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Urban agriculture in Senegal: effect of wastewater on the agronomical performance and hygienic quality of tomato and lettuce

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ABSTRACT

The use of wastewater in urban agriculture has gained a lot of interest in Senegal. The aim of this works was to assess the effect of wastewater on the agronomical performance of two vegetable crops and the hygienic threats as compared to tap water. We also compared the effect of irrigation mode and the addition of fertilizers. Results showed that there were no significant differences between the two irrigation modes. The sturdiness at 2 months had a positive effect on the number of plant (tomato) at the harvest, the yield and fruit average weight. Considering the following parameters studied (overall yield, corrected yield, number of fruit per treatment and fruit average size, there were significant differences between plants (lettuce) treated with tap water and those treated with wastewater. In a chemical point of view, samples from aspersion and draining watering mode treatments were similar in term of their content in heavy metals. On the lettuce, results showed a low presence of worms on crop watered with wastewater. On the other hand, lettuce watered with the aspersion technique contents much more germs of pathogens than those watered in draining mode. As for tomato, there was a total absence of worms and other pathogenic germs in both irrigation modes. This study suggests that use of wastewater in horticulture with a moderate fertilization and taking into account soil chemistry could be gainful to urban farmers. The study addresses the issue of preliminary studies on the wastewater and soil quality before deciding on the adequate crop to grow.

Keywords: Wastewater, irrigation, Public health, urban agriculture, vegetable, fertilizers.

INTRODUCTION

The use of wastewater in urban agriculture has been reported in many countries; United Kingdom, United States of America, Israel, India, China Mexico and Nairobi (Hussain et al., 2002; Sou, 2009; Karanja et al., 2010). In Senegal, urban agriculture, which is mainly dominated by horticulture, was initiated since 1937 and expanded, in response to the drought period, which has severely affected the contribution of agriculture to the country economy, from

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18.75% in 1960-1966 to 11% in 1987-1993 (Kane, 1973; Gningue, 1992). In the Niayes suburbs, a costal agroecozone around Dakar, ground water is superficial and available for small scale farming. At the same time, wastewater released from urban households through a piping system for refinement ends up in stagnation in those area mostly occupied by rural communities seeking for opportunities (Sou, 2009; Ndiaye et al., 2010b) . This situation is favourable to the development of horticulture, which significantly contributed to the diversification of crops and the reduction of imports from 37,000 tonnes (1990-1991) to 17,500 tonnes (1992-1993). For instance, in 2002, the national horticultural gross production was estimated to CFA 92,429,185,000, which is considered as a huge gain to the country economy (Sangharé, 2002). Previous studies in the urban surroundings of Dakar and Accra and in Burkina Faso showed that the use of wastewater in agriculture is also a source of employment (Niang, 1996; Cissé et al., 2002; Keraita, 2002; Koné et al., 2002).

Wastewater reduces the quantity of water required for plant growth and the volume of agricultural inputs (fertilizers, pesticides) (Niassy and Diarra, 2012). It has been reported that most of farmers who use this kind of water make more profit (Niang, 1996; Keraita, 2002).

The daily production of wastewater in Dakar is estimated at 200,000 m^3, which is enough to cover the needs in water consumption for the whole capital city (60,000 m^3) especially when wastewater mixed with ground water is oriented to crop irrigation, yet dependent on the national water rationing network.

The possibility of the optimization of this wastewater for their use in agriculture is not thoroughly studied. Drip watering systems with wastewater treatment have been also suggested to avoid health risks (Faruqui et al., 2004). In that regard, the NGO ENDA-Third World promoted sanitation systems affordable to underprivileged peoples of the outskirts by constructing water treatment stations based on draining refining system using floating plants (macrophytes) such as *Pistia stratioites* (water lettuce) (Charbonnel, 1989; Thui, 1996; Koné et al., 2002). However, the use of wastewater encounters some more serious issues such as health risks (Mara and Cairncross, 1991; Niang, 1996; Keraita, 2002; Ndiaye et al., 2010a). Moreover, eventual safety measures related to the use of wastewater are poorly addressed in Senegal.

This study aims at looking at the impact of wastewater on plant performance of two vegetable crops (tomato and lettuce) and the hygienic quality of the yield.

MATERIALS AND METHODS

Water treatment station

The station covers a surface of 0.5 hectare and consists of a primary sedimentation tank followed by a set of six (6) tanks. The daily input of water debit is 75 m^3. The sedimentation tank operates as an anaerobic digesting system whereas the others can be considered as optional with smaller refining plants (microphytes).

Crop and irrigation

Two crops were selected: lettuces (leaves) variety "*Blonde de Paris*" and tomato (fruit) variety "Mongal". The experimental design was set in a complete random design (CRD) with two (2) blocs and two (2) irrigation techniques. There were 16 plots with two types of irrigation modes: the draining technique (lagoon) and the aspersion technique (sprinkling). These two irrigation techniques were selected to look at the effect of water quality on the yield, the level of contamination in pathogens and heavy metals. Therefore, samples of 100 g of lettuce and tomato of each irrigation type were analysed.

Four (4) treatments were applied, T_1: Wastewater with fertilizers; T_2: Wastewater without fertilizers; T_3: Tap water with fertilizers; T_4: Tap water without fertilizers (control).

Physicochemical and hygienic analyses

The focus was based on heavy metals content in irrigation water and vegetables. The physicochemical analyses were done according to AFNOR standards. They consist in eight (8) samples which were collected

from the optional set of tanks from both before and after water refinement. Analysis of water was based on DBO5, DCO, MES, total Nitrogen, Total Phosphorus, Nitrates, Nitrites, Ammonia and Potassium content. Heavy metal content analysis was performed according to the method of dosage using dithizone with specific pH values (Charlot. 1961). There were two (2) samples: one sample of wastewater and another one of tap water. Analyses were conducted at the Department of Chemistry of the Faculty of Sciences, Université Cheikh Anta Diop.

Bacteriological and parasitic analyses were also performed. They consisted in identifying and counting parasites such as coliforms and streptococcus. Kystes and trophozoites, and parasites eggs (eelworms) were also checked during parasitic analyses.

Agronomic analyses

Description of the lettuce assay

The input of fertilizers was applied according to the Centre for Horticulture and Development (CDH) norms; 250 kg/hectare and fertilizer NPK 10-10-20 as a starter, 20 days after sowing. Organic manure made of cow dung was added at a rate of 30 tonnes/hectare (9 kg per plot). Nursing plants were prepared in two distinct plots and watered with different irrigation water. Plants were transplanted a month later. Plots of 3 m^2 were used; the spacing was set at 0.30 m x 0.25 m and plant density was 40 plants per m^2. The whole experiment was conducted on 48 m^2. The quantity of seeds was estimated at 500 g/hectare.

Description of the tomato assay

The input of fertilizers was applied according to the Centre for Horticulture and Development (CDH) norms; 250 kg/hectare and fertilizer NPK 10-10-20 as a starter and repeated at 15, 30, 50 and 80 days after replanting. Organic manure made of cow dung added in all the plots at a rate of 30 tonnes/hectare (18 kg/plot). Nursing plants were irrigated with different water as mentioned earlier. Plots of 6m^2 (2 m x 3 m) were used in this experiment and a spacing distance of 0.5 m x 0.5 m was adopted corresponding to a density of 24 plants / plot. The total cultural surface was 96 m^2 and the quantity of seeds was estimated at 500 g/ha. The experiment period was 128 days and plots were watered at 6 mm/days. The patterns of irrigation water are indicated in Table 1.

Pest management and chemical application

In both experiments, fungicide Manebe was applied to prevent soil borne pathogens (fungi) and Dimethoate was also applied to control insect pests.

Statistical analysis

The statistical analysis was performed with the software MSTATC. Data were subjected to analysis of variance (ANOVA). Means were separated using Fisher test. A number of parameters were considered during this study; the effects of variables such as bloc homogeneity and the effect of irrigation water in relation to plant sturdiness. Plant sturdiness at 2 months is used to characterize and to appreciate plant growth by a ranking: 1= weak, 2 = fair, 3 = good, 4 = maximal. Other parameters such as number of missing plants after replanting; average weight of lettuce tuft or tomato fruit; total number of fruits per plant (tomato); presence of plants at the harvesting (to assess the population dynamic along with crop development); dry-matter (to assess to shelf life of the yield); the overall yield and the corrected yield in relation to plant presence at 100%. In all statistical analyses the level of significance was kept a 5%.

RESULTS

Quantitative analyses

Interactions blocs - agronomic parameters

There was no significant difference between the two crops (Table 1 and Table 2); demonstrating the homogeneity of the experiment.

Interactions irrigation systems - agronomic parameters

There was no significant difference between the irrigation modes, when applied at the same rate (Table 1 and Table 2).

Interactions sturdiness - agronomic parameters on Tomato

There were no significant interactions between the sturdiness at two months and the

number of fruits per treatment; neither there were significant interactions between sturdiness and dry-matter, although an increasing trend of dry-matter according to sturdiness at two months was observed. On the other hand, there was strong interaction between the sturdiness at two months and the number of missing plants after replanting ($p < 0.0001$), the presence rate at harvesting ($p = 0.02$), the overall yield ($p = 0.004$), the corrected yield ($p = 0.036$) and the average weight per fruit ($p = 0.04$). The sturdiness at two months had a positive effect on the number of plant at harvesting, on the yield and on the average weight of tomato fruits.

Interactions sturdiness - agronomic parameters on lettuce

There was no interaction between plant sturdiness and the other agronomic parameters. However, there was a strong relation between plant sturdiness and yield increase.

Interactions treatments - agronomic parameters on tomato

There was no significant interaction between the number of missing plants and the number of fruits and the dry-matter. However, the number of fruits per treatment was higher in the control than in the treatments with wastewater combined with fertilizer ($p = 0.03$). As for the number of missing plants after replanting, no deterrent effect was observed. Plant watered with wastewater showed spectacular growth, even better than those watered with tap water with exemption of fungal disease. However, one week after replanting, the number of missing plant started to increase significantly, reaching 50%.

On the other hand, plots watered with tap water, performed better although there was no significant difference in dry-matter between the treatments and fruits harvested across all the treatments, tomato fruits had almost the same shelf life.

The interactions between vegetative growth and other parameters were significant respectively number of plants at the harvest ($p = 0.02$), the corrected yield ($p = 0.007$) and the average weight of fruits ($p = 0.01$).

Considering the following parameters: overall yield; the corrected yield; the number of fruits per treatment and the fruit average yield, there was a significant difference between plants treated with tap water and those treated with wastewater (The overall yield was twofold higher). Plots water with tap water gave the higher yields, higher numbers of fruits with a better average weight. Plant watered with the tap water without fertilizer showed a better development and flowering resulting in a better fructification. Moreover, plots watered with tap water had a better response than those watered with wastewater in term of plant presence at harvest.

I*nteractions treatments - agronomic parameters on Lettuce*

The differences in yield, number of missing plant after replanting and the number of plants at harvest (vegetative growth) were not significant (Table 2). In fact, lettuce watered with wastewater without fertilizer performed better than lettuce watered with tap water and fertilizer. Results showed that T_1 and T_2 significantly had higher dry-matter. This suggests that lettuce watered with treated wastewater had better shelf life.

Chemical and hygienic analysis and threats

Heavy metal content

There was no significant difference in heavy metals content between aspersion and draining mode (Table 3).

Pathogens and parasite load

On the lettuce, there was low presence of eelworms on crop watered with wastewater despite the size of the samples (100 g). However, plants on aspersion mode were much more infected with coliforms and streptococci than those watered in a draining mode.

On tomato, there was a total absence of worms and other pathogenic germs in both irrigation modes (Table 4).

Table 1: Interactions agronomic - agronomic parameters variables on lettuce.

	Means of Variable	**Blocs**	**Irrigation mode**	**Treatments**	**Sturdiness at 2 months**
% Missing plants after 1 week	22	NS	NS	NS	NS
Number of plants at the harvest	87.7	NS	NS	NS	NS
Overall yield (tons / ha)	6.83	NS	NS	NS	NS
Corrected yield (tons / ha)	7.41	NS	NS	NS	NS
Tuft Average weight (g)	54.8	NS	NS	NS	NS
Dry-matter (%)	6.71	NS	NS	**HS**	NS

S = significant ($p < 0.05$, Fisher test); **NS** = not significant; **HS** = highly significant ($p < 0.001$, Fisher test).

Table 2: Interactions agronomic variables - tested parameters on tomato.

	Mean Variables	**Blocs**	**Irrigation mode**	**Treatment**	**Sturdiness at 2 months**
% Missing plants after 1 week	41.4	NS	NS	NS	**HS**
Number of plants at the harvest	80	NS	NS	**S**	**S**
Overall yield (tons / ha)	8.39	NS	NS	**HS**	**HS**
Corrected yield (tons / ha)	10.2	NS	NS	**HS**	**S**
Average weight of a fruit (gr.)	19	NS	NS	**S**	**S**
Number of fruit/treatment	445	NS	NS	NS	NS
Dry-matter (%)	8.15	NS	NS	NS	NS

S = significant ($p < 0.05$, Fisher test); **NS** = not significant; **HS** = highly significant ($p < 0.001$, Fisher test).

Table 3: Heavy metal content of lettuce watered by aspersion and draining mode.

Irrigation Modes	Heavy metals (µg/100 g)				
	Cu	Zn	Cd	Hg	Pb
Draining	35	75	0	0	0
Aspersion	32	73	0	0	0

Table 4: Effects of the irrigation mode on the pathogens and parasitic loads of tomato and lettuce.

Irrigation Mode	Eelworms		Fecal coliforms		Streptococci	
	Lettuce	Tomato	Lettuce	Tomato	Lettuce	Tomato
Aspersion 1	1	0	40	0	1020	0
Aspersion 2	0	0	250	0	1800	0
Draining 1	4	0	40	0	210	0
Draining 2	1	0	30	0	240	0

Sample size = 100 g

DISCUSSION

Wastewater is a promising alternative in urban agriculture in Sub-Saharan Africa contributing to poverty alleviation (Niassy and Diarra, 2012). However, in order to optimize its impact, there is urgent need to take into account certain parameters. Results of this study showed that wastewater had negative impact on tomato and this is due to high nutrient content which ends up being toxic to plants. Moreover, further inquiries revealed that the study site was in fact a former dumping of waste from the water treatment station. This high level of nutrient has affected plant in T_1 and T_2 respectively composed of wastewater with and without fertilizer. The addition of fertilizer has negatively affected agronomic performance of crop. It was reported that raw wastewater can contain up to 15 mg/l of total organic carbon TOC (Lauer et al., 1985); and this can alter microbial processes essential to soil mineral balance. Domestic water contents high nitrogen content (over 85 mg/l) due to urine and other components (Bitton, 2005) and tomato plants requires basic nutrients especially N-P-K at moderate rates and a pH ranging between 7 and 9. A change of those nutrients applied at extreme rates can affect plant productivity (Niassy et al., 2010). Plots irrigated with tap water performed better development at T_3 (tap water and fertilizer) which suggest previous investigations of soil quality before any agricultural practice. However, use of wastewater with moderate amendment on lettuce showed better results than tap water. These observations suggest that analysis prior to planting can provide guidance to farmers on the selection of the best type of crop.

The presence of coliforms is considered as an indicator of faecal contamination (Gerardi and Zimmerman, 2005). As such, one of the major concerns about the use of wastewater is the public health aspect. The mode of irrigation seems to affect crop hygienic quality (Ndiaye et al., 2010a). In this study, the lettuce was highly contaminated with streptococci and faecal coliforms as compared to tomato. But the mode of irrigation did not affect the heavy metal content. This means that, the choice of crop in relation to the use of wastewater in urban agriculture is crucial.

Wastewater can be a promising alternative to tap water in the agricultural irrigation system in Senegal. Although it has high agronomic potentials, the reuse of wastewater in urban agriculture should be formally regulated with adequate policies to prevent health risks. Due to its loads in heavy metals and parasites, precautions and sanitary measures are required to protect farmers and consumers. This study suggests

complementary studies such as soil analysis and wastewater quality assessment prior to cultivation.

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