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Short Communication

Pure human urine is a good fertiliser for cucumbers

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Abstract

Human urine obtained from separating toilets was tested as a fertiliser for cultivation of outdoor cucumber (*Cucumis sativus* L.) in a Nordic climate. The urine used contained high amounts of nitrogen with some phosphorus and potassium, but numbers of enteric microorganisms were low even though urine had not been preserved before sampling. The cucumber yield after urine fertilisation was similar or slightly better than the yield obtained from control rows fertilised with commercial mineral fertiliser. None of the cucumbers contained any enteric microorganisms (coliforms, enterococci, coliphages and clostridia). In the taste assessment, 11 out of 20 persons could recognise which cucumber of three cucumbers was different but they did not prefer one over the other cucumber samples, since all of them were assessed as equally good.

Keywords: Edible plants; Home garden; Nitrogen; Soil organic matter; Phosphorus; Tropical climate; Vegetable production; Water saving

1. Introduction

Human urine is a natural resource, which is available in all human societies—even in the poorest ones. Urine is rich in plant nutrients, since the human kidney is the main excretion organ and thus urine contains most of the nutrients present in human food which have not been utilised for new cell growth or energy consumption. The chemical composition of human urine depends on time of day, diet, climate, physical activity and body size (Sullivan and Grantham, 1982). Urea is the main nitrogen component present in human urine. Urea fertiliser production has developed during the last decades so that urea is one of the most important industrial nitrogen fertilisers (Granelli, 1995) and new urea–ammonia fertiliser plants have been built recently, for instance in India (Bhatt, 1998).

When urine becomes mixed with faeces, this mixture is much more difficult to handle hygienically outside of wastewater treatment plants. To overcome this problem, urine separating toilets have been introduced. They are an interesting alternative for houses on islands in the Baltic archipelagos, which are rather isolated and environmentally fragile, with cold climate and shortage of fresh water; also, the valuable shoreline is not suitable for construction of wastewater treatment plants due to many sailing harbours. The shortage of fresh water increases the incentive to select a separating toilet, which typically uses no or 100–200 ml water per toilet visit. The separating toilets in private homes and public sites have led to a new problem: how to utilise human urine for plant cultivation.

Urine which has been collected in urine and faeces separating toilets has been used successfully for cultivating barley (Richert Stintzing et al., 2002). If the amounts of nutrients are correct, urine could totally replace commercial fertiliser, as equal cereal yields are obtained with urine as with ‘normal’ fertiliser methods. Since barley and other cereals are not cultivated in home plots there should be more knowledge about the use of urine in cultivation plants in home gardens. Cucumbers were selected for this work since they and related plant species are very common and

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cultivated in home gardens throughout the world. The other reason to select cucumbers was the fact that these plants might be sensitive to microbial contamination, i.e. cucumbers have been found to be contaminated with faecal microorganisms when fertilised with composted cattle manure in a greenhouse experiment on organic farming (Holopainen et al., 2002), and cucumbers are often eaten raw without cooking.

2. Methods

The urine formed in a kindergarten, in a cafe and in private houses for a period of several months prior to the collection time was taken for microbiological hygiene and chemical nutrient analyses. Coliphages were determined by using hosts *Escherichia coli* ATCC 13706 for somatic phages and *E. coli* ATCC 15597 for RNA-phages according to the ISO (1998) method, faecal coliforms on mFC-agar (SFS 4088, 1984) at 44 °C, enterococci on Slanetz-Bartley agar confirmed on bile-esculine agar and catalase (SFS-EN ISO 7899-2, 2000) and clostridia on sulphite-iron agar after heat treatment and anaerobic incubation (ISO 6461-2, 1986). Dry matter was determined according to SFS 3008 (1990), total phosphorus with Lachat QuickChem method 10-115-01, total nitrogen with SFS 5505 (1988) and potassium with SFS 3044 (1980).

The cultivation test was done in a cowork with a private farmer in Kimito (60°10′N 22°24′E). The study soil was clay loam but no soil analysis data is available. Cucumbers (*Cucumis sativus* L.) variety Adam (Bejo zaden) were seeded in a greenhouse and the young seedlings were planted outdoors on 3rd June as is common practice in the Nordic countries in order to get a longer growth period avoiding night frosts. The seedlings were planted into banks so that seedlings were in two rows in zig-form with distances of 40 cm between each seedling. The banks were 1 m wide and 72 m long and situated side by side. Both rows of one bank were fertilised with urine (urine D, Tables 1 and 2) provided as three doses 10, 30 and 40 days after planting, giving a total of 9.7 l/m^2. Both rows of the next bank were used as control and fertilised with commercial mineral liquid fertiliser (NPK 6-5-26) provided as two doses 10 and 30 days after planting, total 57.1 g/m^2, as recommended by the manufacturer. Both fertilisers were given via underground irrigation pipes. Due to the different nutrient balances of the two fertilisers, the nitrogen fertilisations varied such that the urine rows received 23.3 g N/m^2 and the control rows 3.4 g N/m^2. The phosphorus and potassium fertilisations were 1.5 and 2.9 g P/m^2 and 5.7 and 14.8 g K/m^2 for urine and control mineral rows, respectively. Both cucumber row types were irrigated when needed.

Cucumbers reaching a length of 10 cm were harvested separately in each row from 3rd August to 1st September two or three times a week and the yields were weighed. The main yield was analysed for its microbiological hygiene by running the same tests as for urine. The taste of the cucumbers was assessed by a panel of 20 persons, whose ability to separate basic tastes (sour, sweet, salty and bitter) had been tested previously. The panel persons sitting in a test kitchen were given three fresh cucumber samples marked with blind code numbers, with one or two cucumber samples fertilised with urine and the other one or two with mineral fertiliser. The tasters had to determine which sample was different. They could also write their evaluation, especially if they wished to state a preference for one particular or two similar cucumbers. The tasters could drink water between tests and taste again without any time limitations. They could also utilise the possible differences in form or colour of cucumbers as the evaluation was done in full daylight. The test and the analysis of results have been described ivn detail by Holopainen et al. (2002).

Table 2
Main nutrients in two urine samples

Nutrient	Amount (g/l)	
	Private household D	Private household E
Dry matter	4.7	10.4
Total phosphorus	0.15	0.23
Total nitrogen	2.4	3.1
Ammonium nitrogen	2.3	2.9
Potassium	0.59	1.7

Urine D was used in cultivation trials.

Table 1
The numbers of some faecal microorganisms in separated urine samples (only one combined sample from each) as plaque forming unit/ml or colony forming units/ml, for coliphages and bacteria, respectively

Origin of urine	Coliphages host *Escherichia coli* ATCC 13706	Coliphages host *Escherichia coli* ATCC 15597	Faecal coliforms	Enterococci	Sulphite reducing clostridia
Kindergarten	13	3	170	70	33
Cafe	630	Ldl	Ldl	Ldl	Ldl
Private household A	Ldl	Ldl	Ldl	16,000	Ldl
Private household B	Ldl	Ldl	Ldl	40	14
Private household C	Ldl	Ldl	Ldl	Ldl	Ldl
Mixture of A, B and C	420	2	1	2700	20
Private household D	Nd	Nd	Ldl	>850	Nd
Private household E	Nd	Nd	2	>1000	Nd

Ldl = less than detection limit (1/ml). Nd = not determined. Samples D and E were taken in early summer, the others in early spring.

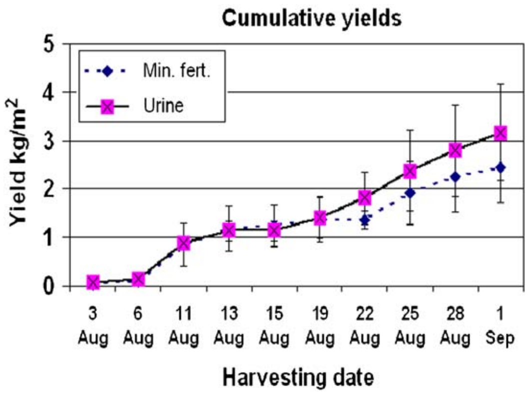

Fig. 1. Cumulative cucumber yields kg/m^2 using urine or mineral fertilisation ($N = 2$).

3. Results

Both fertilisations could be undertaken without any clogging problems. Only a few seedlings died during the cultivation time. Immediately following irrigation with urine a slight smell of urine could be detected but it dissipated rapidly.

The hygienic quality of some urine items is presented in Table 1. The nutrient levels of two urine samples are described in Table 2.

The growth of all cucumbers with both fertilisations was normal. The cumulative yields are presented in Fig. 1. The differences in yields between any two harvesting dates were statistically non-significant, but if the cumulative harvest means of both fertilisations are compared over the whole harvesting time by paired t-test, the urine fertilised yields were statistically slightly higher ($p < 0.05$ in paired t-test).

The hygienic quality of both cucumber samples was approved; somatic coliphage, RNA-coliphage, enterococcus, faecal coliform or faecal clostridium were not detected in any of the cucumber samples (detection limits 10 microorganisms/g fresh cucumber).

In the taste assessment test 11/20 persons could differentiate between the cucumbers, this difference being statistically significant ($p < 0.05$). The tasters did not prefer any particular cucumber samples and all the cucumbers were evaluated as being good-tasting and good-looking with nice texture.

4. Discussion

The results show clearly that recently formed urine could serve as a valuable fertiliser for cucumbers, and these vegetables could be eaten without cooking or used for fermentation. The preservation of fresh urine may not be necessary, especially in tropical developing countries, where the heat may reduce the survival of enteric microorganisms and it would be very difficult to store urine in small home plots even though storage for six months is recommended in Sweden (Jönsson et al., 1997). Anyhow, the bottom sediment of the present work contained more enteric microorganisms as found in the mixture sample and possibly some precipitate of ammonium magnesium phosphate and uric acid (not analysed) or other components with low water solubility. It is possible that the bottom sediment in our experiment contained particles, which protected enteric microorganisms and thus the numbers of coliphages and faecal coliforms were under the detection limit in the liquid phases of urines A, B and C, but the mixing of sediments had loosen the particles with microorganisms so that the detection limit was exceeded in mixture of urines.

Urine could replace the commercial fertiliser and it could be used in soils having excessively high phosphorus content. Urine fertilisation could also be supplemented with ash to improve its phosphorus and potassium contents.

In the present study the cucumbers fertilised with the "standard" mineral fertiliser as control might have suffered from a shortage of nitrogen, limiting its ultimate yield. The urine fertiliser guaranteed a better yield by providing more nitrogen in the later phases of growth, although the residual nitrogen in soil was not tested.

Unfortunately the nitrate levels of cucumbers could not be studied, since cucumber can accumulate nitrate (Dich et al., 1996), but it is known that the accumulation intensity depends on fertilisation (Holopainen et al., 2002). Cucumbers and related plants (such as pumpkins, loofahs, melons, watermelons, gourds and squashes) are rather common in many tropical developing countries, so the results of the trial could be adapted to many locations in home gardens. It is assumed that the same would be true with many other plant families, too.

If human urine with good microbiological quality could be utilised for plant production, millions people living in the tropics or semitropics including the poor or the poorest of the poor (as they are called in Bangladesh) could increase yields of edible and non-edible plants cultivated in small plots or even in pots. Furthermore, the sanitation treatment of solid, dry human faeces would be a much easier process, since it would be more aerobic and the amount of human faeces is low compared to the amount of urine. The amounts of urine needed could be somewhat different to the amounts studied here since many tropical plants with vigorous growth may have different nutrient requirements. Plants growing in tropical poor sand soil with very low organic matter, e.g. the soils found around the coasts of the Arabian Sea in India or Sri Lanka, may require more nitrogen than plants growing in a semiarctic climate in more organic soils. The frequent floods caused by heavy monsoon rains, high tides, cyclones or other reasons may extract the nitrate from the soil so that supplementation with new nitrogen may be necessary after floods.

The chemical composition of human urine has been analysed in Western industrial countries and the results have been published, for instance by Ciba Geigy (1977). However, it can be assumed that the nitrogen content of human urine in most developing countries may be lower than the values presented by Ciba Geigy, e.g. a more vegetarian diet contains less protein than the mixed diet of most inhabitants in industrial countries as shown by Schouw et al. (2002) in one Thai village. The urine from individuals in tropical developing countries may be more concentrated if the amount of drinking water is limited and sweating is high, particularly if the individual does heavy work in a hot climate. Increased sweating increases the dermal nitrogen excretion and thus it decreases the renal nitrogen excretion to urine (Huang et al., 1975; Takahashi et al., 1985). Also, the typically smaller size of South Asian people compared to Europeans may have its effect on the amount of urine forming daily. Thus, if use of urine is planned for fertilisation of vegetables or fruits, the urine nutrient values of Schouw et al. (2002) can be used if there are no analyses.

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