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Yield and nutrient uptake of vegetable crops as influenced by application of human and cattle urine for nutrients sources

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Abstract
The field experiments were conducted with an application of human urine and cattle urine as nutrients sources. Ashgourd (Benincase hispida Thunb.) Cong.), french bean (Phaseolus vulgaris L.), pole bean (Phaseolus vulgaris L.) and pumpkin (Cucurbita maxima) which were grown as test crop. The experimental geographical area had been situated between 13o 292´ North latitude 77o 543´ East longitude and an altitude of 880 meters (2,890 ft) above mean sea level at Bangalore rural district (Karnataka, India). The experiment had 14 treatment combinations to study the effect of repeated application of human urine and cattle urine on yield and nutrient uptake of vegetable crops. Among the treatments application of recommended dose of nitrogen through human urine in three split doses plus gypsum recorded higher yield (39.2, 14.2, 17.4 and 38.7 t ha–1, for ashgourd, french bean, pole bean and pumpkin, respectively).

Keywords: cattle urine, human urine, yield, nutrient uptake, vegetable crops etc

1. Introduction

The strategy for production of vegetables in the present context must be by increasing the productivity of land under cultivation, reduced costs of production and higher input use efficiency with no harm to the soil, ground water, environment and product quality. Soil-plant-environment system should be free from economic exploitation and overuse and misuse of the inputs. No doubt, the use of mineral fertilizers and pesticides was a boon in the past, but their non-judicious use is being considered a bane in the present scenario, causing for a shift towards organic farming which has its own limitations. It is now time to reanalyse the production advantage to the cost of nature destruction, where impairment of soil physical, chemical and biological properties are the key problems associated with indiscriminate and over use of synthetic fertilizers and pesticides. The poor soil respiration rate and complete vanishing of natural decomposer communities from agro-ecosystems further threatens land sustainability and food security around the world. Similarly, the escalation in the cost of chemical fertilizers, particularly N, P and K coupled with related ecological concerns has drawn the attention of scientific and farming community from chemical alone agriculture to integrated nutrient management strategy which utilizes human urine and cattle urine as subsidiary sources or alternatives to chemical fertilizers.

The greatest challenge facing mankind in the world in the twenty first century is to produce the basic necessities of food, fodder, fiber, fuel and other raw materials from 0.14 ha or less land per capita. The nutrient turn over in soil plant continuum concept is considerably high under intensive cropping, neither the chemical fertilizers nor the basic or biological sources alone can achieve production sustainability. Long term studies indicated that the balanced use of only NPK fertilizers could not maintain high yield levels because of emergence of other macro and micro-nutrient deficiencies and deterioration in soil physical eco-system. As a consequence of this and other constraints there seems to be no option but to fully exploit alternative sources of plant nutrients. The judicious use of naturally available resources like human urine (anthropogenic liquid waste) and cattle urine help in maintaining yield stability through correction of marginal deficiencies of macro and micro-nutrients, enhancing efficiency of applied nutrients and providing favourable soil chemical and physical conditions and reducing the environmental pollution. Taking all these factors into consideration, the study was conducted to know the effect of application of human urine and cattle urine on yield and nutrient uptake in vegetable crops as sequence cropping system.

2. Materials and Methods

The experiment was conducted in farmers field for two successive years in the same experimental field with ashgourd (Benincasa hispida (Thunb.) Cong.), french bean (Phaseolus vulgaris L.), pole bean (Phaseolus vulgaris L.) and pumpkin (Cucurbita maxima) as test crops. The experiment design was a completely randomized block design and had three replication with fourteen treatments. The details of vegetable crops and varieties grown, spacing, recommended dose of fertilizer for particular crop and also based on the fertilizer requirement of the crop the quantity of human urine and cattle urine required details are given in the Tables 1 and 2.

Table 1: Details of vegetable crops and varieties used as test crops

Sl. No.	Crops	Varieties	Spacing (cm)	RDF	Human urine (m^3 ha^{-1})	Cattle urine (m^3 ha^{-1})
1.	Ashgourd	C. O.- 1	200 X 100	50:50:0	16.67	20.00
2.	French bean	Arka Komal	30 X 20	63:100:75	21.00	25.20
3.	Pole bean	Kentuki Wonder	100 X 60	63:100:75	21.00	25.20
4.	Pumpkin	Arka Suryamukhi	120 X 80	100:100:40	33.33	40.00

Note: a) The quantity of gypsum applied @ 6.45 kg m^{-3} urine.

Table 2: General composition of human urine, cattle urine and FYM is given below

Nutrient content (%)	N	P_2O_5	K_2O
Human urine	0.30	0.17	0.18
Cow urine	0.25	0.12	0.16
FYM	0.45	0.20	0.35

The total quantity of human urine or cattle urine required per hectare to meet the recommended dose of nitrogen (kg/ha) to different crops was calculated using formula:

The calculated quantity of gypsum was applied as based dose only in case of treatments receiving the human urine/cattle urine with gypsum as per the treatment details to overcome the effect of sodium if any on soil physical and chemical properties. The quantity of gypsum applied was 6.45 kg per cubic meter of urine, which was arrived at by considering the per cent sodium percent in urine (an average of 0.3% Na). Balance of phosphorus and potassium were supplied through chemical fertilizers as single super phosphate and muriate of potash, respectively.

2.1 Treatment details

There were fourteen treatments out of which twelve treatments were divided into three categories based on the application of human urine and cattle urine as N sources during crop growth period viz., single dose, two split doses and three split doses as well as with and without gypsum. The treatments, farmyard manure alone and recommended dose of fertilizer plus farm yard manure (FYM) were used as control. T_1 : Farmyard Manure (FYM) alone, T_2 : Recommended dose of fertilizers (RDF), T_3 : RDN through human urine in single dose, T4 : RDN through human urine in single dose + gypsum, T_5 : RDN through cattle urine in single dose, T_6 : RDN through cattle urine in single dose + gypsum, T_7 : RDN through human urine in two split doses, T_8: RDN through human urine in two split doses + gypsum, T_9 : RDN through cattle urine in two split doses, T_{10} : RDN through cattle urine in two split doses + gypsum, T_{11}: RDN through human urine in tgree split doses, T_{12}: RDN through human urine in three split doses + gypsum, T_{13}: RDN through cattle urine in three split doses, T_{14}: RDN through cattle urine in three split doses + gypsum.

Fruits or pod from each net plot in each replication was harvested and recorded as yield per net plot. Further, this net plot yield was converted to yield per hectare.

2.2 Chemical analysis of plant sample

The plant samples used for recording dry matter production at harvest were used for analyzing nutrients present in the plant. After recording the dry weight from each treatment the samples were powdered in a micro Willey mill. The samples were analyzed for concentration of different nutrients (N, P and K) present in the plant parts. Nitrogen content of pod and stover were estimated by modified micro-kjeldhal's method as outlined by Jackson (1973) [6] and expressed in per cent. Nitrogen uptake (kg/ha) by crop was calculated for each treatment separately using the following formula.

Nitrogen uptake (kg/ha) = (Nitrogen concentration (%)/100) X Dry matter yield (kg ha^{-1})

The phosphorus content in plant samples were determined by Vanadomolybodo phosphoric acid yellow colour method and absorbance of the solution was recorded at 430 nm using spectrophotometer (Jackson, 1973) [6] and then computed the total uptake by crop as detailed under N uptake by the crop. Potassium content in plant sample was determined by flame photometer method (Jackson, 1973) [6] and expressed in kg per ha as explained under N uptake by the crop.

2.3 Chemical analysis of soil

Representative soil samples from the experimental plot were drawn from the top 15 cm depth before sowing of the crop. Similarly, the surface soil samples from 0 to 15 cm depth were also collected from each experimental plot at harvest. Soil samples thus collected were air dried under shade, powdered with wooden pastel and mortar and passed through 2 mm sieve and analyzed for nitrogen, phosphorus and potassium content. Available nitrogen was determined by alkaline permanganate method as outlined by Subbiah and Asija (1956) [14]. Available phosphorus was determined by Olsen's method as outlined by Jackson (1973) [6]. Available potassium was determined by neutral normal ammonium acetate solution using flame photometer as outlined by Jackson (1973) [6].

2.4 Statistical analysis and interpretation of data

Data recorded on various parameters of the experiment was subjected to analysis by using Fisher's method of analysis of variance (ANOVA) and interpreted as outlined by Gomez and Gomez (1984). The levels of significance used in 'F' and 't' test was P= 0.05. Critical difference values were calculated where F test was found significant.

3. Results and Discussion

3.1 Dry matter accumulation and yield

Fruit yield of vegetable crops differed significantly with respect to application of human urine and cattle urine. Application of recommended dose of N through human urine in three split dose plus gypsum recorded maximum yield (39.2, 14.2, 17.4 and 38.7 t ha^{-1}, of ashgourd, french bean, pole bean and pumpkin crops, respectively) followed by recommended dose of N through cattle urine in three split dose plus gypsum (T_{14}: 38.0, 14.1, 16.6 and 37.5 t ha^{-1}, of ashgourd, french bean, pole bean and pumpkin, respectively), and recommended dose of fertilizers. Higher yield recorded with recommended dose of N through human urine in three split doses plus gypsum was attributed to better root development and higher availability of nutrients to the crops. These results are in agreement with the findings of Peter Morgan (2004) [12] and Kedar and Deepak (2003) [9] who used source separated human urine as the nutrient source for the vegetable plants particularly broadbean, blackgram and green pea. Increase in dry matter production per unit area is a first step in achieving higher yield. Higher total dry matter at harvest was established with application of recommended dose of N through human urine in three split doses plus gypsum (701.7, 26.2, 156.8 and 719.3 g plant^{-1}, for ashgourd, french bean, pole bean and pumpkin crops, respectively). The higher yield of vegetable crops with application of recommended dose of N through human urine in three split doses plus gypsum was favorably influenced by higher height or length of ashgourd, french bean, pole bean and pumpkin crop plants and had more number of branches at harvest, more number of leaves, LAI at harvest of ashgourd, french bean, pole bean and pumpkin crops.

3.2 Nutrient concentration and uptake

The highest nitrogen content (4.09, 4.49, 4.01 and 4.33 % in fruits for ashgourd, french bean, pole bean and pumpkin crop, respectively) and highest total nitrogen uptake (108.92, 134.3, 148.8 and 162.8 kg ha^{-1}) by these crops was recorded with application of recommended dose of N through human urine in three split doses plus gypsum (Table 3 and 4). This may be due to increase in the availability of nutrients to the crop from human urine, accumulating more nitrogen in the leaves and nitrogen is evenly distributed throughout the plant and the highest proportion being found in the fruits (Jean Emmanuel Ndzana and Ralf Otterpohl, 2009 and Sridevi *et al*., 2009) [7, 13]. Increased nitrogen content and uptake in treatment receiving human urine in three split doses might be due to split application of N through urine which resulted in decreased loss of N from soil and maintained higher N potential throughout the plant growth period. Similar observations were made by Guzha (2004) [4] and Mnkeni *et al*. (2005) [10] and Guadarrama *et al*. (2001) [3] who opined that the best yield of lettuce was due to high availability of nitrogen. Anthropogenic liquid waste is a soluble liquid fertilizer, which mean that nitrogen is more rapidly available and effective even in dry season (Jonsson *et al*., 2004) [8].

Increased phosphorus content in fruit and uptake by plant due to application of recommended dose of N through human urine in three split doses plus gypsum, recommended dose of N through cattle urine in three split doses plus gypsum and recommended dose of fertilizer plus farmyard manure could be attributed to conversion of fixed phosphorus into readily available form by organic acids released during decomposition of organic manure, applied urine and consequent improvement in the available P content of soil and also due to slow release of nutrients through the application of human urine and cattle urine to soil during crop growth period. These results corroborate with the findings of Mussie *et al*. (2006) [11] who reported higher organic carbon, available N, P and K with the usage of dairy waste for five years. The K concentration in fruit increased with application of human urine and cattle urine (Table 3 and 4). Highest potassium content and uptake was noticed in treatment receiving recommended dose of N through human urine in three split doses plus gypsum along with balanced phosphorus and potassium supplied through chemical fertilizers. This might be due to better root growth and higher absorption capacity resulting in increased assimilation of potassium in plant tissue which in turn improved the absorption and translocation of elements in plant system. Hellstrom (1999) [5] observed that the nutrients in anthropogenic liquid waste were water soluble and were easily available to the plants for uptake and are easily transported into plant parts.

Table 3: Effect of split application of human urine and cattle urine with and without gypsum on total dry matter accumulation (DMA) (g plant^{-1}) and vegetable yield (t ha^{-1}) for different vegetable crops

Treatments	Ashgourd		French bean		Pole bean		Pumpkin	
	DMA	Yield	DMA	Yield	DMA	Yield	DMA	Yield
T_1	518.9	19.7	19.6	8.7	113.6	9.2	522.3	19.5
T_2	676.1	36.7	25.0	13.7	148.7	15.8	699.9	36.8
T_3	534.1	22.2	20.0	9.3	119.7	10.2	537.3	21.9
T_4	551.1	23.6	20.7	9.9	118.1	11.1	557.1	23.3
T_5	524.9	21.1	20.1	8.9	116.9	9.8	530.5	20.8
T_6	542.3	23.5	20.2	9.6	120.6	10.7	547.6	23.3
T_7	561.6	29.0	21.6	10.3	125.9	11.9	574.9	28.6
T_8	603.5	31.8	23.1	11.3	136.4	13.9	616.2	31.4
T_9	554.9	27.8	21.2	10.1	121.4	11.5	564.3	27.5
T_{10}	592.9	30.2	22.0	10.7	131.6	12.8	599.9	29.9
T_{11}	664.1	36.5	24.6	13.5	147.1	15.5	691.4	36.0
T_{12}	701.7	39.2	26.2	14.2	156.8	17.4	719.3	38.7
T_{13}	650.7	35.4	24.5	13.5	144.9	15.1	679.3	35.0
T_{14}	691.1	38.0	22.8	14.1	150.2	16.6	711.4	37.5
S.Em $\pm$	20.4	2.01	0.64	0.4	4.01	0.76	19.4	2.02
C.D.(P=0.05)	59.3	5.8	1.85	1.3	11.7	2.22	56.3	5.9

Table 4: Nitrogen, phosphorus and potassium content (%) in fruits of different vegetable crops at harvest as influenced by split application of human urine and cattle urine with and without gypsum

Treatments	Ashgourd			French bean			Pole bean					Pumpkin
	N	P	K	N	P	K	N	P	K	N	P	K
T_1	3.24	0.23	2.70	3.37	0.22	2.49	3.30	0.19	1.97	3.48	0.25	3.56
T_2	3.96	0.35	3.60	4.32	0.34	3.54	3.90	0.33	2.80	4.20	0.37	4.04

T_3	3.37	0.25	3.11	3.54	0.24	2.62	3.41	0.21	2.12	3.61	0.27	3.65
T_4	3.50	0.27	3.22	3.71	0.26	2.75	3.49	0.23	2.27	3.74	0.29	3.74
T_5	3.31	0.24	3.06	3.45	0.23	2.55	3.36	0.20	2.04	3.55	0.26	3.61
T_6	3.44	0.26	3.17	3.63	0.25	2.68	3.47	0.22	2.49	3.68	0.28	3.69
T_7	3.63	0.30	3.33	3.89	0.28	2.88	3.63	0.25	2.42	3.87	0.31	3.82
T_8	3.73	0.32	3.41	4.03	0.30	3.01	3.71	0.27	2.51	3.99	0.33	3.91
T_9	3.57	0.28	3.28	3.80	0.27	2.81	3.57	0.25	2.34	3.81	0.30	3.81
T_{10}	3.70	0.31	3.38	3.97	0.30	2.94	3.68	0.27	2.49	3.94	0.33	3.86
T_{11}	3.89	0.34	3.54	4.23	0.33	3.14	3.85	0.30	2.72	4.13	0.36	4.00
T_{12}	4.09	0.37	3.70	4.49	0.36	3.33	4.01	0.33	2.95	4.33	0.39	4.13
T_{13}	3.83	0.34	3.49	4.14	0.32	3.07	3.79	0.29	2.64	4.07	0.35	3.95
T_{14}	4.02	0.36	3.65	4.40	0.35	3.27	3.95	0.32	2.87	4.26	0.38	4.08
S.Em $\pm$	0.12	0.01	0.15	0.15	0.016	0.11	0.10	0.016	0.14	0.11	0.017	0.07
C.D.(P=0.05)	0.35	0.04	0.43	0.45	0.046	0.32	0.29	0.046	0.40	0.32	0.050	0.20

3.3 Available nutrients in soil after harvest of crop

Available N in soil differed significantly due to application of human urine and cattle urine. Application of recommended dose of N through human urine in three split doses plus gypsum (290.9, 291.3, 298.2 and 302.2 kg ha^{-1}, for ashgourd, french bean, pole bean and pumpkin, respectively) (Table 5). Vinneras *et al.* (2003) [16] found that the plant nutrients in both anthropogenic liquid waste and faeces emanate from arable fields and thus should be recycled as fertilizers to support sustainability and to retain the fertility of the fields. Anthropogenic liquid waste becomes a quick acting fertilizer rich in nitrogen and with a composition of nutrients that well matches the needs of many crops. The urine is especially rich in nitrogen, and in the higher range of 3-7 g N/l given as indicative values by Jonsson *et al.* (2004) [8]. The split application of human urine and cattle during crop growth decreases the N loss from soil and maintains higher N potential throughout the plant growth period. And thus was found better in terms of N management and consequently better N uptake by crops.

Available P in soil varied significantly due to application of human urine and cattle urine after the harvest of vegetable crops (Table 6). The enhancement in phosphorus availability was due to the combined effect of released organic acids and organic anions on the decomposition of organic matter as a result of improving biological properties of soil and reduction in the activity of phosphorus complexing agent to make phosphorus available to the crop. Similar results were reported by Vinneras (2001) [15]. Human urine and cattle urine application based on the N requirement of vegetable crops along with this also added K to soil. This is due to the fact that, urine had substantial amount of K and is mostly in ionic form and becomes immediately available to the plants. The results are in conformity with the findings of Carlander *et al*. (2001) [1] and Hellstrom *et al*. (1999) [5] and Vinneras *et al.* (2006) [17].

Table 5: Nitrogen (N), phosphorus (P_2O_5) and potassium (K_2O) uptake (kg ha^{-1}) by different vegetable crops as influenced by split application of human urine and cattle urine with and without gypsum

Treatments	Ashgourd			French bean			Pole bean			Pumpkin		
	N	P	K	N	P	K	N	P	K	N	P	K
T_1	60.33	4.65	64.19	64.6	4.82	59.1	77.5	5.25	54.2	67.7	5.7	62.0
T_2	101.21	8.95	96.16	123.4	9.67	110.4	142.1	10.40	102.9	146.1	14.6	135.4
T_3	74.76	5.80	72.78	74.1	5.56	66.3	86.6	6.14	62.0	77.1	7.1	74.9
T_4	80.25	6.45	78.11	84.1	6.36	74.5	97.2	6.87	69.9	91.5	8.6	86.8
T_5	72.46	5.58	70.49	68.8	5.20	62.4	82.6	5.74	58.3	70.7	6.3	68.8
T_6	77.11	6.13	75.21	78.8	6.03	70.6	94.9	6.63	69.5	83.9	7.9	81.0
T_7	85.41	7.15	82.82	94.8	7.19	83.9	107.6	7.67	77.5	106.0	10.3	101.1
T_8	90.18	7.80	87.02	103.4	7.90	90.0	117.5	8.42	84.3	118.2	11.8	113.1
T_9	82.66	6.79	80.24	89.5	6.86	79.0	102.4	7.31	74.1	99.4	9.5	95.1
T_{10}	88.91	7.52	85.85	100.1	7.68	87.9	113.0	8.13	82.4	113.2	11.1	107.4
T_{11}	98.32	8.69	94.33	118.4	9.13	102.8	131.4	9.49	95.0	139.0	13.8	129.7
T_{12}	108.92	9.88	101.98	134.3	10.73	117.4	148.8	11.05	109.1	162.8	16.5	150.8
T_{13}	95.90	8.52	91.88	112.5	8.65	97.4	125.0	8.98	89.9	130.9	12.9	121.1
T_{14}	104.49	9.50	99.30	130.8	10.24	112.2	144.2	10.54	104.4	154.2	15.8	144.0
S.Em $\pm$	3.24	0.58	4.08	7.98	0.81	8.9	8.5	0.79	7.9	6.7	0.6	6.4
C.D.(P=0.05)	9.42	1.68	11.85	23.19	2.35	25.8	24.6	2.30	23.1	19.6	1.9	18.6

Table 6: Effect of split application of human urine and cattle urine with and without gypsum on available nitrogen, phosphorus and potassium (kg ha^{-1}) content of soil at harvest of vegetable crops

Treatments	Ashgourd			French bean			Pole bean			Pumpkin		
	Avail. N	Avail. P_2O_5	Avail. K_2O	Avail. N	Avail. P_2O_5	Avail. K_2O	Avail. N	Avail. P_2O_5	Avail. K_2O	Avail. N	Avail. P_2O_5	Avail. K_2O
T_1	269.6	25.3	274.0	266.5	24.45	265.9	256.2	23.3	259.0	261.0	22.9	257.2
T_2	288.0	30.1	316.2	285.5	30.62	314.5	289.9	30.0	314.3	292.5	30.0	317.9
T_3	272.7	26.7	277.4	270.6	26.24	283.4	264.1	25.2	278.0	265.6	24.9	274.9
T_4	273.4	27.4	284.3	270.6	27.19	293.1	267.5	26.3	288.6	269.3	26.0	286.2

T_5	271.8	26.3	275.7	267.8	25.78	279.0	259.7	24.8	273.2	264.4	24.4	269.8
T_6	273.2	27.1	280.6	275.4	26.71	288.2	265.2	25.8	283.3	266.6	25.5	280.5
T_7	275.1	28.2	291.0	277.0	28.17	296.5	273.2	27.4	299.2	276.2	27.2	297.5
T_8	276.8	28.9	303.1	278.0	29.10	297.0	274.1	28.4	306.2	281.8	28.2	299.4
T_9	273.6	27.8	284.9	276.1	27.70	293.6	268.8	26.8	294.0	271.5	26.6	292.0
T_{10}	275.4	28.6	297.8	277.0	28.65	296.9	273.9	27.9	304.4	279.4	27.7	298.8
T_{11}	283.6	29.4	313.8	282.7	29.72	306.5	281.1	29.1	313.7	289.0	29.0	315.5
T_{12}	290.9	31.4	319.9	291.3	32.29	324.2	298.2	31.8	323.7	302.2	31.9	330.9
T_{13}	281.0	29.3	310.2	281.0	29.63	300.3	280.1	28.9	309.9	286.7	28.9	314.3
T_{14}	287.0	30.5	317.8	288.4	31.09	321.0	294.0	30.6	320.3	295.6	30.6	324.3
S.Em ±	3.0	0.8	5.7	3.0	0.97	8.8	7.9	1.0	5.8	5.3	1.1	10.4
C.D.(P=0.05)	8.8	2.2	16.5	8.6	2.83	25.7	23.0	3.0	16.8	15.5	3.1	30.3

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