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Ecological sanitation technology and agriculture

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Abstract

The purpose of this study is based on the introduction of human urine as fertilizer product nitrogen in agriculture. True source of nutrients, it can be generalized and applied as fertilizer in some developing countries including Morocco. Indeed, the Moroccan countryside experiencing low yields due to soil depletion, lack of sanitation sanitized and excessive costs of chemical fertilizers. The test on growing zucchini made of sanitized urine in five different doses to prove the effectiveness of this alternative. The experiments demonstrate the impact of human urine on crop productivity and to determine the optimum amounts for better agricultural production. The results show that the sanitized urine contains 5.6 g of N-total per liter, with a basic pH. In terms of returns, the urine can be used as nitrogen fertilizer competitive with conventional fertilizer. The recovery rate of N-urine was significantly higher than that of N-fertilizer. Thus, the results show that the dilution of 100% urine optimizes performance. Especially, the rural communities should take the Ecological Sanitation (Eco-San) technology to improve their income, in a healthy environment.

1. Introduction

The population explosion and expansion needs, increasing productivity, which become the major interest of the farmers. This demands excessive use of chemical fertilizers, especially, nitrogen and phosphate without any concern of the implications and risks of pollution threatening the groundwater aquifers and eutrophication [1]. This leads to food insecurity, among other things, by soil depletion, rising fertilizer prices on the international market, and notably the risk of polluting the environment. However, these troubles, requires that we immediately look for other sources of nutrients that can enable a sufficiently sustainable and profitable agriculture [2].

Around the world, some countries have long use urine as nitrogen fertilizer in agriculture. Japan practical recycling of human urine from the twelfth century; Sweden farmers collect human urine and then spread it on their fields; Mexico human urine is used in market gardening production [3]. In Africa, particularly in Morocco, the concept called Ecological Sanitation (Eco-San) is an operational program implemented in partnership between the water environment department and the giz company. The Eco-San system is an alternative approach to realize sustainable sanitation. The Eco-San aims to meet socio-economic requirements, prevent pollution of surface and ground water, sanitize urine and feces, and recover nutriment for food production. It is considered more ready and suitable to be applied in rural areas [4]. In addition, multiple types of Eco-San have been advanced with different user interface, collection, treatment process and reuse. For example, Kjaer et *al.* use the human excreta in agriculture in Central Vietnam [5].

In Morocco, the Eco-San concept, first started work in an ultimate objective of serving some communities of rural areas and to improve their daily living conditions [6]. It is in this light that we worked on the theme "Test

Garden Making demonstrative for the valuation of ecological sanitation products" in a village located in the Atlas region of Morocco.

This study evaluates the use of human urine as fertilizer for zucchini cultivation. The objectives of our work were: to determine the fertilizing value of sanitized urine, show the impact of urine on zucchini productivity, and determine the optimum amount of urine for better production. Urine used, helps nourish plants and contributing to their growth. However, some benefits of applying urine are: it is free compared to expensive fertilizers, it can be a substitution of chemicals that pollute the groundwater, and it has a better fertilization and sustainable performance.

2. Materials and Methods

2.1. Plant Material and cultivation

The study was carried out on the plant zucchini (Cucurbita pepo variety cylindrical), is an annual plant, creeping, from the *Cucurbitaceae* family. It is characterized by a fast growing fruits, require regular harvest and eaten before maturity. It can be elongated or round and takes yellow or green color [7]. This species is cultivated in Morocco. Zucchini, which are commonly used as a vegetable, fruits were young, still tender, harvested before they exceed 10 to 15 cm [8]. The choice of plant material is based on the following aspects: plant that does not refute nitrogen fertilization; some plants can be self-sufficient by fixing atmospheric nitrogen and therefore have no need to add nitrogen (such as legumes) or others, which is in line with the abiotic conditions (soil, temperature, sunlight, rainfall) from the site of the experiment. Also, it has a short cycle and high commercial value. The seeds we used were purchased from the local grain vendor.

Plants were grown in a calcareous soil. Earth, light and clear, dries quickly especially in summer, with characteristic cracks. It is characterized by the presence of abundant pebbles, dating back permanently to the surface. The ground limestone is characterized by its high permeability to water, which promotes the penetration jellies. Moreover, limestone allows the decomposition of organic matter and the fertilizer uptake. The rate of nitrogen in the soil was dosed by the Kjeldahl method [9]. Sampling of the soil, partly determines the results of the analysis. The sample must be representative. However, the mixture consists of about 200 g of soil removed. The number of samples taken depends on the area of the land: sampling was carried out on all the land, with six samples collected at several locations on the surface and at depth.

Sizing of the plots. The size of the plots was determined according to the treatments envisaged. Repetitions of three are considered for analysis of the results obtained. The border effect is important to avoid interference between established treatments. Thus, the organization of the land in plots was carried out by: the establishment of the boundaries of parcels and blocks, the optimal size of the plots depends on the crops envisaged, the alternation and distribution of different treatments within a block of plots the positioning of field inputs to allow easy access.

The sample taken was classified according to the treatment performed. The compliance modes were based on: Fresh Weight and Total Biomass Yield. Sampling of urine-treated crops can determine the efficacy of the product in agricultural fertilization.

2.2. Human urine and fertilizer (NPK)

Urine Collection and Hygiene. The urine for the experiment was collected from several eco-toilets in private homes located in the village, and it was stored for about 2 months at 7 °C. This fertilizer is mainly composed of nitrogen, phosphorus and potassium [10]. Thus, often it has an impact on humans and the environment in which it operates [11]. For the analyses, in order to assess the quality and the composition of the urine, samples were obtained from the urine stored in households. For this purpose, a pump has been used as a tool for the homogenization and sampling.

Nutrient Analyses. The nutrient contents of the urine, Phosphorus, Calcium and Potassium were analyzed according to APHA methods [1] and Total- Nitrogen was analyzed by using the Kjeldahl method [9].

Microbial Analysis. The urine was analyzed for fecal coliforms by General Method on Culture medium Nutrient Agar and Fecal Streptococci by General Method by Seeding in Liquid Medium (Most Probable Number) [13, 14].

The fertilizer used in the experiment is ternary complex granulated NPK (7-12-7), which is largely used in Morocco. The composition of the fertilizer is, by convention, always mentioned in the order N-P-K and percentage (%).

2.3. Application technique

For better fertilization, urine should be incorporated into the soil (shallow) as soon as possible, it allows to eliminate odors and prevent the generation of aerosols. The application is made along furrows 10-20 cm seedlings followed by copious irrigation. Then these lines are covered with soil. The supply of nitrogen is formed to avoid the application on the leaves, which can cause leaf burning or spraying urine, something that can generate losses of ammonia [15]. In the same way, the application of chemical fertilizers for comparing their effect to the use of urine was made according the same application technique. The contribution of NPK takes into account the needs of nitrogen in plants.

Period of application. In the early stages of operation, it is essential to ensure good availability of all important nutrients throughout the plant growth. Thus, the application is divided into two periods: first application; a week after sowing and a second application; approximately one to two weeks of the first application. The final application of urine is accomplished with waiting a month between sowing and harvesting period; this calendar is especially recommended for crops consumed raw [16].

Application Rate. In this study, nutrient requirements boil down to a supply of nitrogen. The pre-treatment is assessed taking into account the nitrogen content in the urine, which is 5.6 g per liter of nitrogen and by counting the nitrogen balance to ground level [17]. Thus, the need of nitrogen zucchini is 90kg/ha. The amount of urine needed for its fertilization is 1.7 l/m². This corresponds to a contribution corresponding to 100% of nitrogen zucchini needs. The dilution used for crop fertilization is 1/2 or 1/3 parts water to a volume of urine [18].

Moreover, the applying of urine considers three parameters:

1- the application method: is to avoid direct application and comply with food safety regulations;
2- the application rate: urine added depending the needs of the plant, density per unit area and the soil nutrient composition;
3- the application time: the amount of urine thus determined is divided in time to meet the needs of the plants at different stages and to get an idea of the degree of assimilation of nutrients by the plant [19].

2.4. Statistical Analyses of Yield

A statistical analysis (Descriptive Statistic) was performed for compared the yield evolution of zucchini through the various treatment used, using the Biostatistica software 6. The yield is expressed in the number of plants per square meter corrected by the density of the feet per square meter and the sampling area of the sample, reduced to kilograms per hectare.

3. Results and Discussion

3.1. Evaluation of nitrogen in soils

The analysis performed on samples of soil used was made to assess soil characteristics, including fertility in nitrogenous matter. The results in table 1 show that considered soil of the field is poor in nitrogen. Also, the results explain that the total nitrogen measured depth is the one draw their plants need fertilizing. The mean surface is of 0.25 g N/kg soil and depth of 0.39 g N/kg soil. Thus, the total nitrogen content of the soil does not exceed 0.39 g N/kg soil with a standard deviation of 0.13 g is a maximum value of 0.52 g N/kg soil (Table 2).

These results conform to those obtained in a study by Elherradi and his team on nitrogen mineralization in two soils of Morocco [20]. It was shown that the examination of the nitrogen in two soils studied indicates that the amount of nitrogen ammonia is low. They are still less than 0.05 g N/kg soil. Thus, we can say that the soils used in our study region are poor in nitrogen.

From an agricultural perspective, the soil mineralization could be a factor in making the availability of high contents of nitrogen to crops. His assessment is recommended to determine the nitrogen may be used by plants early in the growing season.

Table 1: Levels of soil nitrogen by the Kjeldahl method

Samples	Nitrogen assay	
	Titration volume (ml)	**N per thousand**
Sample 1.S	1.90	0.19
Sample 1.P	2.90	0.29
Sample 2. S	3.00	0.30
Sample 2. P	3.50	0.35
Sample 3. S	2.50	0.25
Sample 3. P	5.40	0.54

S: Surface, P: In depth 30 cm.

Table 2: Mean and standard deviation of the nitrogen content

	Mean (g de N /kg of soil)	Standard deviation
Surface	0.25	0.06
In depth	0.39	0.13

3.2. Chemical characteristics of urine

The chemical analysis of urine is to determine the quality and quantity of nutrients in urine collected at the village. The results obtained (Figure.1), show that urine is rich in nitrogen with a concentration of 5.6 g /l, moderately high in sodium 2.5 g/l and relatively low in phosphorus 0.31 g/l, potassium 1.1 g /l and calcium. Moreover, urine is especially rich in nitrogen 5.6 g / l; the concentration increase is possibly due to protein ratio that exists in terms of food consumed by the population of the village. This result is the same obtained by Langergrabera and his team, who argue that most of the nutrients needed by plants are found in the urine [21]. These authors showed that a significant amount of nutrients are present in urine and not in the chemical fertilizers. Also, heavy metal concentrations in human urine are much lower than those found in chemical fertilizers, which is an important asset for the use of urine as fertilizer.

For phosphorus, the average concentration in urine is 0.31 g/l; the low concentration is certainly linked to the food. This concentration is lower than the CREPA network, but can be compared to that obtained by Tanmoy et *al.* [22]. The average concentration of sodium is 2.5 g/l, which justify the high conductivity of urine. This concentration depends on the diet of people like other elements. The average potassium concentration of 1.1g/l. This is slightly lower than the rates presented by CREPA network [15].

Calcium is found in urine at a concentration of 0.33 g/l. Based on these results, it is noted that the urine samples stored about two months are nitrogen-rich, despite the nitrogen loss related to storage conditions. We also note that the urine samples analyzed are low in phosphorus and potassium, compared with mineral fertilizers. These results are consistent with those obtained under the same experimental conditions made by World Organization Health [16]. For our study, we were focused on nitrogen presents in urine, as a major component. Also, potassium and phosphorus are present in lower amount (Figure. 1).

3.3. Bacteriological

The analysis of urine samples in collection canisters directly from households, showed the presence of Fecal coliforms and streptococci whose charges vary. Samples analysis before and after treatments of 2 months of storage were carried out by the laboratory of bacteriology. The intended pathogens are: Fecal Streptococci (FS) and Fecal Coliform (FC). The table 3 shows that the desired elements (FS and FC) are present in the samples. Indeed, the urine collected directly is generally sterile [23]. This contamination may be due to anal cleaning water or improper handling of the containers during collection (collection canister, recovery pump, mixing of flow at the device). The anaerobic conditions in the cans can also influence the development of bacteria. Analysis of urine stored in a sealed container under the shadow gives an abatement rate of high pathogenic (99.6%). This allowance can be of several effects such as the middle of alkalinity (pH 9), salinity and the toxicity of ammonia. In fact, No fecal coliform, fecal Streptococci, found in any of the urine samples. However, it is always important to remember that the urine fertilizer should be spread into the soil around the plants and not applied directly to any part of the plants to avoid microbial contamination and possible burning from ammonia. One basic requirement for the urine use in fertilization is that there should not be any fecal cross-contamination occurring during storage of the urine [24].

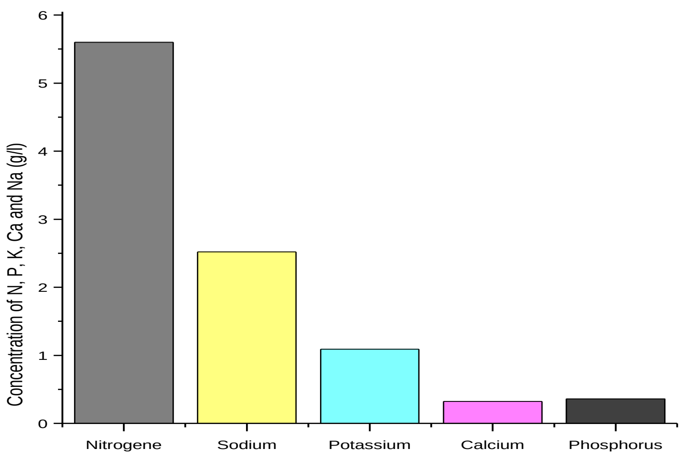


Figure 1: Chemical composition of urine samples.

These results are consistent with those obtained by Surendera et *al.* [23], which showed a significant reduction in fecal coliforms and streptococci in the urine after storage in cans. In view of the bacteriological analysis results, we can say that the contamination of urine is probably of fecal origin from Eco-San latrines and the results should draw attention to the issue of hygiene. It is advisable to conduct awareness campaign villagers to encourage them to take precautions and hygiene requirements and suitable for reuse.

Table 3: Results of microbiological analyzes

	Sample 1		**Sample 2**	
	FS	**FC**	**FS**	**FC**
Fresh urine (FCU/100 ml)	$2.2\ 10^3$	$3.0\ 10^4$	$2.2\ 10^3$	$3.3\ 10^4$
After treatment (FCU/100 ml)	$1.2\ 10^1$	$1.25\ 10^2$	$0.9\ 10^1$	$1.2\ 10^2$
Abatement rate (%)	99.45	99.58	99.59	99.6

3.4. Weight analysis

From the field samples, results, weight average of three repetitions for the different treatments (control, chemical fertilizers and various urine concentrations) are shown in Figure 2. Once calculated, the biomass of each treatment analyzed and compared.

By comparison with the witness (receiving well water as irrigation), the addition of a solution enriched with NPK fertilizer significantly improves the yield of fresh weight of zucchini. This result is normal due to the needs of the plant of essential nutrients and poor soil in these elements. Moreover, the replacement of the NPK solution by water enriched in urine (50%) leads to results similar to those recorded for the rich fertilizer solution. This stimulatory effect of growth is even more pronounced than the urine concentration is high. Thus, a urine concentration five-fold concentrated (250%) causes an increase in yield of about 15% relative to the lower concentration in urine (50%).

The fact that the yield of zucchini is improved by providing the urine compared to that obtained with water from the well suggests the plant has taken advantage of the nutrients in urine, namely N, K, Na, P and Ca. However, when bringing some of these elements (the case of NPK treatment), the biomass yields of zucchini is higher than that shown for well water, reaches not those averages additions (75%, 100% and 150%) and high (250%).

A comparison of the chemical composition of urine (Figure.1) with that of the NPK fertilizer made (7-12-7) suggests that it is the nitrogenous component of the urine which is the cause of this difference.
The fertilizer seems to work well and biomass resulting coincides with that obtained for the dose 50% of urine. Beyond this dose urine, growing zucchini presented a steady increase until the 250% dose. Such a result is unusual because excess urine is likely to cause burns to the roots [25] and causes toxicity in plants. These results are consistent with those obtained by Jörn G. et *al.* [26] on the cultivation of eggplant and asserting that a strong dose of urine gives a low plant growth.

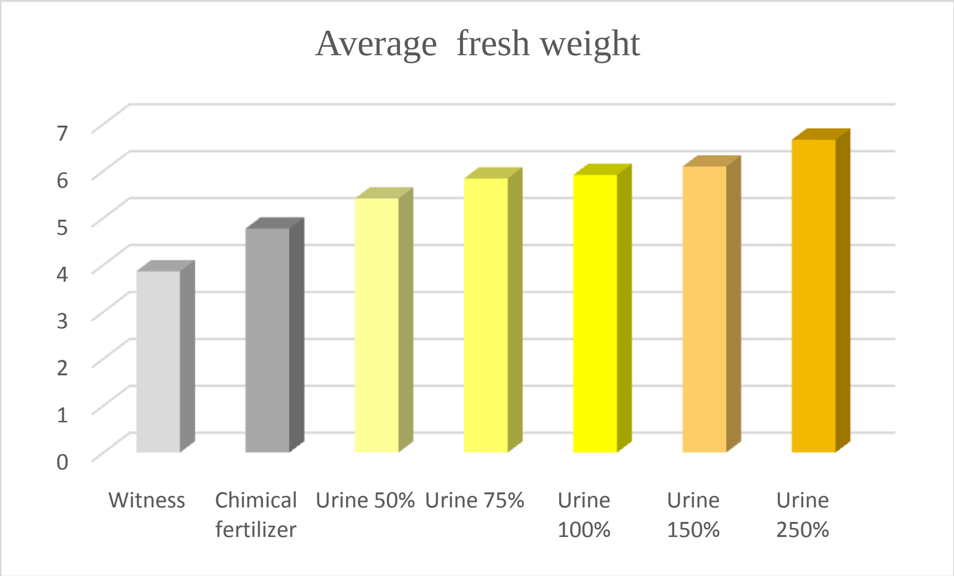
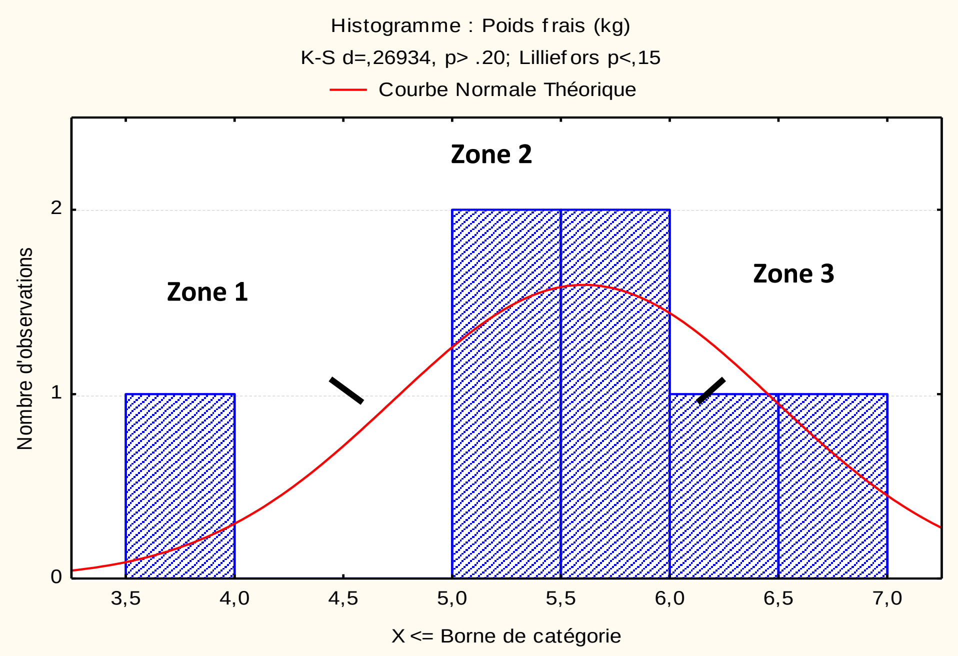


Figure 2: Comparison of biomass obtained from the zucchini depending on the applied treatment.

3.5. Analysis Trendline

The figure 3 shows the trend lines 'bell curve', displaying the product effect used on the yield of zucchini.



Variable	Descriptive statistics				
	Active N	Mean	Minimum	Maximum	Standard deviation
Fresh weight (kg)	7	5.605886	3.861667	6.66533	0.76749

Figure 3: Trend curve showing the evolution of the yield zucchini through various treatments.

Three areas of divergence can be identified: Zone 1 in which the moderate output corresponds to the control, zone 2 at which the production is high with an average of 5 to 6.4 Kg / sample and the number of treatments is higher (manure, urine 50%, 75%, 100% and 150%), Zone 3 in which the production is excessive due to the only treatment that urine is 250%.

The results obtained show that the optimum range in dose urine for zucchini is located within the second group that is urine 50%, 75%, 100% and 150%. Nutrient inputs are very important for the development of zucchini. But, when the need for plants is exceeded, it can lead to a negative effect on the plants which results in toxicity of the medium [27]. This toxicity is not in our case, it remains to be determined in a more advanced and extensive experience.

Conclusion

The agricultural use of different concentration of urine imperatively requires dilution with water. The dilution reduces the odor and prevents plants burns. One can consider the dilution at the time of collection to facilitate spreading. The use of urine has two agronomic advantages: on the one hand, the collection cleanses the environment and improves the living conditions of rural people, on the other hand, improves the productivity of agriculture. However, the sustainability of this technique will depend on the implementation of a collection system and adequate sanitation can ensure the availability of this fertilizer for farmers.

This ecological technology may contribute to the development of positive attitudes about the use of urine as fertilizer as a way to both increase crop yield and reduce water pollution. In addition, findings from this study may contribute to optimize the use of urine to fertilize crops, which will help to maintain fruit yield quality, soil potential. As fact as, more research on this topic need to be undertaken, so that this can be used in the cultivation of different food plants.

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