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Biometric properties and selected chemical concentration of cauliflower influenced by wastewater applied through surface and subsurface drip irrigation system

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ABSTRACT

The necessity of municipal wastewater reuse for irrigation has become imperative for water scarce countries. It is also supportive to limit the environmental pollution. Field experiment was conducted to investigate the biometric properties of the cauliflower crop and its chemical concentration. To limit the entry of heavy metal elements into the food chain, crop was irrigated through drip irrigation system with municipal wastewater. It was treated though three different type filtration processes viz., sand media type, disk type and combined sand media and disk type filters under surface and subsurface placement of drip laterals. Highest leaf area index and curd yield was recorded under subsurface placement of drip laterals at 15 cm depth but highest root length density was recorded under subsurface placement of drip laterals at 30 cm depth. The curd yield was increased by 5% under municipal wastewater irrigation with the saving of 28.3%, 21.1%, and 38.3% of Nitrogen, Phosphorus, and Potassium nutrients, respectively, over groundwater use. Significantly higher concentration of heavy metal elements Arsenic, Cupper, Chromium, Iron, Manganese, Lead, and Zinc was recorded by using municipal wastewater for irrigation over groundwater. However, concentration of all the heavy metals found in the curd of cauliflower was lower than their permissible limit as prescribed by the Food and Agriculture Organisation/World Health Organisation and Indian standards. This study provides an opportunity to utilize municipal wastewater through subsurface placement of drip laterals. It will protect our environment from wastewater pollution with the saving of inorganic fertilizers and fresh water that can be utilized in other priority sectors.

1. Introduction

Water is becoming an increasingly scarce resource in the world, especially in arid and semiarid regions, such as India, China, Spain, south eastern Australia and western USA (Rouphael et al., 2008). In the scenario of scarce water resources minimizing its use in horticulture, while maintaining produce quality and yield, has become a critical issue in some areas due to depletion of groundwater resources and a dramatic decline in rainfall over the past decade, possibly due to climate change. The increased demand of fruit and vegetables outside their normal production period has increased crop value and the profitability of using irrigation (Costa et al., 2007). Avoiding excessive water applications during irrigation is also a necessary step in reducing the contamination of groundwater with excess nutrients, nitrates and pesticides (Burt et al., 2009). However, a major challenge for horticultural producers is the increasing competition for water from urban and industrial users (Scarpare et al., 2015). Water supply and water quality degradation are the global concerns that will intensify further with increasing water demand. Worldwide, alternate water resources with marginal-quality water are needed to fulfill the increasing demand of agricultural water supplies, particularly in water-scarce countries (Qadir et al., 2010).

Municipal wastewater (MWW) is one of the major water resources available in urban and peri-urban areas. It has been recycled in agriculture for centuries as a means of disposal in cities such as Berlin, London, Milan and Paris (AATSE, 2004). However, in recent years wastewater has gained importance in water-scarce regions. In Pakistan 26% of national vegetable production is irrigated with wastewater (Ensink et al., 2004). In Hanoi 80% of

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vegetable production is from urban and peri-urban areas (Lai, 2000). In Ghana, informal irrigation involving diluted wastewater from rivers and streams occurs on an estimated 11,500 ha, an area larger than the reported extent of formal irrigation in the country (Keraita and Drechsel, 2004). In Mexico about 260,000 ha are irrigated with mostly untreated wastewater (Mexico CAN, 2004). Wastewater treatment plants are neither existent nor function adequately in lower stretch of the river Ganges, east coast of India (Sarkar et al., 2007) and most of the cities in developing countries (Qadir et al., 2010). Therefore, wastewater is an alternative and reliable water source for irrigation (Ensink et al., 2004). It is used by urban and peri-urban farmers to grow a range of crops (Murtaza et al., 2010). Use of wastewater for irrigation provides an opportunity for its disposal, and saving of inorganic nutrients but it poses threat to consumers from harmful pathogens, and accumulation of toxic elements.

In India, scarcity of good quality water resources, throughout the year and easy availability of wastewater without any legislation attracts the farmers for its use to produce vegetables in outskirt of cities. Generally farmers are using primitive and unscientific irrigation practice like flood or furrow irrigation technique. It requires more water in comparison with localized drip irrigation method. Long-term application of wastewater accumulates heavy metal elements in the soil at toxic level (Bohn et al., 1985). It is not appropriate for sustainability of the soil system. When capacity of the soil to retain heavy metal elements is reduced due to repeated use of wastewater, soil starts releasing heavy metals into groundwater or soil solution available for plant uptake; consequently, they go to the plants and cause their eventual entrance into the food chain. It is prudent to use drip irrigation method so that limited amount of water can be applied to reduce the soil as well as crop contamination. Kiziloglu et al. (2008) by conducting experiment with flood irrigation concluded that primary treated wastewater can be used in sustainable agriculture in the long term. Therefore it is becoming increasingly important to adopt efficient water application method like drip irrigation system for utilization of MWW (Turral et al., 2010). It is also important to minimize the contamination in agricultural production system. Drip irrigation system provides highest water application efficiency (80–90%) at field level with minimum water losses. Drip irrigation system with subsurface placement of drip laterals provides other associated advantages like elimination of surface runoff, weed control (Oron et al., 1999), reduction in water loss due to evaporation, reduction in crop contamination and protection of the environment with no risk of contamination through aerosol (Tripathi et al., 2014).

Utilization of wastewater through surface and subsurface drip irrigation system leads the problem of emitter clogging. It depends upon the quality of wastewater, types of emitter, filtration system and environmental condition. It is usually the result of two or more of these elements working together (Nakayama et al., 1978). Study about extent of emitter clogging to utilize wastewater through drip irrigation system was conducted by many researchers (Tripathi et al., 2014) with the common view that role of filters are important to combat the problem of emitters clogging. Capra and Scicolone (2007) recommended that screen filter is not suitable for filtration of wastewater. They have also reported almost similar performance by disk and sand media filter with treated municipal wastewater. Tripathi et al. (2014) concluded that combination (gravel media and disk) filter would be the most appropriate strategy against emitter clogging with good coefficient of variation for continuous use of wastewater.

India is second largest producer of cauliflower (*Brassica oleracea* L.) in the world. It is the extensively grown vegetable in peri-urban areas. Its annual production was 7.8 Mt in the year 2013 (DES, 2014) and having a share of around 25% of the global production (FAO, 2016). Water footprints for cauliflowers were estimated as 189 $m^3\ t^{-1}$ for green water, 21 $m^3\ t^{-1}$ for blue water, 75 $m^3\ t^{-1}$ for grey water, and 285 $m^3\ t^{-1}$ for total water (Mekonnen and Hoekstra, 2011). Contribution of poor quality water in production of cauliflowers will increase further. Quality of cauliflower (in terms of chemical concentration) produced with wastewater but without drip irrigation system has been studied by many researchers. Singh et al. (2009) studied by applying wastewater through flood irrigation method in controlled manner. Sharma et al. (2009) studied chemical concentration of cauliflower collected from market without sufficient information of irrigation method. Singh and Kumar (2006) applied wastewater through surface irrigation method in uncontrolled manner. Study on long term wastewater application through flooding method was also done by Sinha et al. (2006). But no studies have been published on the impact of wastewater irrigation under surface and subsurface placement of drip laterals on biometric properties and chemical concentration of cauliflower. In view of the increased compulsion of using wastewater for irrigation and the likelihood of drip irrigation in minimizing the adverse impact on the quality of produce, the present study was undertaken. The objectives of this study were to (i) investigate the effects of surface and subsurface placement of drip laterals on leaf area index, root length density and yield of cauliflower and (ii) compare the chemical concentration available in the curd of cauliflower produced under wastewater application with FAO/WHO and Indian standards.

2. Material and methods

2.1. Study location

The field experiment was conducted at the research farm of Precision Farming Development Centre, Water Technology Centre, Indian Agricultural Research Institute, New Delhi, India (Latitudes of 28°37′22″ N and 38°39′05″ N and longitudes of 77°8′45″ E and 77°10′24″ E and mean sea level (MSL) +228.61 m during the month of October–March 2009–2010 and 2010–2011). The coldest month was January with a mean temperature of 14° C however; the minimum temperature dips to as low as 1° C. Frost occurs occasionally during month of December and January. The mean relative humidity was 34–98 per cent and mean wind speed was 0.5–4.0 $m\ s^{-1}$ (Tripathi et al., 2014).

2.2. Irrigation water sampling and analysis

MWW was collected from the drain passing through Indian Agricultural Research Institute, New Delhi. The groundwater (GW) was collected from the tubewell which provides water from more than 28 m below the ground level. Water from the drainage channel and tubewell both were used for irrigation of cauliflower crop. Both type of water samples were analyzed for physicochemical and biological properties. The water samples analysis was done for pH, electrical conductivity (EC), turbidity, calcium, magnesium, carbonate, bicarbonate, chemical oxygen demand (COD), biological oxygen demand (BOD_5), nitrogen (N), phosphorus (P), potassium (K), arsenic (As), copper (Cu), chromium (Cr), iron (Fe), manganese (Mn), lead (Pb), and zinc (Zn) using standard methods of determination (Tandon, 2005).

2.3. Soil of experimental field

Soil samples were collected upto the depth of 60 cm with 15 cm intervals. To determine soil texture sand, silt and clay percentage was estimated by using mechanical sieve analysis and hydrometer method (Tandon, 2005). The soil of the experimental field was