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UTILIZATION OF NUTRIENTS IN COLLECTED HUMAN URINE FROM ECOSAN TOILET FOR ECO-FRIENDLY CROP PRODUCTION

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ABSTRACT
Studies were conducted to study the important of ecosan toilet in crop production. Human urine though have high nutrient value is being neglected and simply wasted. Out of the human excreta, urine has high nitrogenous fertilizer value than feces. ECOSAN toilet, it can be of great use in fulfilling the fertilizer demand of the country. Human urine is one of them, and has been gaining popularities as a raw material for crop cultivation. In general 3-6 splits urine application in addition with phosphorus and potash fertilizer gave the comparable result with that of chemical fertilizer The main objective of this review paper is to assess the effect of human urine on crop yield and to find out the appropriate urine dose and time of application to different crops.

INTRODUCTION

The NPK fertilizer requirement of our country is 28 million tons but the quantity added through fertilizers is only 18 million tonnes with a gap of 10 mt being mined from soil. But there is no scope for increasing fertilizer production as there will be acute shortage of raw materials required for the manufacture of fertilizers. Furthermore, organic amendments through organic farming are an option for solving the environmentally favorable safe agricultural management strategy (Flavel TC and Murphy D.V .2006.). However, the progress of organic agriculture in the world has been very slow due to rapid declination of organic raw materials such as animal waste, crop residues and green manure which is due to burning of waste and residues and also due to utilization of straw and grass as animal feed (Tejada *et al*., 2008).

Human urine in crop production

Composition of human urine

The different physical and chemical composition of human urine found in different literatures is tabulated in Table 1. In human urine about 75–90%of N excreted is urea and the remainder being in the form of creatinine, amino acids and uric acid (Lentner C and Wink A .1981). Most of the nitrogen fractions in urine are taken up by plant and which is same as that of the urea or ammonium fertilizer with nitrogen efficiency approximately 90% of that of mineral fertilizer (Jonsson H, *et al*., 2004). From Table 1, it is clear that urine contains low concentration of heavy metals. Concentrations of heavy metals in human urine is also lower than that of farmyard manure and have less cadmium than artificial P-fertilizers, making them clean fertilizers (Jonsson, H.2005).Moreover, it comprises of trace elements B, Cu, Zn, Mo, Fe, Co and Mn (Rodushkin. I and Odman F .2001.).

An adult man excretes about approximately 550 kg of human urine, about 4 kg nitrogen are excreted per person (p) and year (y). The nitrogen was found mainly in the form of urea (80 per cent), ammonia (7 per cent), creatine (6 per cent) and the remaining part is in the form of shorter peptides and free amino acids (Lentner C and Wink A .1981). However, the composition of human urine varies from person to person and from region to region depending on his/her feeding habits, the amount of drinking water consumed, physical activities, body size, and environmental factors (Vinneras Johnson , M .2003.).

Human urine is a complex solution containing nutrients as highly diluted compounds. Sodium chloride (NaCl) and urea [CO (NH2)2] are the main compounds, although anthropogenic liquid waste also contains, phosphorus (P), potassium (K), calcium (Ca) and sulphate (SO4). Phosphorus is available as phosphate ions (H2PO4 or HPO42-) and potassium as K+. The majority, around 80 per cent of the total nitrogen present in fresh human urine, exists in organic form as urea [CO (NH2)2] (Altman and Dittmer, 1994). Schouwz N. L, et al., 2002 reported that an excreted nutrient in human urine was about 80-90 per cent nitrogen, 50-65 per cent phosphorus and 50-80 per cent potassium. Jonsson, H.2005 observed that the largest proportion plant nutrients in household waste fraction. Approximately the amount of plant

nutrients excreted in human urine per person per year was measured at 4.5 to 4.6 kg nitrogen, 0.4 to 0.5 kg phosphorus and 1.3 to 1.4 kg potassium. (Table 1)

Effect of human urine on crop growth and yield

Research on urine as a fertilizer is carried out all over the world, in settings ranging from much applied demonstration trials to rigorous scientific studies. Human urine is valuable sources of different nutrients that has been used since ancient times to enhance the growth of plants, notably leafy vegetables and is universally available at little-to-no cost (Jonsson H, *et al*., 2004), were the first who used human urine as fertilizer in scientific experiments. It has been used in varying extents for different crop fertilization in different countries (Table 2). The yield achieved when fertilizing with urine varies depending on many factors. One important aspect is the soil condition. The effect of urine, just as that of chemical fertilizers, is probably somewhat lower on a soil with a low content of organic substances than on a soil with a high organic content. Experience shows that it is beneficial for soil fertility to use both urine and faeces or other organic fertilizers on the soil, but they can be used in different years and for different crops.

Human manure resulted in higher cabbage yields than goat manure but was out-yielded by inorganic fertilizer in South Africa (Mnkeni P. N. S and Austin L M .2009). The greater effectiveness of human manure when compared with goat manure was attributed to the fact that it was a better source of K and P for plants as it maintained higher levels of these nutrients in soil than goat manure.

A experiment in tomato cultivation in a green house to evaluate the efficacy of mineral fertilizer(NPK 9-6-17; 7.4 g per plant), mixture of urine and wood ash(81mL + 10.7 g per plant), only urine (81mL per plant) and control(no fertilization). The result revealed that the urine fertilized tomato plants produced equal amounts of tomato as mineral fertilized plants and 4.2 times more fruits than non fertilized plants (Fatunbi A,O . 2009). The result also revealed that no enteric indicator microorganisms like faecal coliforms, enterococci, clostridia, and coliphages were detected in any tomato fruits. Therefore, they concluded that urine with or without wood ash can be used as a substitute for mineral fertilizer to increase the yields of tomato without posing any microbial or chemical risks.

In India this information is still limited. However, in Karnataka state, harvests of maize, potatoes, french beans ash guard, finger millet and marigold, when urine was used as fertilizer, were very good compared to harvests fertilized with chemical fertilizer, such as urea , single super phosphate and potash (Sridevi G *et al*., 2009).

MATERIALS AND METHODS

Collection and storage of human urine

The use of human urine in agriculture is not possible with the present system of sewage disposal mechanisms. The toilets and urinals in urban centers will have to be redesigned to collect the faecal matter and urine separately. In this direction an eco-friendly design of toilet called 'ECOSAN' (Urine diverting toilets) needs to be popularized which help in source separation of human urine and faecal matter in a hygienic way (Plate 1).

Storage of human urine

Storage of human urine is a crucial part before its application in agricultural field. Losses of nitrogen during storage can be minimized by minimizing temperature, and avoiding aeration above the liquid surface in storage tanks. Human urine was collected in ordinary jerricans or large plastic tanks can be stored for long time and used for fertilization. The ventilation of the collection system should be kept at minimum to prevent losses of nitrogen in the form of ammonia and to prevent odour problems Oldenburg *et al*. 2003.

Stabilization of human urine

During separation, storage and transport, urine is subject to several spontaneous processes such as urea hydrolysis, Precipitation or Volatilization which change the urine composition significantly. Furthermore, in urine, urea is rapidly degraded by urease to ammonium and water, which may elevate pH values up to a pH of 9 (14). Volatilization loss of ammonia from human urine also has adverse effect on environment and human health Udert K,M, *et al*.,2003.

Characterisation of human urine

Representative human urine samples from 10 persons each in the age group of less than 20, 20-40 and more than 40 years from vegetarian and non vegetarian diet category was collected and analysed for nutrient composition and other quality parameters by following standard procedures.

On farm field experiments

Six on farm field experiments were conducted at GKVK farm with 9treatment combinations tried on French bean, finger millet, field bean, tomato, brinjal and bhendi as test crops during first year (2009-10) to assess the fertilizer value of human urine. Cattle urine was also used for comparison. The treatments during 2009-10 tried were Absolute control 40% of rec. N through human urine as basal +60% N in 3 splits with and without gypsum, 40% rec. N through FYM as basal + 60% N through human urine/cow urine. During 2010-11 in addition to these treatments, recommended dose of fertilizer was tried as treatment for comparison.

During second year (2010-11), the experiments were continued in the same experimental plots with aerobic rice,

Table 1:.Physico-Chemical properties of human urine cited in different literatures

Parameters	Nutritive values	References
	1.795–2.610 g L″1	Lentner C, Wink A., 1981
	8gLd1	Winker M, *et al*., 2010
Total nitrogen	0.2-1.2 %	Sridevi G, *et al*.,2009
	0.7gLd1	Pradhan SK, *et al* ., 2009
Total phosphorus	0.2–3.7 g Ld1	Mnkeni P, *et al* ., 2006
	0.15–0.23 g Ld1	Helvi Heinonen -Tanski, , *et al* ., 2007
	0.12 – 0.22 %	Sridevi G, *et al*.,2009
Total potassium	0.10-0.16	Sridevi G, *et al*.,2009
	2gLd1	Pradhan SK, *et al* ., 2009
	0.7–3.3 g Ld1	Yoshinaga J *et al*., 2000
Sodium	0.22-0.35%	Sridevi G, *et al*.,2009
	0.938–0.982 g Ld1	Helvi Heinonen -Tanski, *et al* ., 2007
	0.32mgLd1	Yoshinaga J *et al*., 2000

finger millet, maize, cow pea, soybean and field bean as test crops to study the impact of repeated application of human urine on soil properties, growth and yield of crops.

The quantity of human urine, cattle urine FYM and gypsum to be applied to different crops and for different treatments was worked out based on the N requirement of crops. The balance of P and K was applied through single super phosphate and muriate of potash respectively.

The experiments were conducted during 2011-12, with marigold and cluster beans as test crops in two plots where experiments were conducted with finger millet and aerobic rice as test crop during 2010-2011and 11-12, to assess the impact of human and cattle urine on yield of crops and properties of soil.

Statistical analysis: The data on nutrient composition of urine yield of crops as affected by treatments and changes in soil properties were subjected to statistical analysis as per standard procedure.

The treatments during 2009-10 tried were Absolute control 40% of rec. N through human urine as basal +60% N in 3 splits with and without gypsum, 40% rec. N through FYM as basal + 60% N through human urine/cow urine. During 2010-11 in addition to these treatments, recommended dose of fertilizer was tried as treatment for comparison.

Statistical analysis: The data on nutrient composition of urine, yield of crops as affected by treatments and changes in soil properties were subjected to statistical analysis as per standard procedure.

Table 2 : Studies on the use of human urine in different crops and different countries.

Country	Crop	References
India	Banana	Sridevi G, *et al.*,2009
South Africa	Cabbage, lettuce, maize, beetroot, carrot, tomato	Mnkeni P *et al.*, 2008 and Flavel TC and , Murphy DV 2006.

Table 3: Chemical composition of human urine samples from persons of vegetarian and non-vegetarian diet (20- 40 years).

Sl. No	Parameters	Vegetarian diet <20 -40 years	Non-vegetarian diet <20 -40 years
1	pH	4.26-6.65	4.96-6.81
2	EC (dS/m)	5.64-8.17	6.68-8.75
3	N (%)	0.21-0.43	0.31-0.55
4	P2O5 (%)	0.11-0.26	0.13-0.30
5	K2O (%)	0.12-0.23	0.12-0.25
6	Na (%)	0.13-0.31	0.12-0.34
7	Ca (meq/l)	6.00-24.00	8.00-26.00
8	Mg (meq/l)	15.80-43.46	21.73-39.51
9	S (%)	0.07-0.21	0.09-0.22
10	HCO-3 (meq/l)	5.12-14.08	5.12-7.68
11	Cl- (meq//l)	22.72-36.54	23.61-38.76
12	Zn (mg/l)	16.20-23.40	16.40-23.80
13	Fe (mg/l)	98.60-143.00	116.60-164.80
14	Mn (mg/l)	17.80-27.00	17.80-27.00
15	Cu (mg/l)	41.82-48.04	41.82-48.78

RESULTS AND DISCUSSION

The results obtained in these laboratory studies, field experiments and green house experiments are discussed .

Characteristics of human urine

Slight variation in the pH and EC values of urine collected from persons of vegetarian diet and non- vegetarian diet of different age group was observed (Table-3). The human urine was found to be slightly acidic to neutral in reaction. The pH ranged from 4.26 to 6.65 and 4.96 to 6. 81 respectively. The electrical conductivity ranged from 5.64 to 6 8.17 and 6.68 to 8.75 d Sm-1 for samples of < 20, 40 and >40 years age group respectively indicating that it has appreciable amount of salts.

Ecosan toilet for gents adopted in Bangalore

Ecosan toilet for women in Bangalore

Waterless urinal installed in a male toilet (urine collection)

Table-4 a: Effect of human urine (HU), cow urine (CU) and FYM + human urine on yield of crops during 2009-2010

Crop	RDF (Kg ha-1)	Quantity of human urine/cow urine required supply recommended dose of nitrogen		Fresh vegetable Yield(t ha-1)			
		HU(l ha-1)	CU(l ha-1)	Control	HU	CU	FYM + HU
French beans	63:100:75	33333	50000	1.19	3.99	2.41	4.87
Field bean	25:50:25	8333	12500	1.73	4.61	4.04	4.61
Tomato	250:250:250	83333	125000	16.6	28.3	27.6	29.6
Brinjal	125:100:50	41667	62500	9.2	32.5	29.8	33.6
Bhendi	125:750:63	41667	62500	7	13.2	12.3	13.7
Grain yield (t ha-1)							
Finger millet	100:50:50	33333	50000	2.11	3.78	3.22	6.17

Table-5: Effect of human urine (HU), cow urine (CU) and FYM + human urine on yield of crops during 2010-2011 and 2011-2012

Crop	RDF (Kg ha-1)	Quantity of human urine/cow urine required supply recommended dose of nitrogen			Grain/Seed Yield(t ha-1)			
		HU(l ha-1)	CU(l ha-1)	Control	RDF	HU	CU	FYM + HU
2010-2011								
Aerobic rice	100:50:50	33,333	50,000	1.12	2.58	2.63	1.92	2.74
Maize	150:75:40	50,000	75,000	3.89	6.69	6.82	6.55	6.89
Cowpea	25:50:75	8,333	12,500	0.74	1	1.02	0.98	1.03
Soybean	30:80:38	10,000	15,000	0.56	1.23	1.25	1.16	1.52
Field Bean	25:50:25	8,333	12,500	0.63	1.21	1.42	1.25	1.44
2011-2012								
Cluster Bean	25:75:60	8,333	12,500	5.64	6.65	6.74	6.54	6.88
Marigold (Flower Yield)	225:60:60	75,000	1,12,500	5.67	6.68	6.67	6.35	6.7

Ecosan toilet with Bamboo

Tamil Nadu model adopted in Trichy

China model

The human urine has appreciably higher concentration of all the nutrients elements required by crops. The concentration of nitrogen varied from 0.21 to 0.43 and 0.31 to 0.55 percent, phosphorus concentration varied from 0.11 to 0.26 and 0.13 to 0.30 percent and the potassium content varied from 0.12 to 0.23 and 0.12 to 0.25 percent for samples of < 20, 40 and >40 years age group respectively. In addition, the urine has substantial quantities of calcium, magnesium, sulphur and micronutrient elements. The sodium concentration varied from 0.12 to 0.34 years age group respectively.

The chemical composition of human urine collected from persons of different age group of non-vegetarian diet was slightly higher compared to urine from persons of vegetarian diet (Table 3).

Table 6: Effect of human urine, cattle urine FYM + HU on pH, and EC of soil at harvest stage of crop during (2009-2010 and 2010-2011)

Treatments	pH (1:2.5)			EC dSm-1		
	2010	2011	Mean	2010	2011	Mean
Fingermillet (2010) – Aerobic rice(2011)						
Control	6.7	6.72	6.71	0.15	0.15	0.15
CU	6.31	6.35	6.33	0.2	0.2	0.2
HU	6.38	6.4	6.39	0.29	0.29	0.29
FYM + HU	7.02	7.06	7.04	0.19	0.19	0.19
Standard deviation of Error mean	0.05	0.06		0.15		
CD(P = 0.05)	0.16	0.18		0.46		
Hebbal Avare (2010)-Finger millet (2011)						
Control	5.6	5.77	5.69	0.17	0.17	0.17
CU	6.43	6.62	6.53	0.21	0.21	0.21
HU	6.26	6.45	6.36	0.32	0.33	0.33
FYM + HU	6.43	6.62	6.53	0.25	0.24	0.25
Standard deviation of Error mean	0.14	0.01		0.05	0.02	
CD(P = 0.05)	0.42	0.04		0.16	0.06	
French beans (2010)-Maize (2011)						
Control	6.03	6.05	6.04	0.14	0.09	0.12
CU	6.12	6.12	6.12	0.18	0.17	0.18
HU	5.73	6.18	5.96	0.4	0.39	0.4
FYM + HU	6.15	6.25	6.2	0.16	0.13	0.15
Standard deviation of Error mean	0.16	0.14		0.12	0.1	
CD(P = 0.05)	0.49	0.47		0.35	0.35	
Tomato (2010)-Cowpea (2011)						
Control	5.89	5.92	5.91	0.94	0.95	0.95
CU	6	6.03	6.02	1.25	1.26	1.26
HU	6.21	6.28	6.25	1.35	1.36	1.36
FYM + HU	6.54	6.58	6.56	1.12	1.13	1.13
Standard deviation of Error mean	0.14	0.01		0.05	0.01	
CD(P = 0.05)	0.42	0.04		0.16	0.03	
Brinjal (2010) –Soybean (2011)						
Control	5.91	5.98	5.95	0.97	0.98	0.98
CU	6.1	6.13	6.12	1.25	1.27	1.26
HU	6.33	6.38	6.36	1.3	1.32	1.31
FYM + HU	6.64	6.73	6.69	1.16	1.17	1.17
Standard deviation of Error mean	0.15	0.16	0.05	0.06	0.07	
CD(P = 0.05)	0.44	0.47	0.16	0.18	0.2	
Bhendi (2010) - Hebbal avare (2011)						
Control	5.98	6.09	6.04	0.93	0.94	0.94
CU	6.08	6.19	6.14	1.2	1.21	1.21
HU	6.4	6.44	6.42	1.25	1.26	1.26
FYM + HU	6.64	6.69	6.67	1.18	1.2	1.19
Standard deviation of Error mean	0.15	0.03		0.06	0.01	
CD(P = 0.05)	0.46	0.06		0.17	0.03	
Note CD = critical difference						

On station field experiments

In the field experiment conducted at the University farm during 2009-10, the effect of human urine and cattle urine with and without FYM and gypsum was studied and the details are given below.

Effect on yield of crops

Significant difference in the yield of crops was recorded due to application of human urine and cow urine with and without FYM and gypsum. The yield of all the six crops was significantly highest in treatment receiving human urine + FYM followed by human urine alone and cattle urine alone. The yield of French bean crop was lowest in control (1.1qt./ha) while human urine + FYM treatment recorded highest yield (4.87t/ha) followed by human urine alone (Table 4). Human urine alone recorded significantly higher yield of crops compared to cattle urine alone thus indicating its superiority over cattle urine. This increase in yield might be due to ready supply of nitrogen and other nutrients which had a positive impact on overall improvement in crop growth, enabling the plant to absorb more nutrients which empowered the plant to synthesis more quantity of photosynthetic and accumulating them in reproductive parts. Similar type of results was supported by (Ganrot Z *et al* ., 2008).

During second year (2010-11), the cumulative effect human urine and cattle urine with and without FYM and gypsum was evaluated and compared with treatment receiving fertilizer alone. During third year also, a similar trend of results were obtained. Treatment receiving human urine + FYM recorded the highest yield of all the six crops. Human urine alone recorded slightly higher yield of all the crops compared to treatments receiving fertilizers. Yield of all the crops was appreciably higher due to human urine application compared to fertilizers, thus clearly indicating the fertilizer value of human urine (Table 5).

Table-5 Effect of human urine (HU), cow urine (CU) and FYM +

Maize

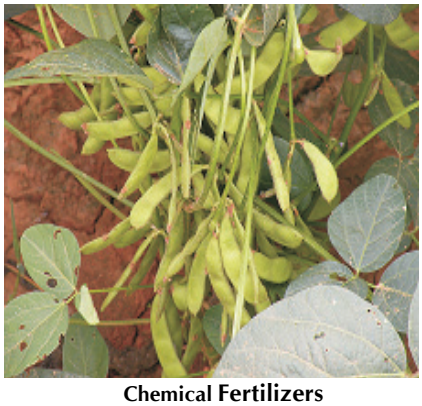
Control

Chemical Fertilizers

Human Urine + FYM

Soybean

Control



Chemical Fertilizers

Human Urine + FYM

human urine on yield of crops during 2010-2011 and 2011-2012

Effect on soil properties

There was positive impact of human/cattle urine application on soil properties. During 2009-10 and 2010-11, the pH and salt content of the soils after harvest of crops was found to be within the permissible limits (Table 6). This is attributed to the presence of higher quantity of salts in human urine which depends upon the individual intake diet of food.

Table-6 Effect of human urine, cattle urine FYM + HU on pH, and EC of soil at harvest stage of crop during (2009-2010 and 2010-2011)

Precaution of human urine use

Therefore, human urine may be used for agricultural production by maintaining the following precautions:

1. Human urine is generally free of pathogens (germs) when excreted by a healthy person. However, post excretion, cross-contamination, may occur. Therefore, urine should never be applied directly into the part of the plant to be harvested and crops should not be fertilized within a month before harvest followed by the test of possible contamination due to endocrine disruptors (WHO, 2010 & Guzha, E . 2004)

2. Spreading the urine at the wrong time or unevenly on the field can cause considerable crop failures.

3. Naturally, as with all other manures, hand washing after working with urine is strongly recommended (Palmquist, H. and Jonsson, H., 2007).

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