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Yields, Quality and Metal Accumulation of Chinese Cabbage Irrigated with Diary Effluent

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Abstract: In order to investigate the short-term effects of wastewater (dairy effluent) and EM treated wastewater on cabbage quality (vitamin C, nitrate), yield, Nitrogen (N) and Phosphorous (P) uptakes and heavy metals (i.e., Hg, Pb and Cd) accumulation in Cabbage, field experiments were conducted with the following irrigation treatments: Clean Water (CW), Waste Water (WW), Reclaimed Water-EM treated wastewater (RW), Clear Water-wastewater rotation (C/W) and clear water-treated wastewater rotation (C/R). The results showed that: yield of cabbages, concentration of total N and P in cabbages could be improved in treatment irrigated with both untreated and EM treated dairy effluent, especially in treatments RW and C/R. Heavy metals in cabbages irrigated with/without dairy effluent showed non-significant difference. The highest nitrate was obtained with C/W treatment and the lowest was obtained with the RW treatment. With integrate comparative study of nutrition, nitrate and heavy metal, EM treated dairy effluent is more suitable to irrigate cabbage than raw dairy effluent. And the cabbages under RW and C/W treatment grew better than other treatments. It is suggested that the EM treated wastewater can be used as a safe alternative for irrigation of cabbages edible.

Keywords: Effective microorganisms, food quality, heavy metal, reclaimed water, wastewater irrigation

INTRODUCTION

Water is essential in food production, especially for vegetable. With increasing municipal and industrial demands for water, allocation for agriculture is decreasing steadily. Therefore, there is an urgent need to conserve and protect fresh water and to use the water of lower quality for irrigation (Li *et al*., 2009; Yi *et al*., 2011; Xue *et al*., 2012). The treated wastewater, which is less expensive, is considered as an attractive source of irrigation water and the interest in reusing wastewater for irrigation is rapidly growing (Singh *et al*., 2004; Hassanli *et al*., 2009; Bedbabis *et al*., 2010). Wastewater from livestock is considered much more suitable for irrigation than municipal or domestic sewage, since it is rich in nutrients of Nitrogen (N) and Phosphorus (P) and with less toxic substance (Wang *et al*., 2004). Researches reported that livestock wastewater can improve growth, yield and quality of plant and can increase soil fertility (Hawke and Summers, 2003; Marmiroli *et al*., 2012). On the contrary, livestock wastewater may contain undesirable chemical toxics and pathogens that pose negative environmental and health impacts (Wang *et al*., 2004; Liu and Haynes, 2012). Therefore, management of livestock wastewater irrigation should consider the wastewater nutrient and toxic content, specific crop nutrient requirements, soil nutrient content, soil pollution status and other soil fertility parameters.

Effective Microorganisms (EM), a mixture of groups of organisms including Lactic acid bacteria, Photosynthetic bacteria, Yeasts and Fermenting fungi as a multi-culture of coexisting anaerobic and aerobic beneficial microorganisms (Higa, 2004), have a number of successful applications, including agriculture, livestock, gardening and landscaping, composting, bioremediation, algal control and household uses (Jin *et al*., 2005; Safalaoh, 2006; Ekpeghere *et al*., 2012; Hu and Qi, 2013). If EM treated waste water from livestock or aquaculture is economical and safe to be used for irrigation on vegetables, it is at present far from clear. The objectives of the current research conducted on EM treated dairy wastewater reuse in agriculture, with Chinese cabbage as case, focus mainly on its short-term effect on plant growth, yield, nutrients uptakes, vegetable quality and heavy metal pollution risks, as well as the effect of treated waster-clear water rotation irrigation.

MATERIALS AND METHODS

Site description and experimental design: Field experiments were carried out in Nanjing Banqiao Agricultural Ecological Garden (31° 56'N, 118° 37'E).

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Table 1: The average quality characteristics of untreated and effective microorganisms (EM) treated dairy effluent

Item	NO_3^- -N (mg/L)	NH_4^+ -N (mg/L)	EC (μs/cm)	pH	TP (mg/L)	TN (mg/L)	COD_{cr} (mg/L)
Dairy effluent	28.66~49.72	0.33~3.29	532~746	7.86~8.49	5.6~10.2	39.5~50.6	2740~5180
EM Treated dairy effluent	7.94~22.43	15.62~25.57	142~198	7.41~7.69	4.8~8.9	33.9~42.7	357~2130

Table 2: Fresh yields of Chinese cabbage and irrigation water volumes

Treatments	CW	WW	RW	C/W	C/R
Yield (kg/ha)	49475a	50373a	51576a	51208a	51827a
Irrigation volumes (mm)	50.7a	47.6 a	46.9 a	47.1a (32.8)	46.3 a (32.0)

Treatment means with the same letter are not significant at the p≤0.05 level; Data in bracket is the volumes of waste water or treated waste water in rotation treatment of C/W and C/R

The climate is subtropical monsoon climate, with 15.7°C of annual average temperature and 1,106.5 mm of annual average rainfall. The ground water depth is ranged from 30 cm to 150 cm. Soil type is yellow brown soil, 0~20 cm topsoil is clay loam, with bulk density of 1.32 g/cm^3 and field capacity of 0.3478 (v/v). Soil organic matter, Total N (TN), Total P (TP), available N, available P, available potassium contents is 10.20 g/kg, 1.31 g/kg, 0.194 g/kg, 90.44 mg/kg, 101.53 mg/kg, 41.7 mg/kg, respectivly. The soil electronic conductivity is 118 μs/cm. Chinese cabbages, variety of Aijiaohuang, were transplanted at 23 September and harvested at 24 November in 2006. The planting density was 100,000 per hectare, with row spacing and plant spacing of 0.3 m. *Organic-inorganic compound* fertilizer (N, P_2O_5 and K_2O are 10, 4 and 6%, organic matter contents≥20%) in dose of 250 kg/ha was applied pre-transplanting.

There were five irrigation treatments: Waste Water (WW) treated waste water (RW), clear water-waste water rotation (C/W) and clear water- treated waste water rotation (C/R), Clear Water (CW). Upper and lower thresholds for irrigation were 90 and 70% of field capacity. Each treatment was replicated 3 times, with a total of 15 experimental plots (14 m^2 = 7 m×2 m). All experimental plots were arranged randomly, with 1 m width buffer isolated zone between the plots to avoid water and fertilizer interpenetrating.

Irrigation water quality: Waste water was collected from the dairy and treated with EM technique, followed the following procedure. First dairy waste water was mixed with EM solutions, molasses and clear water, with the proportion of EM solution: molasses: waste water: clear water = 2:2:5:91 and rejuvenated for ten days to acquire EM activated solution. Then dairy waste water was treated with EM activated solution at the ratios of EM activated solution: waste water of 1:100. Table 1 summarizes the average quality characteristics of untreated and treated dairy effluent used for irrigation.

Field observation: Field soil moisture contents were measured by oven-dry (105°C for 24 h) method, at intervals of 5 days. Above ground vegetables were collected and fresh yield were determined. Contents of nitrate in fresh sample were determined by the of method nitrification for salicylic acid (Cataldo *et al*., 1975). Vitamin C levels were measured with Spectro photometrically (UV-1600) by the method in which 2, 6-dichlorophenolindophenol dye is reduced by ascorbic acid (Nursal and Yücecan, 2000). Three samples were selected and washed with distill water, before those were dried up in oven under 70°C for 48 h. Dried samples were crushed into powder. The dry plant samples were digested by Kjeldahl method and the TN and TP contents were determined by AA3 automated colorimeter (Norderstedt, Germany). Pb, Cr contents were measured in the dry ash digestion by Atomic Absorption Spectrophotometer (Chapman and Pratt, 1961) and Hg contents by using cold-vapor atomic absorption method (Welz and Schubert-Jacobs, 1988).

RESULTS AND DISCUSSION

Yields and irrigation volumes: Fresh yields of Chinese cabbage for different treatments are listed in Table 2, as well as seasonal irrigation water volumes. Irrigation treatments with different water quality did not result in significant difference in irrigation volumes and fresh yields of Chinese cabbage. For different treatments, irrigation volumes ranged from 46.3 to 50.7 mm and fresh yields ranged from 49,475 to 51,827 kg/ha. Fresh yield of Chinese cabbage for C/R treatment was the highest and followed by RW, C/W, WW and CW treatments sequentially. They were increased by 4.25, 3.50, 1.82 and 4.75% for RW, C/W, WW and C/R treatments, respectively, compared with yields for CW treatment. So EM treated dairy wasted water was helpful to improve vegetable yields, due to effect of effective microorganisms on soil fertility and soil environment. Rotation irrigation with Clear Water and Waste Water (C/W) and rotation irrigation with clear water and treated wastewater (C/R) were also helpful to improve vegetable yields. That might attribute to high nutrients availability under C/W and C/R rotation.

Vitamin C contents: Vitamin C (Vc) is an important index for vegetable quality and storage stability. Vc concentration in cabbage of different treatments is showed in Table 3. Vc in Chinese cabbage for RW treatment was the highest and followed by WW, CW, C/R and C/W treatment sequentially. Vc content for

Table 3: Vitamin C and nitrate concentration in cabbage plant with different irrigation treatments

Treatments		RW	WW	CW	C/R	C/W
Vc (mg/g FW)		32.10a	29.89a	24.51b	24.48b	23.24b
Nitrate/	Leaf lamina	122.99d	139.43bc	144.15ab	113.10d	157.45a
(mg/kg FW)	Leaf petiole	475.25d	691.23bc	768.42ab	516.75c	841.73a

FW means fresh weight; Treatment means with the same letter are not significant at the $p \leq 0.05$ level

Table 4: Total nitrogen, total phosphorous and heavy metals contents content in cabbage with different irrigation treatments

Treatments	CW	WW	RW	C/W	C/R
TN (g/kg DW)	30.96 b	37.57 ab	38.44 ab	42.50 a	43.40 a
TP (g/kg DW)	5.135 a	5.255 a	5.565 a	5.275 a	5.360 a
Hg (mg/kg DW)	0.0034a	0.0036a	0.0039a	0.0034a	0.0036a
Cr (mg/kg DW)	0.3079a	0.2859a	0.3798b	0.2608a	0.4730b
Pb (mg/kg DW)	0.1692a	0.1549a	0.1652a	0.1440a	0.1740a

Treatment means with the same letter are not significant at the $p \leq 0.05$ level; DW means dry weight

RW and WW were increased by 31.00 and 21.95% compared with CW treatment. There were significant difference between treatments RW, WW and treatments CW, C/R, C/W. It suggested that irrigation with EM treated wastewater maybe improve the cabbage quality and Vc content is proportional to wastewater amount.

Nitrate content: Cabbage is a kind of leafy green vegetable that easy to accumulate nitrate, which are potentially harmful to humans. Table 3 showed that the nitrate contents in cabbage leaf blade are much higher than that in petiole. In general, all values were far below the limit (3600 mg/kg) established by China for nitrate content in non-pollution fresh vegetables (GB18406.1-2001). The nitrate contents of leaf lamina in different treatments are in the order of C/R＜RW＜WW＜CW＜C/W and the nitrate contents of leaf petiole are in the order of RW＜C/R＜WW＜CW＜C/W. The highest nitrate level was observed in the C/W treatment. It is maybe due to there was more ammoniacal nitrogen in the dairy effluent than nitrate nitrogen in wastewater, especially in treated dairy effluent and EM might help to reduce nitrate content of plant.

But some other reports argued that domestic and municipal wastewater irrigation increased nitrate concentration in plant. Papadopoulos and Stylianou (1988) reported that the NO_3-N in petioles and lamina, during the third irrigation season for trickle irrigation cotton, was greater with the treated effluent supplemented with no nitrogen fertilizer. Xue *et al*. (2011) reported found that the nitrate concentration in cucumber and tomato fruits irrigated with treated urban sewage was increased by 5.3% and 32.9%, respectively, but still lower than the state food safety standard of China. And other researches reported nitrate in plant is proportional to land nitrogen application (Zhang *et al*., 2004). Therefore, nitrate content should be monitored periodically when vegetable is irrigated with dairy effluent, to avoid its accumulation to critical levels that might affect its quality for food.

Nitrogen and phosphorus uptakes: N and P uptakes for Chinese Cabbage are listed in Table 4. As essential nutrient, N and P were higher in plants grown in soils irrigated with wastewater and treated wastewater. That meant nutrients in dairy waste water and treat dairy waste water were available to cabbage. Nitrogen content increased 21.4, 24.2, 37.3, 40.2% in WW, RW, C/W and C/R treatment respectively compared the CW treatment. It indicated that wastewater application provided the soil with these nutrients which enhanced required for plant growth and soil fertility (Rusan *et al*., 2007; Day *et al*., 1979). Nitrogen concentration can increased evidently in the soil irrigated with dairy effluent (Barkle *et al*., 2000; Hawke and Summers, 2003; Wang *et al*., 2004). The results also indicated that rotation irrigation promoted nitrogen release from soil. There was no significant difference in phosphorus concentration between the control and the treatments irrigated with wastewater and EM treated wastewater. However, other researchers reported an increase in P uptake by the plants irrigated with dairy effluent (Marmiroli *et al*., 2012; Wang *et al*., 2004).

Heavy metals in vegetables: Usage of dairy effluent can create problem of accumulation and transfer of heavy metals in the soil-crop systems, which are mainly derived from the animal diet and from disease prevention or treatment (Bolan *et al*., 2003). The heavy metals (Hg, Pb, Cr) in the plants are shown in Table 4. Metals levels were much lower than the safe recommended values (GB2715-2003). And there was no significant difference among five treatments. However, the content of Cr in plant irrigated with EM treated wastewater was higher than other treatments; one possible explanation is that the microorganisms in EM led to change in binding forms and bioavailability of Cr which enhanced crop uptake. Although, these concentrations remain within the acceptable level for food safety in current research, regularly monitory should be done when wastewater is used for irrigation in long-term.

CONCLUSION

This study aimed at examining some quality attributes of cabbage irrigated with dairy effluent. Results showed that that cabbage yield increased in treatments irrigated with treated/un-treated wastewater compared with clean water, especially the cabbage irrigated with EM treated wastewater. Results also indicated that crop quality parameters were affected by wastewater irrigation and the management of wastewater irrigation. The lowest nitrate but highest Vitamin C was obtained within the EM treated dairy effluent irrigation treatment. In general, the cabbages under EM treated wastewater irrigation and clear water-treated wastewater rotation irrigation grew better than other treatments. It is suggested that the treated wastewater can be used as a safe alternative for irrigation of cabbages eaten cooked. However, it needs a continuous monitoring of the effluent quality to avoid metal contamination in both soil and crops.

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