Utilising Human Urine as a Liquid Fertiliser in Agriculture. A Case Study of Brinjal (Aubergine) cultivation in India.

Abstract

On average, one person produces approximately 4.6 kilograms of nitrogen and 0.5 kilograms of phosphorus in their urine each year. Since urine is almost sterile it does not need to go through the rigorous sanitising required by faecal matter. In many cases diluted urine can be used directly on a farm or garden, but to better understand the nutrient values and the adaptability of its use, a more detailed research programme was carried out.

The results indicate that human urine performs better when used in combination with chemical fertiliser and is a viable alternative in Brinjal cultivation. The subject study was undertaken to evaluate human urine as a fertiliser in Brinjal (Aubergine) cultivation with cross comparisons made with chemical fertiliser and no fertiliser treatments.

This paper describes a field study carried out at Iyanthur village in the Cuddalore District of Tamil Nadu, India between February 2013 and June 2015 to determine the NPK (nitrogen, phosphorous, potassium) effect of human urine and chemical fertilisers on Brinjal (*Solanum melongena)* giving consideration to growth, yield, nutrient uptake and soil characteristics.

The research revolved around five treatments. Chemical fertiliser was mixed with two different dosages of urine, 50% (T2), 75% (T3) and one was simply 100% urine (T4). All the mixes were calculated to take account of the optimum NPK requirements of the plants. In addition there was one treatment of just chemical fertiliser (T1) and one treatment without any urine or chemical fertiliser.

The results revealed that application T3 (75% urine) gave significantly greater growth when compared to other treatments. These results included plant height (54.7cm in Season I, 50.3cm in Season II and 51.2cm in Season III), fruit weight (49.4g in Season I, 42.1g in season II and 40.1g in season III) and average fruit yield per harvest per plant (286.4g in Season I, 250.5g in Season II and 238.7g in season III). Yields dropped because the soil becomes compacted when using high concentrations of urine. One way to overcome this is to use compost derived from human waste as a soil conditioner and by doing this yields should remain constant.

The results in this trial indicate that human urine performs better when used in combination with chemical fertiliser and is a viable alternative in Brinjal cultivation.

The economic value of urine was also calculated by comparing the price of mineral fertiliser on the local market and the average economic value of human urine, resulting in a per litre value of circa 3.5 pence.

Using human urine in agriculture also reduces environmental pollution and the costs of cultivation due to heavy fossil fuel usage in chemical fertiliser production.

This field study was carried out jointly by Wherever the Need India Services (WTNIS) and Centre for Sustainable Development (CSD) in collaboration with the Agricultural Economics Department of Annamalai University, Chidambaram, India.

1. Introduction

India's population is projected to overtake that of China and reach 1.6 billion people by 2050. This population growth will bring with it an increased demand for water, food and energy (Lehane, S. 2014). Out of 194 million hectares of agricultural land in India, 8.5 million hectares was under vegetable cultivation in 2010-11 with the country producing 146.5 million tons of vegetables (Holmer et al., 2012). It is estimated the consumption of rice and wheat in India has been declining by between 1% and 2% per annum (for dietary reasons), whilst the demand for fruits and vegetables has been rising by 2% - 3% per annum (DNA, 2015).

Shifting to biological practices offers a wide range of opportunities for improving cultivation by benefiting soil, products and farmers.

Currently increased crop production in India largely relies on chemical fertilisers used to supplement essential nutrients for plants. According to the Department of Fertilisers (2013), the consumption of fertiliser during 2011-12 had increased by 23% as compared to 2006-07. The actual consumption of chemical fertilisers in India during 2012-13 was 492.4 thousand metric tonnes and the Government of India released INR 705,920 Million (circa £8 billion) as fertiliser subsidies in the same year (Parliament of India, 2013).

The impact of chemical fertiliser application on agricultural land needs to be seen not only in terms of the soil quality but also on the condition of soil organisms. Excessive use of chemical fertilisers and pesticides causes environmental pollution both at the manufacturing and application levels. Foods grown with chemical fertilisers can cause various deteriorating health hazards in animals as well as human beings. Indians consume about 40 times more pesticides through food than the average American (Kumari et al., 2014).

The utilisation of urine as a fertiliser indirectly reduces the impact of global warming. Researchers Brentrup and Pallière (2008) reported that nitrogen fertiliser production is responsible for large emissions of both carbon dioxide (CO_2) when produced using natural gas, and of nitrous oxide (N_2O) from nitric acid production that is a part of the nitrate production process. The use of phosphate rock for the production of chemical fertilisers is also of concern, as the economic reserves of phosphate rock is finite and likely to be depleted in the next 30-37 years (Cordell and White, 2011; USGS, 2013).

Various studies show that on an average, each year, one person's urine provides approximately 4.56 Kg of Nitrogen, 0.55 Kg of Phosphorous and 1.28 Kg of Potassium. All of these elements are vital for plant growth. The use of human urine in agriculture could potentially replace a large amount of commercial chemical fertilisers. The urine from normal, healthy people is virtually free of any disease carrying germs (or pathogens). It contains the majority of nutrients that are excreted by the body, although its composition varies depending on diet, gender, climate, water intake, etc.

Most essential plant nutrients can be found in human urine, roughly 80% of the Nitrogen, 60% of the Potassium and 55% of the Phosphorus of the average requirement (Pettersson 1995, Claesson and Steineck 1996, RICHERT et al., 2010). Based on a recent study (GENSCH et al., 2011), this suggestion is actually born out by the actual 'agreed' average nutrient content per person/year being 2.18 kg of Nitrogen, 0.20 kg of Phosphorus and 0.87 kg of Potassium.

Due to its high nutrient content and its low and manageable health risks, urine can be used almost immediately as a liquid fertiliser. It is fast acting making it an easy replacement for synthetic fertilisers. In Sweden (2012), statistics showed that the nutrient content, before natural evaporation creates small losses in urine and faeces excreted by the local population was the equivalent of 28% of the total nitrogen and 44% of the total phosphorus of all chemical fertilisers sold in Sweden between 2010 and 2011.

The nitrogen in urine consists mainly of ammonium and has 85-100% of the nitrogen needed by a plant (Jonsson et al., 2000; Spangberg et al., 2014). Phosphorus in urine is provided mainly in the form of phosphate ions and is as available to plants as soluble phosphorus fertilisers (Kirchmann and Pettersson, 1995). The nitrogen (N), phosphorus (P), and potassium (K) values in the urine used for the present study is 0.2875 %, 0.2890 % and 0.81%, respectively.

With consideration to the above, this study investigates the potential of urine as a liquid fertiliser in agricultural production under Indian growing conditions. The study sought to determine urine productivity rates for Brinjal cultivation and compares it to applications of no fertiliser and conventional chemical fertiliser.

2. Methodology

The Research was conducted at the Iyanthur village located in Kundiyamallore Panchayat, Kurinchipadi Block in Cuddalore District, Tamil Nadu from February 2012-June 2015.

2.1 Experimental details

A randomised block design (5 x 5 factorial) was used for the experiment. The total plot size was 11.4 m x 20.4 m and each experimental unit was 6.80 m x 6.80 m consisting of seven rows of 88 plants. The planting distance was 0.75 m x 0.6 m. Overall five treatment combinations were used and each treatment was replicated five times. Treatments were randomly arranged in each replication and were divided into twenty-five plots.





Urine was applied with chemical fertiliser in three different dosages of 50% (T2), 75% (T3), and 100% (T4) of the calculated optimum N-requirements of the plants. One application was given with 100% chemical fertiliser (T1) using the manufacturer's recommended dosage. This served as the positive control. Finally one plot was grown without the use of either urine or chemical fertiliser (T5). This served as the negative control. The detailed ratio is given in Table 1.

Table.1 Treatment ratios and application rates

Treatment	Composition
T1	Application with 100% of chemical fertiliser RDI (Recommended Dosage Input)
T2	Application of 50% chemical fertiliser RDI and 50% urine, corresponding to the calculated optimum NPK requirements of the plant.
T3	Application of 25% chemical fertiliser RDI and 75% urine, corresponding to the calculated optimum NPK requirements of the plant.
T4	Application of 100 % urine, corresponding to the calculated optimum NPK requirements of the plant.
Control T5	Control plot with no urine/chemical fertiliser application

The NPK (nitrogen, phosphorous and potassium) contents of the urine were tested in the laboratory and the results determined the quantity of urine to be used. All treatments therefore contained the same amount of NPK. All plants were selected to record yield contributing characters. The chemical fertiliser and urine used for different treatments in this study was recommended by Tamil Nadu Agriculture University (Table 2).

Table 2. Chemical fertiliser and urine used for the treatments

Treatments	Urea (g)	Superphosphate (g)	Potash (g)	Urine (l)
T1	2850	2500	330	Nil
T2	1425	2415	290	168.75
T3	710	2375	265	284.75
T4	0	2330	240	284.75
T5	0	nil	nil	Nil
Total	4985	9620	1125	738.25

The areas for observation included: (a) Changes to the physical and chemical properties of the soil (b) Growth components: plant height, number of leaves, leaf area/canopy, root length and the dry weight of the root (c) Yield components: average weight of harvested Brinjal per hectare, (d) Quality of Brinjal: Length and diameter, e) The economic value of human urine.

2.2 Fertiliser Treatments

Both the chemical and urine fertilised plots were treated according to the recommendations suggested by Tamil Nadu Agriculture University. The suggested quantity of urine was dripped close to the plant at a distance of approximately 30 cm. The soil surface was tilled before and after application of the urine fertiliser so that the liquid could be better absorbed.

All treatments were made on the soil's sub-surface. A month after applying the treatments they were repeated at the same rate as described above. Urine, collected from local schools, was stored in a well-calibrated container and stirred to avoid any settlement before application. The chemical characteristics of the urine and chemical fertiliser were determined before application. The urine mix was applied through a drip system with holes 30 cm away from the plants and 1-4 cm deep. The holes were covered immediately with soil as described by Heinonen-Tanski and Wijk-Sijbesma (2005). This simple practice mimics the successful injection technique used by Richert Stintzing *et al.* (2002) and avoids ammonia losses. The soil was slightly watered before the urine was applied late in the evening to avoid volatilisation. Brinjal seedlings were grown in a nursery during the first week of February 2013 and transplanted to the field in the third week of the month. At transplanting, seedling height and the number of leaves were recorded. This was to ensure that the transplanted seedlings had some level of conformity. Watering, weeding, pest and disease control with an IPM (integrated pest management) system was carried out as and when necessary. Soil samples were collected before and immediately after harvest, air-dried, sieved and analysed for pH, EC (earthworm count), and NPK. Harvested plants were oven dried at 70°C for two weeks, and milled before analysis. The data collected was subject to statistical analysis using ANOVA (analysis of variance) and means separated by the LSD (Least Significant Difference).

Brinjal plants being watered, fertilised with urine and measured as part of the field trials

2.3 Urine Collection and Hygiene

The urine used in this study was collected from a nearby school at an average of 75 litres per day. The urine was transported to the test field and stored in a 1,000 litre tank. Chemical analysis of this urine was carried out at a laboratory in the Department of Agriculture, Annamali University, Chidambaram. The stored urine was analyzed for microbiological properties. The detailed concentration of urine is given in Table 3.

Table 3. Nutrient analysis of urine used for Brinjal cultivation

Parameters	Quantity
pH	7.3
Total Nitrogen (%)	0.2875
Phosphorous (%)	0.2890
Potassium (%)	0.81
Ammonical N (%)	0.810
Manganese (ppm)	251.8
Iron (ppm)	3941.4
Zinc (ppm)	172.5
Coliforms (cfu/g)	ldl
E.coli (cfu/g)	ldl
Mould Count (cfu/g)	30000
S.aureus (cfu/g)	<10
Salmonella spp (cfu/g)	ldl
Shigella spp (cfu/g)	ldl

Yeast Count (cfu/g)	50000
ldl - less than detection limit	

2.4 Population of earthworms

Earthworms are the engineers of the soil; they create burrows through which oxygen and water can enter and carbon dioxide can leave. They also help dispose of dead organic matter. A healthy earthworm presence indicates a healthy soil.

Earthworms were enumerated manually. Monthly population counts were undertaken on all the experimental plots. The work was carried out on 5th to 10th of every month with sampling beginning at 6.30 am. The density of population of earthworms was measured by the quadrate random sampling method used in 50cm x 50cm sections. A cow dung slurry with jaggery (palm sugar) (1:0.5 w/w, with water, was prepared, sprayed on the quadrate marked site, covered with jute bags and left overnight undisturbed. The next day in the early morning the topsoil was dug to a depth of 20cm and the number of worms were manually counted from the excavated soil in each quadrate and expressed as number of worms/cm2. The number of worms extracted per site was plotted against the number of sites surveyed.

2.5 Climate and Irrigation

The climatic parameters were recorded at a meteorological observatory at a distance of 16km from the experimental field. The precipitation during the study period was 407.15 mm, 430.3 mm and 478 mm in February to August 2013, February to July 2014 and February to July 2015 respectively. The experimental site was characterized as semi-arid zone with Annual mean rainfall of 1,125 mm. No irrigation was given on rainy days. The average temperature was 24.4°C - 34.2°C, 24.3°C - 33.8°C and 20.4°C - 37.4° in the above mentioned study period.

3. Results and discussion

3.1 Urine Quality.

The smell of the urine used was mild. Very few indicator microorganisms were detected in the hygiene analysis of the urine. The physical and chemical parameters of the urine are given in Table 3. It was observed that the application of pure urine or if combined with chemical fertiliser produced considerable influence on the vegetative growth of the crop.

3.2 Plant growth characters

The effects of treatments on Brinjal growth characteristics including height, branches and total leaf area per plant, were observed at different stages in the study period with the results set out in the Table 4. Plant growth characteristics were measured every two weeks after transplanting. At week 0 (after transplanting), all plants were virtually the same height, ranging from 5.4 cm to 6.1 cm.

A significant difference in plant height was observed throughout the plant growing stages with the different ratios of RDI (recommended daily intake) and urine application. The plants fertilised with 75% human urine and 25% RDI [T3] showed a greater plant height of 54.7 cm. The other treatments produced the following results: 100% RDI [T1] (50.3 cm), 50% RDI and

50% human urine (47.2 cm)[T2], 100% human urine (41.5 cm)[T4] and the no additive control (46.3cm)[T5].

Similarly, the plants fertilised with 75% human urine and 25% RDI [T3] produced the highest number of branches per plant (21.3). The lowest number of branches per plant (15.4) was obtained from the control plot [no additives][T5]. Interestingly, the 75%/25% [T3] treatment also showed the largest total leaf area per plant (2,865cm^2). See Table 4.

Table.4 Effect of treatments and their combinations on growth and morphological characters of Brinjal, 2013-2015.

Treatments	Plant height (cm)			Number of branches per plant			Total leaf area per plant (cm2)		
	Season 1 (2013)	Season 2 (2014)	Season 3 (2015)	Season 1 (2013)	Season 2 (2014)	Season 3 (2015)	Season 1 (2013)	Season 2 (2014)	Season 3 (2015)
T1	50. 3	49.6	43.8	18.7	16.3	12.2	2544	2293	2024
T2	47.2	41.5	39.6	17.5	18.1	15.1	2345	2271	2023
T3	54.7	50.3	51.2	21.3	22.4	20.1	2865	2564	2327
T4	41.5	39.2	34.7	16.9	12.3	9.7	2305	2117	2004
Control T5	46.3	34.5	29.8	15.4	11.7	8.6	2162	2040	2040
Average	47.4	43.0	39.8	18.0	16.2	13.1	2444.2	2257.0	2083.6
STDV	5.5	6.8	8.2	2.2	4.4	4.6	272.0	201.5	136.7

3.3 Brinjal Yield

The various treatments produced significant variations in the average fruit weight, number of fruits and yield per plot. Considerable differences were also observed among the five treatments on the overall average yield, which can be attributed to the urine and chemical fertiliser input. From the three investigated urine treatment groups, in most cases the 75% urine and 25% chemical fertiliser [T3] showed significantly better results in terms of average marketable yield .The plots with 100% urine application [T4] alone gave the lowest weight of the three groups. See Table 5.

The highest number of fruits per plant were observed from plants treated with 75% urine 25% chemical fertiliser [T3](9 in Season I, 7 in Season II and 7 in season III) followed by 100% RDI [T1](5 in seasons I and II with 4 in season III) then 50% urine 50% RDI [T2](4 in season I and 3 in seasons II and III). The lowest quantity of fruit per plant was observed in 100% urine application [T4](3 in seasons I and III and 5 in season II). See Table 5.

Compared to the control plot, all treatments showed a significant difference in yield. The 75% urine and 25% chemical fertiliser [T3] application was the best performing treatment in all seasons, with a higher mean yield than the control plot [T5] of more than 25.9%, 22.2% and 13.2% in seasons I, II and III respectively. The 100% urine plot [T4] produced 118.4g in season I, 150.6g in season II and 101.7g in season III, as compared to the chemical fertiliser treatment [T1].

The results set out in Table 5, using urine as an alternative to chemical fertiliser is likely to increase Brinjal yields significantly. However, it should be noted that the 50% urine [T2] added plot produced 166.2 g in Season I, 144.4g in season II, 134.5g in season III showing lower yields in plots that had this particular application. This result highlights that all mixes of urine do not outperform chemical fertilisers, although as Table 4 shows urine can still be a valuable liquid nutrient source and a potential synthetic fertiliser substitute in agricultural production.

Table.5: Yield and yield attributing characters of Brinjal in 2013-2015.

Treatments	Fruit length (cm)			Fruit diameter (cm)			Fruit weight (g)			Fruit yield/per plant (g)		
	Season 1 (2013)	Season 2 (2014)	Season 3 (2015)	Season 1 (2013)	Season 2 (2014)	Season 3 (2015)	Season 1 (2013)	Season 2 (2014)	Season 3 (2015)	Season 1 (2013)	Season 2 (2014)	Season 3 (2015)
T1	9.1	9.0	7.0	3.8	2.3	4.1	44.6	36.5	38.6	223.0	180.4	201.0
T2	8.8	5.0	6.0	2.6	3.1	2.4	41.5	41.8	32.4	166.2	144.4	134.5
T3	10.9	10.0	10.0	4.5	4.2	4.1	49.4	42.1	40.1	286.4	250.5	248.7
T4	6.9	9.0	5.0	2.1	2.5	2.2	39.6	40.0	38.4	118.4	150.6	101.7
Control	7.4	7.0	7.0	2.9	2.3	2.9	40.2	31.4	37.2	220.8	200.5	209.2
Average	8.6	8.0	6.6	3.2	2.7	3.0	43.1	38.4	37.3	203.0	185.3	177.0
STDV(±)	1.6	2.0	1.1	1.0	1.1	0.8	4.0	4.5	2.9	63.6	43.0	56.8

3.4 Insect and Mite Pests

Pests in general were not a major problem and, whenever noticed, an Integrated Pest Management (IPM) strategy was followed. Whitefly (*Bemisia tabaci* Gennadius), Fruit and Shoot Borer (Leucinodes orbonalis Guenee), Thrips (*Thrips palmi* Karny) are common in the region and Aphid (*Aphis gossypii* Glover) and Leafhopper (*Amrasca devastans* Distant) were also indentified. Yellow sticky traps were used to attract whitefly, leafhoppers and blue sticky traps whenever a pest appeared.

3.5 Economic Value of Urine

The urine fraction contains an average of 80% of the nitrogen, 55% of the phosphorus, and 60% of the potassium from one person in a year (Richert et. al. 2010). Most of the nitrogen in human urine is in a liquid form is suitable for plants, for example ammonia nitrogen (Kirchmann and Pettersson 1995, Claesson and Steineck 1996).

Table.6 Amount of nutrients urine excreted by one person in one year.

Source	Nitrogen		Phosphorus		Potassium	
	kg/person /year	%	kg/person /year	%	kg/person /year	%
Drangert (1998)	4	88	0.4	67	0.9	71
Magid et al. (2006)	4	91	0.55	75	0.91	71
Vinneras et al. (2006)	4	88	0.36	67	1	73

The nutrients contained in urine are an excellent and readily available source of crop fertiliser, but the transport and storage of large volumes of urine makes it difficult to use. It should be noted that the value of urine is directly related to the ease with which it can be stored and distributed.

The monetary value of nutrients in urine can be calculated by determining the chemical fertiliser equivalent of the basic macronutrients, including NPK, with those present in locally available chemical fertilisers.

Urea is a nitrogen-based fertiliser, the value of which is 290 INR for a 50 kgs bag (2013 market rate). This means that one kilogram of urea is worth 5.8 INR. However, in a 50 kgs bag only 46% by weight is nitrogen, the rest being a filler compound. It can therefore be calculated that the price of 23 kgs of nitrogen is 290 INR and one kg 12.60 INR (Indian Rupees).

Similarly, the current market rate for a 50 kgs superphosphate (P) bag is 360 INR. The bag actually contains only 50% phosphorus with the balance being a filler compound. The actual cost of phosphorus per kg is therefore 14.40 INR.

The current market value of potash is 800 INR for a 50 kgs bag that only contains 16% potash, with the balance being a filler compound. The true value of potash is therefore 100 INR per kg.

Considering one person flushes out annually about 500 liters of urine, which contain 4 kgs of N, 0.44 kgs of P and 0.94 kg of K, the actual market price of these nutrients can be calculated as follows:

Available N – 4 Kgs @ 12.60 = 50.40 INR

Available P – 0.44 Kg @ 14.40 = 6.35 INR

Available K – 0.94 Kg @ 100.00 = 94.00 INR

The total value of the macronutrients (NPK) available from one person's annual urine output is 150.75 INR (circa £1.75 or 3.5p per litre).

3.6 Changes in physical and chemical properties of the soil

Chemical analysis of the physical soil properties in the treatment area showed a change before and after the applications of the various combinations of fertiliser. There was a positive impact after the application of human urine. During the entire study period, the pH and salt content of the soils after harvest was found to be within the permissible limits of the Department of Agriculture. See Table 7. The available NPK content of the soil was increased appreciably in treatments receiving human urine when compared to the soil fertility before treatment. The treatment receiving 75% urine and 25% fertiliser [T3] recorded higher values of nitrogen, phosphorus and potassium when compared to other treatments. The results can be seen in Table 7.

Table.7 Result of soil analysis before and after treatment

Parameters	Before Treatment	After treatment				
		T1	T2	T3	T4	Control
pH	5.98	6.1	6.33	6.76	6.08	5.91
EC μScm^{-1}	0.93	1.25	1.3	1.16	1.26	0.97
C/N Ratio	253.9	268	297.9	302.8	361.4	199.6
Nitrogen as N (kgha^{-1})	200	270.5	334.8	349.2	271	226.9
Phosphorous as P (kgha^{-1})	22.5	23.5	25.3	27.1	21.2	20.1
Potassium as K (kgha^{-1})	245.3	224.0	284.3	316.2	200.6	210.5

3.7 Estimates of earthworm population and biomass

Estimates of the earthworm population was carried out in the cultivated Brinjal plots during the first season of February-July 2013 and the resultant data is set out in Table 8. It showed that the population of earthworms varied greatly in different plots. The earthworm *including Lampito mauritii, Perionix excavatus* and *Eudrillus euginea* are the most common species in the study area. The population structure constituted juveniles, immature worms and adults. The adults and immature worms were a larger percentage of the earthworm population throughout study period.

Table 8. Population and biomass of earthworms in different treatment plots

Treatments	Juvenile	Immature	Adult	Total Number	Total wt in g
T1	2±0.6	2.1±0.4	1.3±0.1	5.4±0.1	5.60±0.5
T2	1.45±0.2	1.3±0.2	1±0.2	3.8±0.3	4.25±0.7
T3	3±0.6	3.6±0.7	2.3±0.6	8.9±2.1	11.60±2.0
T4	1±0.2	1.8±0.2	1.3±0.2	4.1±1.3	5.60±1.5
Control	1.2±0.3	2.2±0.3	1.5±0.3	4.9±1.6	6.80±1.6

The research reveals as shown in Table 8 that adding chemical fertiliser to soil has a negative effect on earthworms.

It is observed from the Table that the presence of earthworms was quite high in the 75% urine 25% chemical fertiliser (T3) (8.9±2.1) when compared to the other plots and the biomass of the earthworms was also prominent in T3 (11.60±2.0) followed by the control plot [T5]. In addition the total earthworm population in T3 were found to be 58% higher than the control site [T5].

The higher earthworm population in the 75% urine 25% chemical fertiliser [T3] treated plot is attributed to the more favourable soil conditions, ambient temperature and moisture. Other plots were more compacted creating less than optimum conditions for earthworm presence. When compared to the other urine and chemically treated plots, T3 provided good surface and topsoil environmental characteristics and thus created a more favourable microhabitat for soil organisms. Earthworm populations are sensitive to change in pH, as they prefer a neutral reactive condition, the earthworm find difficult to survive if the pH falls below 6 and thus they migrate or are killed (Agarwal, 2005; Gajalakshmi and Abbasi, 2004).

4. Conclusion

The results of this study indicate that human urine performs better when used in combination with chemical fertiliser. This experiment also demonstrated that the use of urine as a fertiliser sustained soil fertility and is an efficient, low-cost and low-risk practice. The treatment plot that received 75% urine with 25% of chemical fertiliser [T3] performed best and gave the highest yield even when compared to the 100% chemical fertiliser treatment [T1].

The study also provides valuable insights into the effective use of human urine for crop production clearly showing it as a way to increase crop yields and reduce the use of chemical fertilisers thereby reducing environmental pollution released during the manufacture and transportation of chemical fertiliser.

In addition the micronutrients available in urine can help secure better growth and yield with the 75%/25% RDI [T3], thus considerably reducing the cultivation cost. Also observed over the three year period, probably due to the necessary micronutrients being available to the plants, was a negligible level of pest attack.

No pesticides were used, further reducing the cost of cultivation and improved fruit quality. The cultivation was close to being fully organic.

The 'tasters' who tested the Brinjal from the site were unable to notice any difference in taste when compared with Brinjal bought from an organic farm.

The study highlights and supports the argument that urine fertilisation is a viable strategy to enrich soils. Based on the principles of effective use of resource, nutrient recycling and low-cost agriculture, farmers should consider urine utilisation as an integral part of agricultural practices and management.

Recognising human urine as a potential source of plant nutrient and using it in farming is a sensitive cultural issue in India. To overcome this, further research in the cultivation of other crops will help improve the acceptance of the effective utilisation of human waste in agriculture. Going forward, additional research should be carried out on the use of human urine on a wide range of crops in different locations in India to study their long-term effects on soil, environment, and crop productivity.

The current study has clearly shown that the use of human compost as a replacement to chemical fertiliser is a genuine possibility. To maximise yield and maintain soil condition, there needs to be a reduction in chemical fertiliser and an increase in the use of human waste. It is likely that each crop will thrive on different mixes of waste and chemical fertiliser. In addition certain plants will require other natural additives to thrive. For example, roses like calcium so by adding eggshells to fertiliser a bespoke compost for roses can be created.

It is clear to the researchers that chemical fertilisers whilst boosting productivity also denude the soil resulting in each year greater quantities of fertiliser being necessary. By using human waste in combination with or without chemical fertilisers it is possible to maintain soil condition and still improve yields. By isolating specific additives for particular plants it is the researchers belief that one could create fertilisers free of all chemicals that would compete with chemical fertilisers on a yield basis and at the same time maintain or even improve soil condition. The continuing use of chemical fertilisers will potentially lead to more desertification and dustbowls. The potential of human waste to reverse this situation is very possible. This natural fertiliser is environmentally friendly and readily available for minimum cost. In addition, of course, by using processed human waste as a fertiliser you remove the massive health problems posed by 550 million people openly defecating daily in India alone. The World Bank estimates the cost of open defecation in India is $50 billion per annum. The opportunity to remove this cost and improve agricultural production is both real and possible.

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