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RESEARCH ARTICLE

Effects of nitrogen recycling by human urine fertilization on butterfly pea (*Clitoria ternatea*) plant in green wall system on AIT campus

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ABSTRACT

The use of wastewater (urine) as a fertilizer was shown to potentially reduce the campus wastewater load and contribute to saving in expensive wastewater treatment, while dealing with it as valuable resource. If one assumed that this wastewater fertilizer (arguably, one of the best agriculturally acknowledged fertilizers), was applied at odor appropriate and physiologically sustainable rates (Nitrogen Loading Rate (NLR) of up to 0.73 g N m^{-2} $week^{-1}$ equivalent to 104.28 mL urine m^{-2} $week^{-1}$ applied for 16 weeks) and considered total available area for potential green walls, it could be stated that the entire urine stream generated daily on campus (varying from 2.2 to 4.5 m^3) could be accommodated on campus green walls as a valuable resource with significant benefits. In the studies on monitored plant physiological parameters under various conditions, it was observed that urine fertilizer positively affected to the food production, inflorescences and health of butterfly pea (C*litoria ternatea*) plant as well as could say that it was the most suitable plant for green wall. Further integration of urban wastewater management and agriculture (urban food production) into this scenario can make it even more attractive and economically sustainable.

Keywords: Fertilizer, fertigation, human urine, nitrogen loading rate, wastewater

1. INTRODUCTION

Urine is a liquid item, yellowish color that's emitted by the kidneys from the human body. Depends on the amount of liquid, a person drinks, the range of urine produced per day by person. More often, for a mature person, the ranges from 0.8 L to 1.5 L per day and around half range for children [1-2]. Less than 0.5 % of entire household wastewater constitute by urine but it contains basic nutrients N, P and K which are essential for plant growth. Flush less urinals or urine diversion toilets or no mixing toilets are very effective to gather raw urine for use it as a fertilizer in agriculture [3-4]. On the other word, stored urine which has been gathered a partly and hygienised, is a concentrated source of nutrients too that could apply as a liquid fertilizer in green wall and could be a good substation with the commercial chemical fertilizers [5]. Expand the time of storage is the only, cheapest and common way to treat urine with the point of pathogen kill and nutrients restoration [6]. Pathogen removal is accomplished by a composition of the ascending of pH and ammonium concentrations, temperature and time. Relevant on the chance for cross-impurity and the crop species to be fertilize, the perfect storage time at temperatures of 4 to 20 °C differ between one to six months for large-scale systems [7]. The capacity for changing these nutrients has limitations. It would be recognized that biological efficiencies are continuously less than 100%. Typical N uptake capacities of most agronomic crops range from 30 to 70%, due to many factors [8]. First, it is impossible for a plant to drain the entire inorganic N from the soil solution. As the nitrate and ammonium concentrations reduce in solution, the range of N uptake also reduces, in a connection similar to substrate-enzyme reactions [9]. Second, little N concentrations in the soil are needed to run the N influx into crop roots. In addition, some N vaporize (volatilization or leaching) from the root level are obvious during the season [10]. As a result, not all of the N accumulated will be available for consumption of plant. Finally, perhaps most significantly that to earn major or average yields, N must be stored at high levels [11].

A 2:1, 3:1 to 4:1 ratio mean mix of water and urine is an effective ratio of dilution for urban agriculture which

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also avoid odor [12]. Urine should not be deploying on leaves, the roots, stems or other parts of the plants to cause foliar burning [13]. A proper distance of plants should be observed, and make a hole on the soil then urine spread and applied on the hole. In the rainy season, urine application can also be done directly into holes nearby plants, then the rain will dilute it naturally [14].

2. MATERIALS AND METHODS

Wastewater (urine) will be used for fertigation of plants for 16 weeks. Different rates of nitrogen (N) fertigation will apply to the plant. The initial loading rate will be 0.036 g N m^{-2} $week^{-1}$ with dilution of 4L of water and the value of (N) will increase by 2 times every week. The nitrogen loading rate through conservative (low-rate) fertigation with wastewater fertilizer (urine) applied based on (g) of nitrogen m^2 $week^{-1}$ and mL of urine m^2 $week^{-1}$ while the composition of nitrogen per 1 liter urine is 7 g [15]. The values are given in Table 1.

Table 1. Nitrogen loading rate application on green wall in 16 weeks

Conservative (low-rate) fertigation with wastewater fertilizer (urine)		
Time (weeks)	**g N m^{-2} $week^{-1}$**	**mL urine m^{-2} $week^{-1}$**
1	0.036	5.10
2	0.080	11.40
3	0.120	17.10
4	0.170	24.30
5	0.210	30.00
6	0.250	35.70
7	0.300	42.80
8	0.340	48.50
9	0.380	54.30
10	0.420	60.00
11	0.470	67.10
12	0.510	72.80
13	0.550	78.57
14	0.620	88.57
15	0.680	97.14
16	0.730	104.28

Table 2. Analytical methods for urine analysis

Parameter	Analytical Methods
pH	pH meter
NH_3-N (mg L^{-1})	Titrimetric method
TP (mg L^{-1})	Persulfate digestion method
TN (mg L^{-1})	Kjeldahl Method

The different parameters to be analyzed include pH, amount of ammonium nitrogen (NH_3-N) and amount of total phosphorous (TP) in different method as given in Table 2. Since nitrogen and phosphorous are important plant macronutrients, the effect of their availability on the plant will be compared. The plants will be irrigated with different sources of water namely wastewater from canal and tap water. The plants irrigated with canal water and tap water will also undergo urine fertigation [16-17].

The experimental set up will be as follows: 4 blocks of passage each containing the same type of plants will be considered.

- The plants in the first treatment will be irrigated with canal water.
- The plants in the second treatment will be fertigated with wastewater (ww) fertilizer urine dilute with different urine and water ratio.

Urine fertigation is classified into four stages consisting of urine generation point (source), collection, storage, dilution and finally using as fertilizer [18-19] as given in Fig 1.

Fig 1. Schematic diagram of fertigation process

3. RESULTS AND DISCUSSION

3.1. Determination of the nutrients concentration present in wastewater (WW) fertilizer (urine)

The concentration of total nitrogen (TN), total phosphorous (TP), and ammoniumia (NH_3) has been analyzed in fresh (first weeks) and stored (3-4 months) urine [20]. The average TN, NH_3, and TP concentration of fresh urine was 9,625 mg L^{-1}, 4,424 mg L^{-1}, 1,165 mg L^{-1}, respectively. The average TN, NH_3, TP concentration of stored urine was 9,625 mg L^{-1}, 5,166 mg L^{-1}, 964 mg L^{-1}, respectively, as given in Table 3.

Table 3. Chemical composition of fresh urine and stored urine on lab analyzation

Parameter	Fresh urine	Stored urine	Number of sample
pH	7.1	8.7	10
Total nitrogen (TN, mg L^{-1})	8,894	10,360	10
Ammonium/ammonia (NH^{4+}/NH_3, mg L^{-1})	4,424	5,166	10
Total phosphorous (TP, mg L^{-1})	992	964	10

3.2. Plant species used in green wall construction

In total 60 butterfly pea (*Clitoria ternatea*) plants are grown in 2 blocks of passage and has shown its performances on the effects of human urine in percentage of plant coverage, food production, inflorescence and health of butterfly pea (*Clitoria ternatea*).

3.3. Integration of wastewater fertilizer (urine) recycling into green walls

Urine fertilization was collected manually and stored for minimum of 3 months before use. The plant species fertigated with urine fertilizer with respect to their Nitrogen Loading Rate (NLR) measured in g N m^{-2} $week^{-1}$ over a period of 16 weeks as shown in Table 1. The experiment was carried out with wastewater (ww) fertilizer with different N application rates (0.036–0.73 g N m^{-2} $week^{-1}$) [21]. The quantity and quality of experimental plants and control plants were analyzed with the effect of wastewater (ww) fertilizer [22].

The NLR for the conservative fertigation carried out on the plant species located in the passage green wall. The initial loading rate was 0.036 g N m^{-2} $week^{-1}$ and this value was increased by 2 times every 2 weeks as shown in Fig 2.

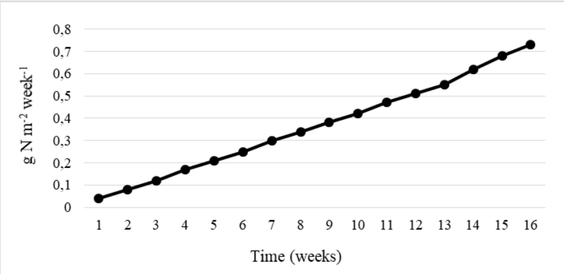

Fig 2. Progressive increase in fertigation rate (nitrogen loading rate, g N m^{-2} $week^{-1}$) for all the butterfly pea (*Clitoria ternatea*) plants over the period of 16 weeks on the green wall

3.4. Growth rate of butterfly pea (Clitoria ternatea) with and without application of wastewater (WW) fertilizer

The wall area covered by butterfly pea (*Clitoria ternatea*) grown in block 1 and 2 and the area of each block is 15 m^2 while the block wide is 6m and its height is 2.5m. The area covered by plant before and after growing was calculated using the Canopeo Software. Canopeo Software used for finding the green wall percentage coverage of control and experiment blocks before and after fertigation. Then, through the percentage coverage of green wall and growth rate of plants we can also calculate and find the area of coverage by (m^2) as follow:

Initial fertigated (experiment) block characteristics

- Area of block = 2.5m x 6m = 15m^2
- Initial percentage coverage = 24.42%
- Area covered by plants = 0.2442 x 15m^2 = 3.66m^2

Ultimate fertigated (experiment) block characteristics

- Area of block = 2.5m x 6m = 15m^2
- Percentage coverage = 59.09%
- Area covered by plants = 0.5909 x 15m^2 = 8.86m^2

Initial unfertigated (control) block characteristics

- Area of block = 2.5m x 6m = 15m^2
- Initial percentage coverage = 20.41%
- Area covered by plants = 0.2041 x 15m^2 = 3.1m^2

Ultimate unfertigated (control) block characteristics

- Area of block = 2.5m x 6m = 15m^2
- Ultimate percentage coverage = 43.33%
- Area covered by plants = 0.4333 x 15m^2 = 6.49m^2

Fig 3. Actual initial image of fertigated (experiment) section of butterfly pea (*Clitoria ternatea*)

Fig 4. Actual image of fertigated (experiment) section of butterfly pea (*Clitoria ternatea*)

Fig 5. Binary image showing percentage coverage of fertigated (experiment) section of butterfly pea (*Clitoria ternatea*) using Canopeo Software

The first block of plants was irrigated with canal water from the canal. The second block was fertigated with wastewater (ww) fertilizer (urine) also irrigated with canal water once a week [23]. The growth rate in the experimental block was higher than the control block as a result of the added wastewater (ww) fertilizer (urine) as shown in Fig 3. The initial growth of fertigated (experimental) plants in block 1 is 3.66 m^2. However, the ultimate growth of fertigated (experimental) plants in block 1 is 8.86m^2 and the initial growth of unfertigated (control) plants in block 2 is 3.5 m^2. However, the ultimate growth of unfertigated (control) plants in block 2 is 6.49m^2 as shown in Fig 3. After 16 weeks the wall area covered by the fertigated and unfertigated section were 8.86m^2 and 6.49m^2, respectively. On an average the wall area covered by the fertigated section was 26% higher than that covered by the unfertigated section (Fig. 9).

Fig 6. Actual initial image of unfertigated (control) section of butterfly pea (*Clitoria ternatea*)

Fig 7. Actual image of unfertigated (control) section of butterfly pea (*Clitoria ternatea*)

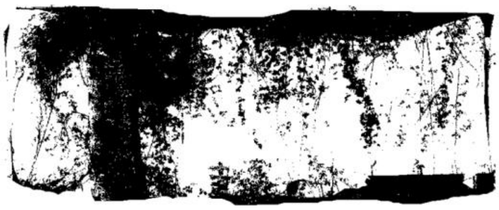

Fig 8. Binary image showing percentage coverage of unfertigated (control) section of butterfly pea (*Clitoria ternatea*) using canopeo software

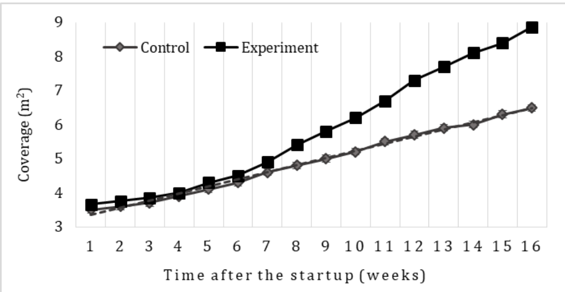

Fig 9. Comparison of wall area coverage of fertigated (experiment) and unfertigated (control) section of butterfly pea (*Clitoria ternatea*) growing at the passage green wall

3.5. Food production

The fruits were planted on the two blocks at the east side of the green wall. The total number of experimented and control plants of butterfly pea (*Clitoria ternatea*) was 50. The experimented plants were fertigated by wastewater (ww) fertilizer (urine) which they were very bright and impressive during the 16 week observation while the control plants were irrigated by canal water which the plant were not in a good health of producing food. The experimented plants block which was fertigated by wastewater (ww) fertilizer, plants were produced 0.95 kg of peas per 50 plants. However, in the control plants block, plants were produced 0.58 kg peas per 50 plants. The value given in Fig 10.

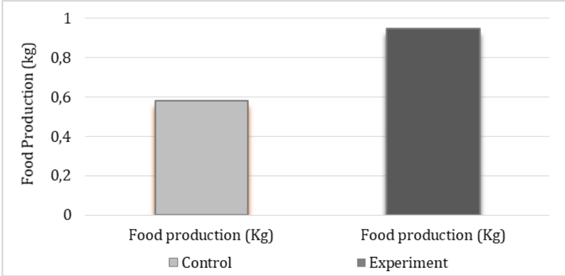

Fig 10. Comparison of food production of (experiment) and (control) of butterfly pea (*Clitoria ternatea*) plants on the green wall

3.6. Inflorescence

Butterfly pea (*Clitoria ternatea*) flowers are sometimes not much clearly seen. However, if this plant irrigates and fertigate properly it will produce flowers very dense and visible. Butterfly pea (*Clitoria ternatea*) flowers were consist of 0.0002 m^2 while the flowers biomass for each flower regarding to laboratory result was 0.039 g m^{-2}. Number of flowers in the entire experimented plant sections at passage green walls was 300 which is equivalent of 11.7 g m^{-2} biomass of flowers per 50 plants. However, the number of flowers in control plants was 55 which is equivalent of 6.4g biomass of flowers per 50 plants as shown in Fig 11.

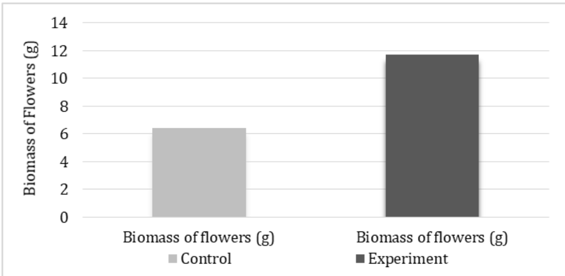

Fig 11. Comparison of biomass of flowers of (experiment) and (control) of butterfly pea (Clitoria ternatea) plants on the green wall

4. CONCLUSIONS

According to results of small scale experiment and conservative (low-rate) fertigation with wastewater (ww) fertilizer of the green wall, it was possible to recycle the amount of 100,500 mg of urea, 2,512.5 mg of ammonia (NH_3), 5,025 mg of phosphorous (P) and 35,175 mg of nitrogen (N) from total 5.025 liters of wastewater (ww) fertilizer (urine) per 16 experimental weeks which had the contribution of 0.05 m^3 in total 56,000 m^3 wastewater of AIT campus in the 16 weeks period [24]. Irrigated water and wastewater fertilizer (urine) could easily go through the poorly pervious soil and plants root easily took up fertilizer nutrients. A conceptual design for combining urine fertigation and water irrigation was developed and based on different fertigation rates, the optimal start-up wastewater fertigation rate was suggested as 100 ml m^{-2} $week^{-1}$ which corresponds to NLR of 0.73 g N m^{-2} $week^{-1}$. The optimum irrigation rate was found to be 4 L $plant^{-1}$ per day. As a result of this experimental design quantify of plants benefits like food production and inflorescence were studied. The results shown that a domestic green wall was able to produce considerable harvest from butterfly pea (*Clitoria ternatea*) plant (up to 0.95 kg pea per month per section), flowering and plant biomass increased and this all testified for efficiency of wastewater (ww) fertilizer application. Moreover, a higher inflorescence rate was observed in the section fertigated with wastewater. Thus, it can be said that the waste nutrients are utilized to produce flowers and fruits in butterfly pea (*Clitoria ternatea*). Urine fertigation was shown to increase the growth rate of butterfly pea (*Clitoria ternatea*) with regard to the studies carried out to monitor plant physiological parameters under various conditions.

Using conservative low level of human urine on plants as fertilizer can be a good idea in real life. It does not produce odor meanwhile it is rich of nitrogen and phosphorous which help the growth and physiological performance of plants. Moreover, this is very low cost system for small scale practices that everyone can collect urine from separate urinal and store it in tanks or containers at 4 to 20°C for two to 6 months out of sunlight and proper hygiene behavior should be observed while storing the urine until fertigating plants. However, this system can be used for large scale but it needs some cost from the first stage of collecting until the end of application to the plants.

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