FertiliCalc has several characteristics that make it suitable for the pedagogical purposes, such as flexibility to design different crop rotations, adaptability to integrate various soil and management situations, and ease to use by a student with basic knowledge in agronomy. Additionally, FertiliCalc is freely available from the web page of the U. Cordoba and as it is used also by agronomists and farmers that require estimates of rates for nutrient application, it can be used as a link between academic education and the future professional career of the students.

Nevertheless, pedagogical tools should be evaluated under actual academic situations to ensure their role and usefulness in the learning process [7]. Among the multiple methodologies available for evaluation, pre-test-post-test control group designs are suited to assess the effect of new tools on the learning process and common in educational research [8]. When the number of students is limited, all students are allocated to a unique group and score on a test before and after conducting the activities associated to the pedagogical tool that is being evaluated. Compared to the post-test only design, the pre-test-post-test controls threats to internal validity and increases the statistical power associated with the comparison of students' scores [9]. Additionally, graphical representation of the pre-test versus the post-test scores provides information about the individual response and may reinforce the conclusions of the statistical analysis. Therefore, the aim of this study was to describe and assess the potential application of the Windows software FertiliCalc to teach fertilizer management in Bachelor and Master degrees related to agriculture.

# 2 METHODOLOGY

## 2.1 Description of the pedagogical tool

FertiliCalc is a Windows program developed with Visual Basic 2015. It contains a single file of 1.6 Mb which can be downloaded freely at the official web page of the University of Córdoba (http://www.uco.es/fitotecnia/fertilicalc.html). A detailed description of the program can be found in the web page and has been published elsewhere [3], therefore, this section includes a short description of the tool that emphasizes its pedagogical abilities. The software has been developed in up to 87 languages, ensuring ease of use for a broad community of students and helping the users to learn the technical terminology in foreign languages.

The interface of the program is user-friendly and has three forms to interact with the student: "Crop and soil", "Fertilizers" and "Results". In the first form, the student designs a crop rotation by picking from a list of 149 crops as many as needed (Fig. 1). The selected crops are shown to the student along with data on harvest index, N, P and potassium (K) concentrations in harvested organs and percent of residues remaining in the field after harvest. The crop data are average values gathered from the literature but can be customized by the students to adapt to local conditions or analyse how the crop nutrient demand changes. The student defines the expected yield and can specify a coefficient of yield variation. There is also an option to mark the proportion of residues that are left in the field and thus can be considered as nutrient inputs, a relevant operational practice that allow comparison of different agricultural strategies.

Once the crop rotation is defined, the student has to select the soil type based on soil texture and supply the available P and K obtained in soil test. The student can play with these values for the different soil fertility levels and the reference range for the various tests can be obtained from [6]. Other soil data that are demanded to the student are organic matter, pH and cation exchange capacity. In this form, he/she is also expected to indicate whether tillage is performed or not and whether the crop rotation designed suffer water scarcity (rainfed or arid and semi-arid climate) or is not water limited (irrigated or humid climate). Finally, the student has to select among four strategies of fertilization: sufficiency strategy (minimum fertilizer), build up and maintenance (reduced fertilizer), build-up and maintenance (maximum yield) and the maintenance option (which is automatically selected if soil analysis are not available). A more detailed description of the fertilization strategies can be found in [3] but what is relevant for the pedagogical purposes is that the program allows the student to calculate and compare the different fertilizer recommendation rates under the selected strategies.

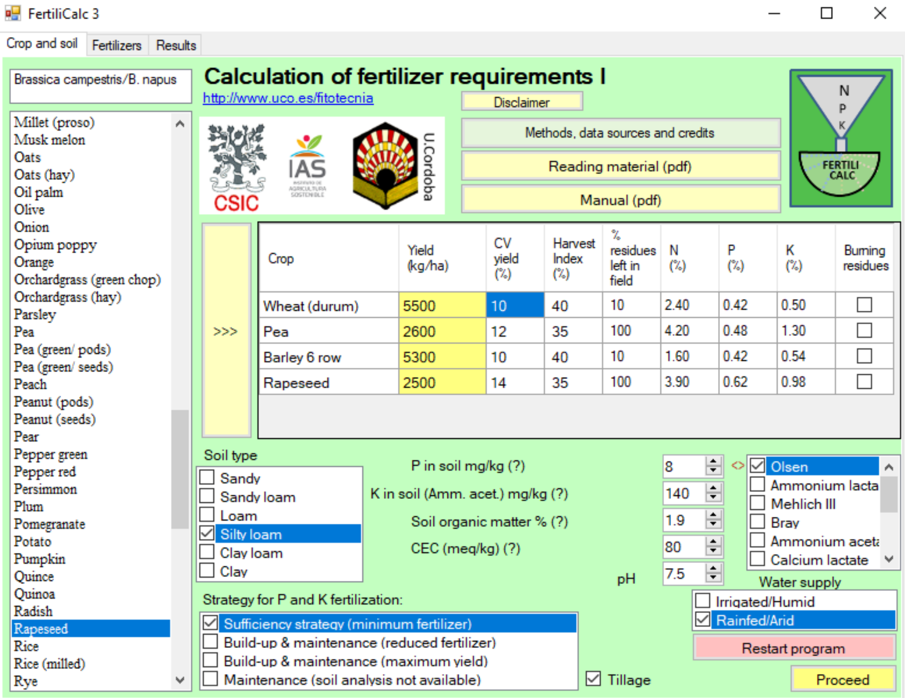


*Figure 1. Crop and soil form in FertiliCalc interface. Example of a selected four crop rotation.*

The second form shows a table with the crop nutrients (N, P, K) requirements calculated according to [5] and [6] and based on the data introduced by the student (Fig. 2). On the right side of the screen appears a list of available fertilizers (44 mineral and 24 organic) from which the student can pick and add products to a list of selected items. Once a product is selected, the nutrient concentrations are shown, so the student learns about the fertilizers and can add a product not included originally in the program. Additionally, in this form the student can customize if fertilizers are incorporated into the soil or not, a relevant issue that determines N losses and is related to agricultural practices. The price of the selected fertilizers can also be updated by the students as they vary with the region or country.

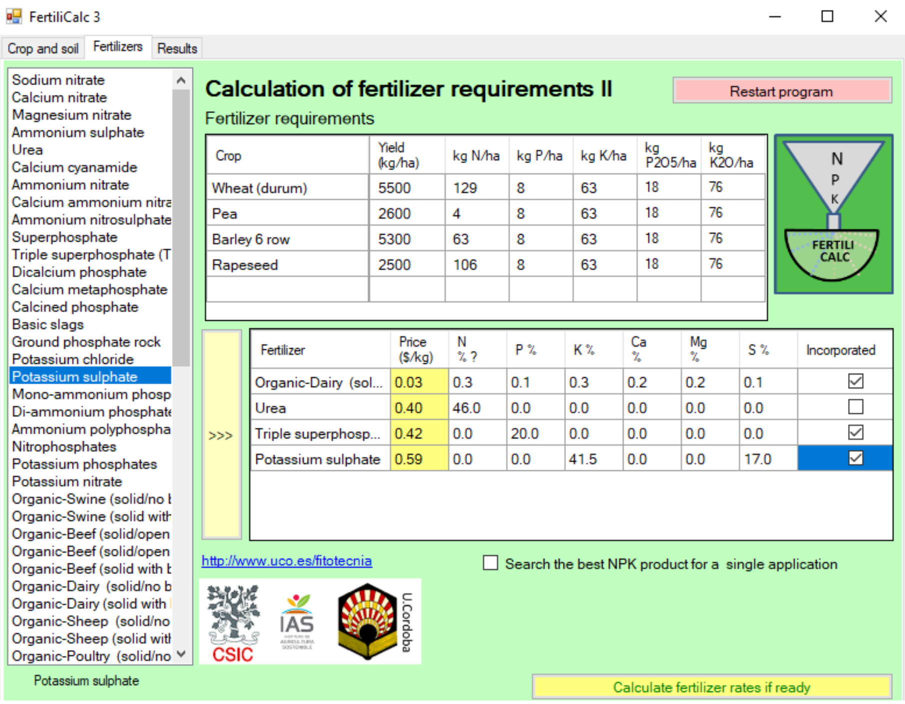


*Figure 2. Fertilizers form in FertiliCalc interface. As an example four fertilizers has been selected.*

The last form shows fertilizer rates required for each crop, together with the economic costs of the products (Fig. 3). Two relevant environmental aspects are estimated: i) N losses by volatilization of ammonia, denitrification and nitrate leaching according to [10], and ii) soil acidification based on the N source and nutrients exports [11]. On the other hand, the application evaluates the adequacy of the fertilizer program by indicating the possible excess or deficit of N for each crop. The excess of P or K is evaluated for the whole rotation, and the Ca, Mg and S balance are provided if information is available in the database.

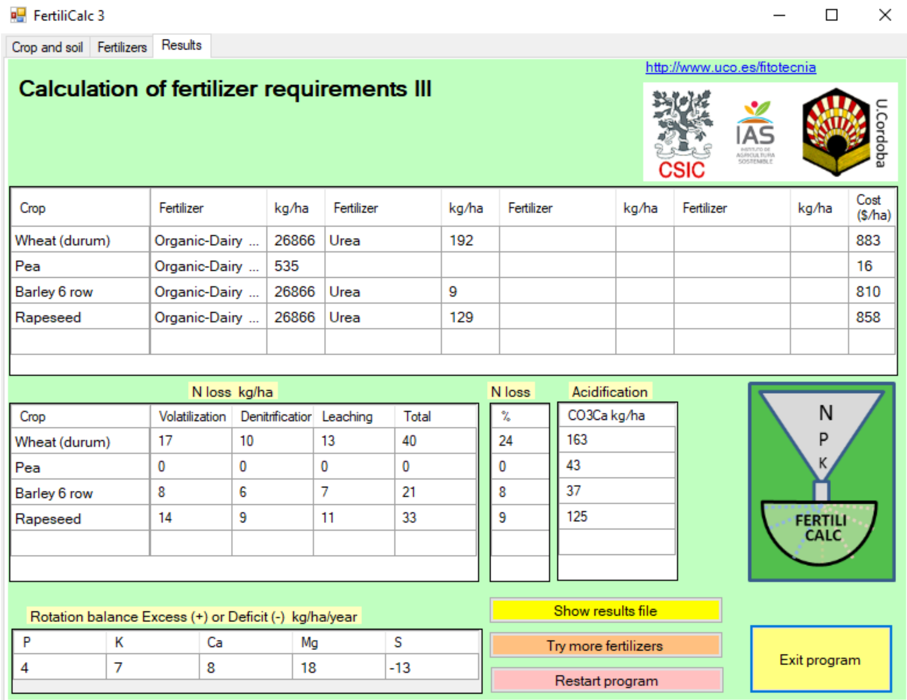


*Figure 3. Results form in FertiliCalc interface for the example above.*

All this information in the Results form is crucial in the pedagogical process because it gives the student the opportunity to analyze the economic and environmental costs of the selected crop rotation and management. The student can easily return to the first and second forms, modify crops, soil characteristics, fertilizer selection, or management practices and see how the results change. In addition to this flexibility, the program calculates the cheapest fertilizer combination to satisfy the N, P and K crop rotation requirements when the option is selected (Fig.2).

## 2.2 Pedagogical activities and evaluation

The pedagogical activities were developed during 4 hours, involving: i) lectures explaining the program and its connections with basic concepts on fertilizer management according to the information provided in [4, 5, 6, 10], and ii) practice with the program in combination with the previous lectures to capacitate the students of using the program by themselves. Afterwards, the students used the program during a minimum of 2 hours as personal work. Finally, a discussion of the results with the teacher took place in which comments on the usefulness and limits of the program were collected.

The effect of FertiliCalc as a learning tool was assessed by means of a pre-test-post-test design applied to a group of 24 students of the third year of the School of Agriculture Engineering (Universidad Politécnica de Madrid). All the students were allocated to a single group and, before practicing with FertiliCalc, they answered a knowledge survey that contained 20 questions. After the lectures and working sessions, students answered the same survey a second time. For each student pre- and a post-test scores were calculated as the percentage of correct answers in each test. The mean, median and standard deviation were calculated for the pre- and post-test scores. Comparison of students' pre- and post-test scores was conducted by one-way analysis of variance. The graphical representation of students scoresthe results follows the approach proposed by [7, 12]. The statistical analyses were conducted with R software (version 3.6.1; R CoreTeam, 2018).

The knowledge survey was designed to evaluate the individual knowledge of each student on nutrient management. The survey contained 20 multi-choice or true/false questions, five related to fertilizers in general and 15 to the N, P and K management in cropping systems. For each question, the student earned 1 point if the answer was correct, 0 points for no answer, and -1 point if the answer was incorrect. The students' scores were converted to a percentage to facilitate analysis and interpretation.

## 3 RESULTS

The mean pre-test score of the students was 41% and the median 36%, whereas for the post-test score the mean and the median were 54% (Fig. 4). The median of the post-test score was significantly higher ($p>0.001$) than that of the pre-test. The graphical representation of the pair values showed that pre- and post-test students' scores were strongly correlated ($r = 0.82$ ; $p<0.001$); therefore, students who had a high pre-test score tended to have also a high post-test score (Fig. 5). Overall, 18 students increased their scores, 3 had the same and 3 slightly decreased their scores. Finally, the pair values comparison also pointed out that students that already had a basic knowledge (pre-tests score > 20) were able to increase more their learning.

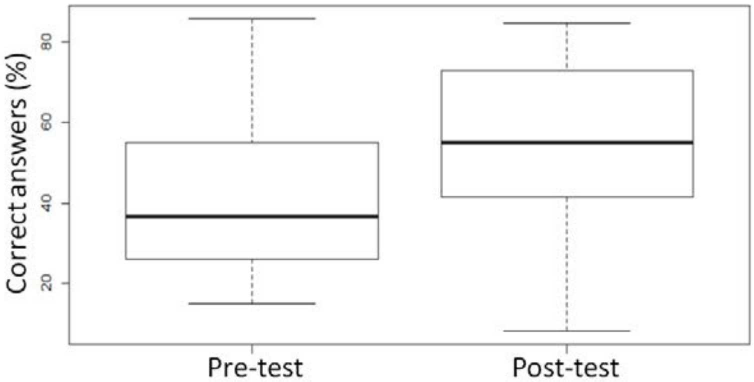


*Figure 4. Boxplots of students' score on the knowledge survey for the pre- and the post-test. Boxes show 25 and 25% percentiles, whiskers 5 and 95% percentiles, and the line in the middle the median.*

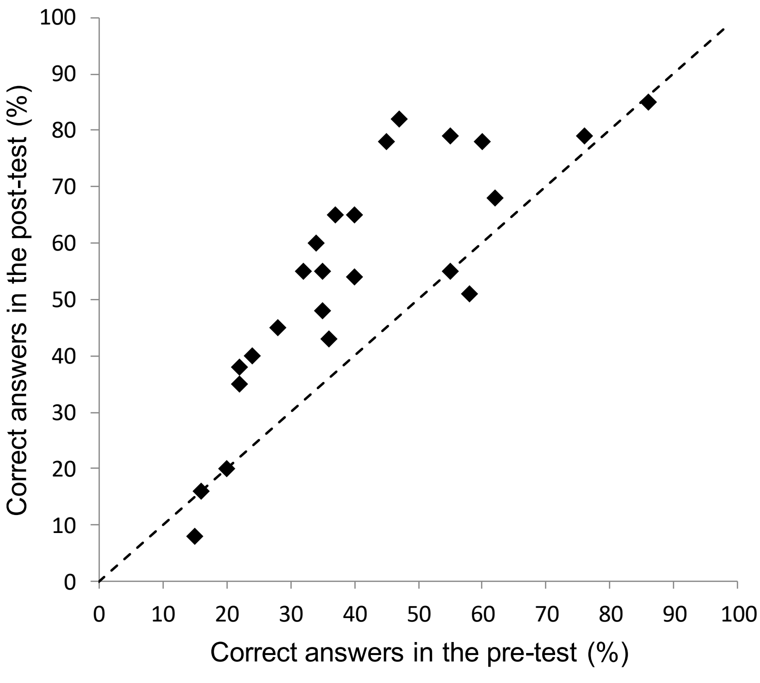


*Figure 5. Relationship between student pre-test and post-test score on the knowledge surveys.*

## 4 CONCLUSIONS

FertiliCalc showed high potential for being used as a teaching tool since it helps understanding the rationale behind fertilizer management. After attending an explanatory lesson and using the pedagogical tool the students increased their knowledge in nutrient management and fertilizer recommendation, with a mean increase of thirteen percentage points in the post-test knowledge survey with respect to the pre-test. Pair value score comparison showed that students that already had a basic knowledge on nutrient management in cropping systems were able to get the most out of FertiliCalc and increase more their learning. These results were obtained in a small group of students (n=24) and, therefore, need further verification in more groups and with students of different backgrounds or degrees. Finally, students enjoyed using FertiliCalc as a pedagogical tool and remarked that it also contributed to learn the technical terminology in foreign languages.


## ACKNOWLEDGEMENTS

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