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Use of compost supplemented human urine in sweet pepper (*Capsicum annuum* L.) production

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ABSTRACT

Human urine, rich in plant nutrients, is a readily available fertilizer but limited information is available about the best use of human urine in crop production. A field experiment was carried out in Kathmandu, Nepal during the year 2011 to evaluate the fertilizer value of human urine in different combination and compare the value with compost, urea and their combinations based on plant performance. The experiment was laid out in Randomized complete block design (RCBD) consisting of eight treatments with three replications. Each treatment was fixed to a supply of 100 kg N ha^{-1}. California Wonder, a popular open pollinated sweet pepper (*Capsicum annuum L.*) variety was selected as an experimental crop. The highest plant height (54.7 cm), number of fruits per plant (9.1), and fruit yield per plant (553.9 g plant^{-1}) were recorded with the plants fertilized with human urine in combination with compost. Human urine supplemented with 50 kg PK ha^{-1} gave highest fruit weight (67.2 g) and fruit diameter (5.5 cm). Plants fertilized with the combination of human urine and compost showed better growth and yield compared to the application of fertilizer sources alone. The results indicated that the human urine performs better when used in combination with compost, and can be used as a promising fertilizer source in sweet pepper production.

1. Introduction

Intensive agriculture, which results in elevated use of chemical fertilizers, is now being widely practiced to combat increasing challenges to meet the demand for food around the world. Chemical fertilizers are expensive and their prices are expected to increase in the years to come. Small-scale farmers often find it hard to meet the expenses for chemical fertilizers necessary to maintain soil fertility (Gensch et al., 2011). Many developing countries like Nepal, which have subsistence economies, are spending millions of dollars every year to import chemical fertilizers from other countries. Besides, excessive and indiscriminate use of chemical fertilizers leads to soil degradation and imposes a serious threat to human health (Fujimoto, 1998). All the above reasons underscore the acute need of alternative sources of fertilizer for sustainable crop production. Human urine could be a viable alternative to chemical fertilizers for sustained crop production.

Human urine, a biological fertilizer, is readily available with no cost in all human societies—even in the poorest ones (Heinonen-Tanski and van Wijk-Sijbesma, 2005). As a liquid fertilizer, it contains nitrogen (mostly as urea), phosphates and potassium in dissolved forms (Richert et al., 2010). Fresh human urine is composed of total nitrogen (8830 mg L^{-1}), ammonium/ammonia (460 mg N L^{-1}), total phosphorus (800–2000 mg L^{-1}), potassium (2740 mg L^{-1}), sulphate (1500 mg L^{-1}), sodium (3450 mg L^{-1}), magnesium (120 mg L^{-1}), chloride (4970 mg L^{-1}) and calcium (230 mg L^{-1}) (Munch and Winker, 2009). The use of human urine in cabbage (Pradhan et al., 2007), tomato (Pradhan et al., 2009a), cucumber (Heinonen-Tanski et al., 2007) and pumpkin (Pradhan et al., 2009b) proved safe without any significant hygienic threats to human health. A six month of storage at 20 °C makes human urine a risk-free fertilizer source for several crops (Hoglund et al., 2002; Hoglund and Stenstrom, 1999). Reuse of human urine in crop production not only provides valuable fertilizers but also limits the negative impact on environment and water bodies if properly managed (WHO, 2006).

Despite growing interest in exploiting human urine as a fertilizer source (Karak and Bhattacharyya, 2011), limited information

Abbreviations: NARC, Nepal Agricultural Research Council; RCBD, randomized complete block design; T, treatment; ANOVA, analysis of variance; LSD, least significant difference.

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Table 1
Analysis of soil samples from three blocks of experimental plot at Chanlakhel, Kathmandu before field experiment.

Soil parameter	Mean
pH	5.7
Organic matter (%)	6.0
Available nitrogen (%)	0.21
Available phosphorus (kg ha^{-1})	184
Available potassium (kg ha^{-1})	344
Soil texture	Sandy loam

is available about the best use of it in crop production. To address this lack of information, we formulated a research based on the use of human urine in the commonly grown vegetable, sweet pepper, as an experimental crop. The selection of sweet pepper was largely driven by its wide distribution, growing popularity across the country and higher nitrogen requirement. The edible part, fruit, doesn't come in direct contact with human urine and is easily accepted by consumers. The main objective of the study was to evaluate the fertilizer value of human urine in different combination and compare the value with compost, urea and their combinations based on plant performance.

2. Materials and methods

2.1. Experimental site

The experiment was conducted at a farmer's field in Chanlakhel of Setidevi Village, in Kathmandu district during summer season in 2011. The site is located at 27°63′ N, 85°29′ E and an elevation of 1306 m above sea level. The experimental site received 1057 mm rainfall from February to July of this year with maximum rainfall recorded during last week of July. The average temperature during crop growing period was 20.78 °C. The mean weekly maximum temperature was 30.19 °C during third week of June and minimum temperature was 4.16 °C during first week of February 2011.

Soil samples were collected from upper soil surface (0–15 cm) of experimental plots prior to treatment application. Total nitrogen was determined by the Macro-Kjeldahl method (Jackson, 1967), available phosphorus by the Olsen's bicarbonate method (Olsen et al., 1954), available potassium by the ammonium acetate method (Black, 1965) and organic matter was determined by the Walkley and Black method (Walkley and Black, 1934) in Central Soil Science Laboratory of Nepal Agricultural Research Council (NARC), Khumaltar (Table 1).

2.2. Experimental design

The experiment was laid out in Randomized complete block design (RCBD) consisting of eight treatments with three replications. Each treatment was fixed to a supply of 100 kg N ha^{-1} (Pundir and Porwal, 1999). In the treatments having the combination of two or more fertilizer sources, equal dose of nitrogen was supplied from each fertilizer source. The treatments were; T_1 – urea only, T_2 – human urine only, T_3 – compost only, T_4 – human urine supplemented with 50 PK kg ha^{-1}, T_5 – human urine + compost, T_6 – human urine + urea, T_7 – compost + urea, and T_8 – human urine + compost + urea. Individual plot size comprised of 3 m in length and 2.25 m in width with an area of 6.75 m^2. Plants were spaced at a distance of 45 cm in the row and rows were spaced at 60 cm apart in the plot. Each plot consisted of 5 rows accommodating 5 plants in each row. Net experimental plot area was 162 m^2 (approximately 3.7 plants per m^2). California Wonder, a popular open pollinated sweet pepper variety was selected as an experimental crop. The healthy seedlings at 5–6 leaf stage were lifted in the afternoon and were transplanted into 10 to 15 cm deep pits in the main field on 5th March 2011.

Table 2
Analysis of nutrient content in compost and human urine.

Parameter	FYM compost	Human urine
Total nitrogen (%)	1.30	0.73
Total phosphorous (μg g^{-1})	1.01	0.42
Total potassium (%)	3.50	2.00

2.3. Collection, preparation and application of human urine and compost

Human urine was collected in plastic drum from the mobile public toilets at Narayanhiti palace, Kathmandu on 2nd February 2011. The toilets were cleaned without using chemicals before the collection of human urine. The collected urine was stored for one month under shade in a black plastic drum with a closed mouth. The compost was prepared from cattle manure in a pit. The hipped manure was turned upside down twice at an interval of a month. The nutrient content of both human urine after one month of storage and the compost were analyzed at central soil laboratory of Nepal Agricultural Research Council (NARC) in Lalitpur (Table 2).

The total compost, one third of the urea and human urine, and total phosphorus and potash were applied at the time of final land preparation, on 1st March 2011. One third urea and human urine were top dressed at one month after transplantation of seedlings and remaining one third at two month after transplantation. Human urine was diluted with fresh ground water in 1:1 ratio and applied in a ring around the plant and later covered with soil.

2.4. Observations and measurement

Observations were taken regarding vegetative, reproductive, yield and yield attributing characters. In each plot, five experimental plants were randomly selected and tagged for data collection leaving sixteen plants as border plants. Total Leaf area was calculated by multiplying leaf length with leaf width and 0.604 (Ray and Singh, 1989). After final picking of the fruit, experimental plants were uprooted by digging and fresh shoot weight and root weight were taken. Root spreading was measured as the maximum linear distance (two sided) reached by lateral roots in horizontal plane. The fruit length was measured as the length from the base of the fruit to the tip excluding the fruit stalk while fruit diameter was taken from the middle part of the fruit. Harvesting of fruits was conducted between 17th June 2011 and 28th July 2011.

2.5. Statistical analysis

Statistical analysis was performed for different fertilizer sources across morphological characters, shoot and root characters, and yield and yield attributing characters. Data were subjected to analysis of variance (ANOVA) using MSTAT C package to evaluate the significance of treatment effect. Means were compared using the Least Significant Difference (LSD).

3. Results

3.1. Plant growth

Sweet pepper grown on the treatments—human urine, urea, compost and their combinations—showed similar growth response prior to 30 days after transplanting. However, significant effect was observed at the later stage (Table 3). The tallest plants were

Table 3
Effect of different sources of fertilizers and their combinations on growth and morphological characters of sweet pepper var. California Wonder at Chanlakhel, Kathmandu, 2011.

Treatments	Plant height (cm)	Number of leaves per plant	Total leaf area per plant (cm^2)
U	47.2^{bc}	151.3^{ab}	2340^{b}
HU	46.3^{bc}	146.6^{b}	2196^{b}
C	43.3 ^{c}	146.7^{b}	2197^{b}
HU + PK	49.5 ^{b}	156.5^{ab}	2354^{b}
HU + C	54.7 ^{a}	166.9^{a}	2900^{a}
HU + U	50. 3^{ab}	170.8^{a}	2579^{ab}
C + U	49.7^{ab}	163.2^{ab}	2959^{a}
HU + C + U	50.0^{ab}	169.1^{a}	2580^{ab}
Mean	48.89	158.88	2513.33
SEm (±)	1.56	5.85	129.20
LSD (0.05)	4.73	17.76	392.00
CV (%)	5.53	6.38	8.91

Means within the column followed by the same letter (s) do not differ significantly at 5% level of significance by LSD.
U, urea; HU, human urine; C, compost; HU + PK, human urine + 50 PK kg ha^{-1}; HU + C, human urine + compost; HU + U, human urine + urea; C+U, compost + urea; HU + C + U, human urine + compost + urea.

obtained from human urine + compost (54.7 cm) which was at par with human urine + urea (50.3 cm), human urine + compost + urea (50.0 cm) and compost + urea (49.7 cm) application. Conversely, plants fertilized with compost only showed significantly lower height (43.3 cm) (Table 3). The plants fertilized with human urine only and urea only showed similar plant height of 46.3 and 47.2 cm respectively.

The plants fertilized with human urine in combination with urea produced the highest number of leaves per plant (170.8). Lower number of leaves (146 leaves per plant) was obtained from plants fertilized with human urine, and compost only. Interestingly, plants fertilized with the combination of two or more fertilizer sources showed greater height, number of leaves and total leaf area than plants fertilized with single fertilizer source (Table 3).

3.2. Shoot and root characters

The fresh shoot weight of sweet pepper plants fertilized with human urine + compost (268.3 g) was at par with that of compost + urea (265.5 g), human urine + compost + urea (255.3 g) and human urine + urea (243.7 g) but differed significantly ($p < 0.05$) from plants fertilized with human urine (231.4 g) and urea only (236.5 g) (Table 4).

Plants treated with compost only showed highest fresh root weight (40.7 g $plant^{-1}$) whereas the fresh root weight of remaining treatments was considerably similar and ranged from 27.4 to 33.6 g $plant^{-1}$ (Table 4). The sweet pepper plants fertilized with human urine + PK produced shorter roots (14.5 cm) and lower root spreading (17.5 cm). Similarly, higher fresh shoot weight was obtained from plants treated with combined fertilizer sources. Fresh root weight of all treatments was similar except from the plants fertilized with compost only (Table 4).

Table 4
Effect of human urine, urea, compost and their combinations on shoot and root characters of sweet pepper var. California Wonder at Chanlakhel, Kathmandu, 2011.

Treatments	Fresh shoot weight (g $plant^{-1}$)	Fresh root weight (g $plant^{-1}$)	Root length (cm)	Root spreading (cm)
U	236.5^{c}	29.3^{b}	19.2^{a}	24.2^{ab}
HU	231.4^{c}	32.0^{b}	18.1^{ab}	23.9^{ab}
C	240.7^{bc}	40.7^{a}	19.6^{a}	28.8^{a}
HU + PK	241.0^{bc}	28.0^{b}	14.5^{c}	17.5^{c}
HU + C	268.3^{a}	30.9^{b}	15.7^{bc}	23.7^{abc}
HU + U	243.7^{abc}	29.7^{b}	17.5^{abc}	24.6^{ab}
C + U	265.5^{ab}	33.6^{b}	19.2^{a}	23.0^{abc}
HU + C + U	255.3^{abc}	27.4^{b}	18.7^{ab}	20.7^{bc}
Mean	247.79	31.43	17.83	23.29
SEm (±)	8.18	2.22	0.95	1.89
LSD (0.05)	24.82	6.75	2.90	5.74
CV (%)	5.72	12.27	9.31	14.10

Means within the column followed by the same letter (s) do not differ significantly at 5% level of significance by LSD.

Table 5
Effect of different sources of fertilizers and their combinations on yield and yield attributing characters of sweet pepper var. California Wonder at Chanlakhel, Kathmandu, 2011.

Treatments	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (g)	Number of fruits per plant	Fruit yield per plant (g $plant^{-1}$)
U	6.3^{b}	5.0^{b}	57.7^{b}	6.8^{bc}	390.2^{bc}
HU	6.6^{ab}	5.0 ^{b}	57.5^{b}	6.3^{c}	363.2^{c}
C	6.6^{ab}	5.2^{ab}	61.3^{ab}	5.8^{c}	354.9^{c}
HU + PK	6.4^{b}	5.5^{a}	67.2^{a}	5.5^{c}	368.8^{c}
HU + C	6.7^{ab}	5.2^{ab}	60.9^{ab}	9.1^{a}	553.9^{a}
HU + U	6.4^{b}	5.0^{b}	58.0^{b}	6.5^{c}	377.1^{c}
C + U	6.9^{a}	4.9^{b}	58.8^{b}	8.4^{a}	495.6^{abc}
HU + C + U	7.1^{a}	4.9^{b}	56.3^{b}	8.2^{ab}	463.7^{ab}
Mean	6.64	5.10	59.69	7.08	420.9
SEm (±)	0.14	0.12	2.08	0.50	34.72
LSD (0.05)	0.44	0.37	6.33	1.53	105.3
CV (%)	3.87	4.25	6.05	12.38	14.29

Means within the column followed by the same letter (s) do not differ significantly at 5% level of significance by LSD.

3.3. Fruit yield and yield attributing characters

The highest fruit weight was obtained from human urine + PK (67.2 g) application followed by compost alone (61.3 g) and human urine + compost (60.9 g), although the later were at par with each other (Table 5). The highest number of fruits per plant was observed from plants fertilized with human urine + compost (9.1) which was at par with compost + urea (8.4) and human urine + compost + urea (8.2) but significantly higher than that of plants fertilized with single sources or combination without compost (Table 5). The highest fruit yield per plant was observed with plants fertilized with human urine + compost (553.9 g $plant^{-1}$) which was followed by compost + urea (495.6 g $plant^{-1}$) and human urine + compost + urea (463.7 g $plant^{-1}$) (Table 5).

4. Discussion

Human urine, a rich source of nitrogen, phosphorus and potassium (Kirchmann and Pettersson, 1995) is increasingly being used as a fertilizer source in different horticultural crops. In this study, better growth and yield response of sweet pepper plants was observed with the application of human urine in combination with compost. This is largely attributed to the synergistic effect of human urine with compost. Similarly, higher plant height, number of leaves per plant, total leaf area and fresh shoot weight of the sweet pepper plants fertilized with human urine + compost might have occurred due to the synchronization of nutrients supply with actual crop demand. Guzha et al. (2005) reported higher plant height and total leaf area of plants fertilized with human urine in combination with human manure compared to plants fertilized with human urine only. Similarly, Pradhan et al. (2009a) reported higher vine length and leaf area of tomato plants fertilized with human urine supplemented with wood ash compared to plants fertilized with human urine only. A large body of literature findings suggest higher plant height supplied with the combined application of fertilizers (Ghoname and Shafeek, 2005; Jaipaul et al., 2011). Lower plant height of sweet pepper fertilized with compost can be attributed to the slow release of nutrients and its unavailability at the critical stage of nutrient requirement. Gopinath et al. (2008) also reported shorter height of sweet pepper plants solely fertilized with organic manures compared to plants fertilized in combination with inorganic fertilizers. We observed no significant difference in plant growth between plants fertilized with human urine and urea. Kirchmann and Pettersson (1995) suggested that the fertilizing effect of human urine and urea are identical as nitrogen in human urine is primarily present in ammonical form.

Moreover, in this study, higher fresh shoot weight was observed with plants fertilized with combined sources of fertilizers compared to plants fertilized with urine or urea alone. In contrast, no significant difference was observed among different treatments for fresh root weight except for plants fertilized with compost only. Plants adjust themselves to nutrient uptake and absorption via profuse growth of roots. Similarly, the results may in part be explained by the increased microbial activities and release of phytohormones and enzymes with compost application. Plants treated with human urine + PK produced significantly shorter roots and consequently, lower fresh root weight. Plants may invest lower energy due to easy availability of plant nutrients at soil-plant interface resulting from surface application of different fertilizers and human urine.

Although the addition of compost to human urine and urea promoted the number of fruits per plant, compost alone did not increase the number of fruits. Gopinath et al. (2008) observed higher number of fruits per plant in sweet pepper with the application of organic manures in combination with inorganic fertilizer. Arancon et al. (2006) reported significantly higher number of fruits with plants treated with humic acid compared to untreated plants. In this study, the fruit yield per plant of sweet pepper plants fertilized with human urine + compost was higher compared to other treatments. Guzha et al. (2005) also reported higher yield with plants fertilized with human urine in combination with human manure compared to plants fertilized with human urine only. As this study shows, plants seem to perform better in treatments receiving human urine + compost due to the presence of growth promoting substances (Sridevi and Srinivasamurthy, 2010), micro-nutrients, and a variety of inorganic and organic compounds in human urine (Kirchmann and Pettersson, 1995; Munch and Winker, 2009). At the same time, addition of organic amendments improves soil structure, aggregate stability and moisture retention capacity (Bhattacharyya et al., 2008). Lower growth and yield of plants fertilized with human urine may be associated with larger gaseous nitrogen losses from human urine (Kirchmann and Pettersson, 1995). Higher crop productivity from combined application with compost in this study can be explained by enhanced organic carbon content and microbial activity in soils (Nakhro and Dkhar, 2010), reduced emissions from nitrogen fertilizer use, and higher nitrogen use efficiency (Pan et al., 2009).

We observed slightly lower number of fruits with human urine application compared to urea alone, this result is consistent with Pradhan et al. (2009a,b) who reported slightly lower number of tomato and pumpkin fruits from plants fertilized with human urine alone compared to mineral fertilizer. This was possibly due to the salinity that dominated the plots fertilized with human urine (Mnkeni et al., 2008; Pradhan et al., 2009b). Similar trend in pepper fruits, due to salinity, was reported by Huez-Lopez et al. (2011). Our research was a field based experiment and we presume leaching of salts from experimental plots fertilized with human urine during rainfall events. However, sweet pepper may produce higher yield with the addition of nitrogen via organic fertilizer in saline soil (Huez-Lopez et al., 2011). Despite higher fruit weight, we observed lower yield of pepper plants fertilized with human urine + PK due to lower number of fruits. Higher fruit weight of plants fertilized with human urine + PK may be associated with the additional supply of phosphorus and potash nutrient. Findings suggest that increased potassium fertilization may result in increased fruit weight of sweet pepper (El-Bassiony et al., 2010). However, it may reduce the number of fruits, often associated with negative effect of potassium on flowering (Medina-Lara et al., 2008; Ruiz et al., 2000).

5. Conclusions

The results of this study indicated that human urine performs better when used in combination with compost than alone and that it can be used as a promising fertilizer source in sweet pepper production. They also provide valuable insights into the effective use of human urine for crop production. Further research should be carried out on the use of human urine across different crops and their long term effect on soil, environment, and crop productivity.

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