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Wastewater Use for Corn and Bean Crops

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Abstract: The global demand for water for agricultural use is continuously increasing worldwide as a result of population growth and food supply, approximately 1% per year since the 1980s. Irrigated agriculture represents 20% of the total cultivated area and contributes 40% of the total food production worldwide. Competition for water resources is particularly much needed in arid and semi-arid regions, where irrigation is essential for successful agriculture. This leads to the need to treat larger amounts of wastewater, in order to compensate for the lack of rainwater to irrigate crops and thus favor the environment and the economic development of farmers. In Mexico there are two highly consumed food products, they are: corn and beans, a fundamental part of the Mexican people diet. It can be said that corn is basic in the diet of Mexicans, it is consumed mainly as "tortilla" and in "tamales", also in some stews; there is a variety called fodder corn to feed cattle. Beans are also an essential part of the Mexican diet for its nutritional value and pleasant flavor. To solve the challenges of the future in the supply of water for agriculture, it is necessary to reconsider that not all farmers can afford irrigation systems and depend on rainwater, so the use of treated wastewater in treatment plants can be useful.

Key words: Corn, beans, wastewater treatment.

1. Introduction

The human being in its growth, demographic, technological and scientific, has not made sufficient efforts to sustainably preserve natural resources. Within such resources, water is one of the essential and vital for all forms of life, but every day this precious liquid for human use is scarcer due to multiple factors associated with population growth, impacting agriculture, livestock, urbanization and industrialization; direct and indirect causes of climate change [1].

In Mexico the main crop is corn since it is essential in the diet of Mexicans, consumed as tortillas, tamales and some stews. It is also used for syrups, sweeteners, flour and a host of processed foods, in addition there is a variety that is cultivated mainly for cattle and bovine fodder.

Beans are the main legume crop because they are also an important part of the Mexican people diet.

Most of these two products are planted on rainfed land, that is, they are subject to the rainy season that varies according to the weather. Both crops require water for planting and growth.

Lately with climate change, the rainy season is more uncertain in its periodicity.

Every day the demand for agricultural and livestock products is greater since the human and animal population increases daily. In Mexico currently the use of water for agricultural irrigation represents between 76% and 80% of drinking water, which will increase in the future and there will be special requirements for agricultural and livestock production [2].

Irrigation systems, including drip irrigation, are used by farmers who have the economic capacity to install it. Temporary irrigation depends on the rainy seasons, being irregular, sometimes it rains enough and in others there are prolonged droughts, as it has been this year 2023 in Mexico.

Contamination of water, air, soil and food is a collateral consequence of the activities that man has developed to live and improve his quality of life.

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Currently, about 80% of wastewater is disposed without treatment for agricultural irrigation, representing a significant health problem due to the presence of pathogenic and toxic elements.

In Mexico there are wastewater treatment plants that are mainly reused in industry.

The treatment and use of wastewater constitutes a challenge, because it is a viable alternative that farmers who do not have access to drinking water can count on, so it becomes a valuable resource from the economic and environmental point of view.

2. Methodology

2.1 Corn

Maize is one of the main cereals in the world, it is of great importance as a staple food, mainly in developing countries due to its nutritional value; Likewise, a variety is used as a forage grain [3]. Mexico ranked fifth worldwide with 4.5% of the total harvested area [4]. Corn is the most representative crop in Mexico due to its economic, social and cultural importance, with an average per capita consumption per year of 433 lb. (196.4 kg) of white corn, especially in tortillas; it represents 20.9% of the total expenditure on food, beverages and tobacco made by Mexican families.

Corn is in the form of a cob, the grain is a flattened caryopsis. Its high carbohydrate and protein content make it the ideal cereal for every day.

Corn is very sensitive to water shortages during the flowering phase and early pomegranate; between 60 and 95 days after sowing.

2.2 Bean

Beans belong to the Fabaceae family, Papilionoideae subfamily, Phaseolae tribe, and *Phaseolus vulgaris* L. species. Due to its high protein content 20%-25%, it is the third most important crop in the world among legumes, after soybeans and the peanut [5]. A regular intake of beans helps lower cholesterol levels and reduces the risk of cancer [6]. Particularly in Mexico, bean is the legume with the highest human consumption and represents 36% of the daily protein intake.

Beans belong to the type of annual or cyclical crop, which is one whose vegetative period is less than 12 months and a new planting is required to obtain a harvest. These are concentrated in two productive periods: Spring/Summer and Autumn/Winter. They have the advantage of being able to sow and plan the crop, so you can change crops when you want [7].

It is said that the bean is native to America, currently around 150 species of beans are known, of which 70 are found in Mexico [7]. There are various kinds of beans such as black, yellow, white, purple, bay, pinto and speckled. Beans contain complex B, thiamine, riboflavin, niacin, folic acid and are an important source of iron, magnesium, potassium, zinc, calcium and phosphorus, ideal for a healthy and balanced diet for Mexicans who consume more than one million ton. every year.

Like all legumes, beans have the ability to associate with soil bacteria called rhizobia (singular rhizobium).

2.3 Wastewater Treatment

Wastewater treatment plants are facilities that are responsible for cleaning wastewater from toilets, sinks, bathtubs, mainly in residential homes, and from some industries. They are an integral part of the sanitation process to care for health in a community. Wastewater is collected to be processed with different processes and machines. During the treatment process at the plant, as many bacteria and contaminants as possible are removed from the water, before it is reused.

In general, wastewater contains substantial amounts of beneficial nutrients such as N, P and K that can promote plant growth and yield as they also contain Fe and Zn [8], in addition to reducing the demand for chemical fertilizers [9]. Therefore, the careful use of wastewater can reduce the application of fertilizers, economic and environmental costs, reduce the content of toxic elements such as heavy metals that cause problems for agricultural production [10, 11] and therefore of consumers.

The content of heavy metals in irrigation water can result in the degradation of the physical and chemical properties of the soil [12]. Excessive accumulation of these metals in agricultural soils through irrigation with untreated wastewater can result in soil contamination and also lead to high uptake of heavy metals in crops, and therefore affect the quality and safety of crops food [13].

3. Materials

3.1 Corn

In months with high temperatures and less rainfall, the water requirements of well-grown maize plants can reach 2.36 in. (60 mm) per week, approximately 0.53-0.80 gal. (2-3 L) per day. An irrigated crop in the dry season will require between 5 and 7 tons of water per hectare, while for the entire growing season the total amount fluctuates between 14.82-22.23 acres (6-9 tons) of water per hectare.

This practice prevails because it provides many benefits to the agricultural system such as increased yield, efficient use of labor, decreases the risk of production in the presence of adverse environmental factors, reduces weed, pest and disease problems, increases levels of nitrogen available in the soil, reduces the need for synthetic fertilizers, achieves a balance in nutrient consumption, avoids the dominance of the same type of root exudate that inhibits the growth of other crops, reduces soil erosion and helps to maintain the sustainability of soils [14]. In addition to providing different products for self-consumption that allow complementing the diet of the family unit.

3.2 Bean

Mexico is known as the primary center of bean domestication and genetic diversity. This legume represents 36% of the daily protein intake of the Mexican population.

In the highlands of Mexico, rainfed beans are of great social and economic importance. Some of the problems faced in its production is that 90% of the planted area is rainfed, so it is a crop highly affected by recurring drought problems; condition that has reduced the volume of production.

Drought, physical deterioration and the low level of soil fertility limit its production. Irrigation must be managed in an integral way, that is, consider all the factors that determine crop water demands, such as: phenology, soil, climate, and crop management. In general, for the early dates from October 1 to 10, three types of auxiliary irrigation are recommended, applied at 29, 49 and 66 days after planting, respectively, with an average net irrigation requirement per aid of 2.36 in. (6 cm), which represents a volume of 131,981.5 gals/acres (600 m^3/ha). The variations and intervals and irrigation requirements in the different sowing dates, are a clear sample of the influence of the climate in the development of the crop. Excess moisture should be avoided, which may favor the proliferation of disease-causing pathogens.

Traditionally and for hundreds of years, the Mexican farmer has planted in his chinampas and milpas, in a combined way, beans and corn. The corn stalk supports the bean vine and this, in turn, fertilizes the soil, favoring a greater production of the cereal. This ecosystem (the milpa), where maize, beans and squash are traditionally planted, as well as chili and tomato, constitutes a model of ecological agriculture which favors biological control of insects in addition to the aforementioned biological fixation of nitrogen. The nutritional characteristics of each of these crops, added together, produce a balanced diet.

3.3 Wastewater Treatment

There are different types of wastewater treatment plants, with different processes and therefore their cost. The following can be mentioned: System of rotating discs, activated sludge, submerged aerated filters and sequential batch reactors.

The one that operates with a rotating disc system only removes sludge once every 12-18 months, which can help save time, effort, and cost.

3.3.1 Activated Sludge Plant

These plants use oxygen and microorganisms to clean and sanitize wastewater. They work by oxidizing contaminants, which creates a thick, sludge-like substance.

3.3.2 Submerged Aerated Filter (SAF) System

These treatment plants are one of the simplest systems that exist. A submerged aerated filter system requires very little maintenance and has only a few moving parts, making it very easy to keep running. This type of wastewater treatment plant is also known as a SAF system. It is a great option for plants looking to reduce overhead without affecting the sanitation process.

3.3.3 Batch Sequential Reactors

This system is one of the most flexible types of wastewater treatment plants and treats wastewater through a series of steps. However, each of the steps takes place in the same tank, reducing the need to transfer wastewater. The reason why this system is so popular is its flexibility. A sequential batch reactor wastewater treatment plant is capable of handling strong and dilute wastewater quite easily. In addition, these treatment plants usually have a lower carbon footprint, another great advantage of this type of wastewater treatment plant.

4. Results

4.1 Corn

For its cultivation there is a noticeable difference in yields between producers who sow under rainfed conditions and those who use irrigation, indicating that the water resource is essential to increase yields per hectare.

In corn crops, 35% of producers planted corn associated with other crops, especially beans, broad beans and amaranth.

The percentage of producers that carried out crop rotation grew considerably, sowing corn alternately with legumes, beans, alfalfa, broad beans and barley.

From an agroecological approach, rotary crop management has greater respect for the environment where the agricultural system is developed, since according to Altieri [15] it tries to optimize the recycling of nutrients and organic matter, close energy flows, conserve water and soil and balance the populations of pests and natural enemies.

4.2 Bean

More than 570,000 producers in Mexico participate directly in its cultivation, it generates more than 382,000 permanent jobs, and the annual value of production is around 13 billion pesos.

The association between legumes and rhizobia comprises most of the 18,000 legume species and results in an ecologically important nitrogen-fixing symbiosis that contributes, annually, a quarter of the nitrogen fixed in the biosphere [16]. In the roots of the plant, the bacterium induces the formation of an organ called a nodule, within which it establishes itself intracellularly. Under these conditions, the bacterium is capable of converting atmospheric N^2 into ammonium NH_4^+, which constitutes the nitrogen source that allows plant growth. These nitrogen-fixing symbiotic associations between legumes and rhizobia fertilize the soil and it is estimated that they incorporate 132.27-264 lb. (60 to 120 kg) of nitrogen per hectare.

4.3 Wastewater

Agriculture is the largest consumer of water, since it represents 70% of annual water withdrawals worldwide, mainly for the production of food, fiber and for the processing of agricultural products [17].

In this regard, the reuse of treated wastewater in agriculture is an option that is being applied and adopted more and more in regions with water scarcity [18, 19].

It is considered that more than 10% of the world population consumes agricultural products grown by irrigation with treated wastewater.

5. Conclusions

Corn is currently the only crop present in all the States of the Mexican Republic, each Mexican consumes 321.9 lb (146 kg) per year on average, mainly in the form of tortillas. It is proposed to use water in a sustainable manner and its scope is less limited for human use, agriculture and livestock activities.

Beans rank 9th in export worldwide, contain B complex, thiamine, riboflavin, niacin, folic acid and are an important source of iron, magnesium, potassium, zinc, calcium and phosphorus, ideal for a healthy and balanced diet of Mexicans who consume more than a million tons each year.

The treatment of wastewater and the reuse of treated water, in addition to the economic benefit, has ecological benefits due to sustainable water management: reduction of the consumption of water resources for agriculture and industry and reduction of wastewater discharges to bodies of water.

With the increase in intensive agriculture and emphasizing that it is one of the largest users of water globally, it is essential to find sustainable solutions [20].

Technical solutions are essential to take advantage of wastewater as a valuable resource for agricultural production, aimed at improving the use of reclaimed water, can help reduce the negative effects of water scarcity worldwide and improve the quality of life for all.

References

[1] Junguo, L., Hong, Y., Simon, N. G., Matti, K., Martina, F., Stephan, P., Naota, H., Yoshihide, W., Xinxin, Z., Chunmiao, Z., Alcamo, J., and Taikan, O. 2016. "Water Scarcity Assessments in the Past, Present, and Future." *Earth's Future* 5 (6): 545-59.

[2] Grant S. B., Saphores, J., Feldman, D., Hamilton, D. L., Fletcher, A. J., Cook, T. D., Stewardson, P. L. M., Sanders, B. F., Levin, L. A., and Ambrose, R. F. 2012. "Taking the 'Waste' Out of 'Wastewater' for Human Water Security and Ecosystem Sustainability." *Science* 337 (6095): 681-6.

[3] Oikeh, S. O., Kling J. G., and Okoruwa, A. E. 1998. "Nitrogen Fertilizer Management Effects on Maize Grain Quality in the West African Moist Savanna." *Crop Quality & Utilization* 38 (4): 1056-61.

[4] FAOSTAT. 2010. *Production. Corn Crops. Directorate of Statistics*.

[5] Singh, S. P., Gutierrez, J. A., Molina, A., Urrea, C., and Gepts, P. 1991. "Genetic Diversity in Cultivated Common Bean: II. Marker-Based Analysis of Morphological and Agronomic Traits." *Crop Breeding, Genetics & Cytology* 31 (1): 23-9.

[6] Miguel Lara Flores, The Bean Cultivation in Mexico. National Autonomous University of Mexico, Digital University Magazine. ISSN: 1607-6079.

[7] Secretary of Agriculture and Rural Development, Mexico Government Blog October 2022.

[8] Pereira, B., He, Z., Stoffella, P. J., Montes, C. R., Melfi, A. J., and Baligar, V. C. 2012. "Nutrients and Non-essential Elements in Soil after 11 Years of Wastewater Irrigation." *Journal of Environmental Quality* 41 (3): 920-7

[9] Carlsson, G., and Huss-Danell, K. 2003. "Nitrogen Fixation in Perennial Forage Legumes in the Field." *Plant and Soil* 253 (2): 353-72.

[10] Raveh, E., and Ben-Gal, A. 2016. "Irrigation with Water Containing Salts: Evidence from a Macro-Data National Case Study in Israel." *Agricultural Water Management* 170: 176-9.

[11] Turlej, T., and Banaś, M. 2018. "Sustainable Management of Sewage Sludge." In *Proceedings of the E3S Web of Conferences*, 13 August 2018.

[12] Assouline, S., Russo, D., and Silber, A. 2015. "Balancing Water Scarcity and Quality for Sustainable Irrigated Agriculture." *Water Resources Research* 51 (5): 3419-36.

[13] Muchuweti, M., Birkett, J. W., Chinyanga, E., Zvauya, R., Scrimshaw, M. D., and Lester, J. N. 2006. "Heavy Metal Content of Vegetables Irrigated with Mixture of Wastewater and Sewage Sludge in Zimbabwe: Implications for Human Health." *Ecosystems & Environment* 112 (1): 41-8.

[14] Harwood, R. 1974. "Farmer Oriented Research Aimed at Crop Intensification." In *Biodiversity and Pest Management in Agroecosystems*, edited by Altieri, A., and Nicholls, C. Vilassar de Dalt: Editorial Icaria.

[15] Altieri, M. 1994. *Biodiversity and Pest Management in Agroecosystems*. New York: Haworth Press.

[16] Jung, K., Jang, T., Jeong, H., and Park, S. 2014. "Assessment of Growth and Yield Components of Rice Irrigated with Reclaimed Wastewater." *Agric. Water Management* 138: 17-25.

[17] Weinzettel, J., and Pfister, S. 2019. "International Trade of Global Scarce Water Use in agriculture: Modeling on Watershed Level with Monthly Resolution." *Echo. Econ.* 159 (3): 301-11.

[18] Jaramillo, M. F., and Restrepo, I. 2017. "Wastewater Reuse in Agriculture: A Review about Its Limitations and

Benefits." *Sustainability* 9 (2): 1734-53.

[19] Hanseok, J., Hakkwan, K., and Taeil, J. 2016. "Irrigation Water Quality Standards for Indirect Wastewater Reuse in Agriculture: A Contribution towards Sustainable Wastewater Reuse in South Korea." *Water* 8 (5): 169-87.

[20] Taurus, F., Selker, J., Van de Giesen, N., Open, T., Uijlenhoet, R., Porfiry, M., Manfreda, S., Caylor, K., Moramarco, T., Benveniste, J., Ciraolo, G., Estes, L., Domeneghetti, A., Perks, M. T., Corbari, C., Rabiei, E., Ravazzani, G., Bogena, H., Harfouche, A., Brocca, L., Maltese, A., Wickert, A., Tarpanelli, A., Good, S., Lopez-Alcala, J. M., Petroselli, A., Cudennec, C., Blume, T., Hut, R., and Grimaldi, S. 2018. "Measurements and Observations in the XXI. Innovation and Multi-disciplinarity to Sense the Hydrological Cycle." *Hydrological Sciences Journal* 63 (2): 169-96.