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The impacts of magnetic treatment of irrigation water on plant, water and soil characteristics

Surendran U.*, Sandeep O., Joseph E.J.

Water Management (Agriculture) Division, Centre for Water Resources Development and Management, Kozhikode 673571, India

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ABSTRACT

Magnetic treatment has remained a controversial process for antiscale treatment of industrial and domestic water treatment over the past many years. Hence a study was initiated to evaluate the magnetic treatment of irrigation water on growth and yield parameters of cow pea and brinjal using pot and field experiments. Also, the impact of magnetic treatment on water properties and soil moisture were also evaluated. Under pot experiment, the treatments tried are normal water, hard water 150 and 300 ppm, saline water 500, 1000 and 2000 ppm of both control and magnetic treated solutions, respectively. Two permanent magnets with the strength of 1800–2000 G was used. The results showed that magnetic treatment of irrigation water types led to an improvement in crop growth and yield parameters of cow pea. Magnetic treatments tend to reduce electrical conductivity, total dissolved solids and salinity levels of all solutions except normal irrigation water, whereas a definite trend of increase in pH was noticed for all the treatments. Soil moisture study results showed that the differences in soil moisture for days 1–3 after irrigation with magnetized irrigation water were lesser than those for the control solutions. Irrigation with magnetized irrigation water caused higher soil moisture compared with the control for different solution of saline and hard water respectively. In the field experiment with brinjal also the magnetic treatment of normal and saline water improved the yield by 25.8 and 17.0% over control. Scanning electron microscope image analysis results confirmed that under magnetic treated hard water, there was variation in the crystal structure of calcium carbonate. The length of these crystals is more when compared to control solutions. These results indicated the beneficial effect of magnetically treated irrigation water on growth and yield of crops, the properties of water and confirmed the possibility of using low quality water for agriculture.

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1. Introduction

In India, agriculture is the largest (81%) consumer of water and hence more efficient use of water in agriculture needs to be top most priority (WRI, 2007). Agricultural water input per unit area will have to be reduced in response to current water scarcity, increasing competition from other sectors of water use and other environmental concerns (Surendran et al., 2014, 2016). Due to various reasons, water resources are being constantly under pressure and require a scientific approach to sustain the productivity of agricultural crops. Besides, the use of low quality irrigation water *viz*., high salinity, hardness and waste water, is gaining importance in Indian agriculture as well as in many other countries because of the water quality problems and due to the scarcity of good quality water. Hence, modern agricultural efforts are now in search of an efficient ecofriendly production technology for improving the crop productivity without harming the environment.

Magnetic water treatment is one such area, and the magnetic field applications have been known for centuries (Colic and Morse, 1999) Michael Faraday introduced the concept of induction as early as 1830, claiming that when a magnetic field flux is crossed by flow ions or a conductive material, electrical current is induced. Although magnetic field applications were rapidly pursued in order to prove Faraday's claim, attention from researchers and industrialists worldwide was still lacking (Zaidi et al., 2014) The first commercial magnetic device for water treatment was patented in Belgium by Vemeiren (1958).

Experiments have shown that water may be magnetized by a magnetic field, even though the magnetized effect is small (Amiri and Dadkhah, 2006; Chang and Weng, 2006; Ji et al., 2007; XiaoFeng and Bo, 2008) and researchers are trying to use the practical applications in different fields. Some of the earlier stud-

* Corresponding author.
E-mail address: u.surendran@gmail.com (S. U.).

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ies showed that, when water is exposed to a magnetic field, the magnetization of water changes its properties including optics, electromagnetism, thermodynamics and mechanics, for example, changes in the dielectric constant, viscosity, surface tension force, freezing and boiling points and electric conductivity compared with pure water. Thus, magnetized water has extensive applications in industry, agriculture and medicine (Fathi et al., 2006; Kney and Parsons, 2006; Maheshwari and Grewal, 2009; Selim and El-Nady, 2011; Teixeira da Silva and Dobránszki, 2014, 2016).

The review by Teixeira da Silva and Dobránszki, 2014; Zaidi et al., 2014, quotes that the practical application of using magnetic field on agriculture starting from seed treatment, germination studies, seedling development and yields of different species, such as agricultural, horticultural, herbs and medicinal plants, fodder and industrial crops have been reported. The results tend to be both positive and negative. The effects of magnetic field on plant growth and development depend on many factors of magnetic fields (MFs), such as polarity, intensity, exposure time, and magnet type. Since the observed effects were always genotype-dependent, all MFs should be tested individually before going in a larger scale.

Most of these studies, however, employed a static magnetic field on seed (Tanaka et al., 2010). However, some studies have employed magnetized water and found that it can improve water productivity and crop yield (Maheshwari and Grewal, 2009). These findings suggest that, there is a possibility of using magnetic treatment of water to improve the crop production even with the use of low quality water. Using of magnetic field treatment to improve plant growth is not so expensive, if we consider on long term basis and at the same time not hazardous to the environment. Using of low quality water is also gaining popularity in India because of water scarcity, spatially and temporally in the context of climate change associated impacts of drought. There is hardly any study reported in India, with valid scientific experiments, on the effects of magnetic treatment of water on crop yield and water productivity. However, some closely related studies conducted elsewhere have reported on some beneficial effects of magnetic field, and it has been referred herewith.

Review of literature suggests that water can be magnetized when exposed to a magnetic field (Turker et al., 2007; Pang and Deng, 2008; Maheshwari and Grewal, 2009). The beneficial effects of magnetically treated irrigation water have also been reported on germination percentages of seeds (Hilal and Hilal, 2000; Matwijczuk et al., 2012); emergence rate (Podleoeny et al., 2004), root growth (Turker et al., 2007), essential element uptake (Maheshwari and Grewal, 2009), and seed yield (Selim and El-Nady, 2011). Apart from these an increase in soil electrical conductivity (Maheshwari and Grewal, 2009), mobility of nutrients from fertilizers (Hozayn and Abdul Qados, 2010), water holding capacity of soil (Al-Khazan et al., 2011); and a reduction in soil pH, water viscosity (Chang and Weng, 2006), surface tension (Rashed-Mohassel et al., 2009), vaporization rate (Toledo et al., 2008), and pH of water (Fathi et al., 2006) were observed by all these researchers. Tomato seeds irrigated with magnetized water and magnetized seeds irrigated with magnetized water treatments were the best treatments for overcoming the bad effects of water deficit on tomato plant growth characteristics, water relations, proline concentration and photosynthetic pigments, as well as anatomical structure of some organs of tomato plants (Selim and El-Nady, 2011).

Similarly negative effects on MFs on the root growth of various plant species (Belyavskaya, 2001, 2004; Turker et al., 2007) were also reported. Turker et al. (2007) reported that weak magnetic field had inhibitory effect on growth of primary roots during early growth. Overall, it appears that the influence of magnetically treated water depends upon the plant species, the pathway length in the magnetic field, and the flow rate (Gabrielli et al., 2001).

According to Baker and Judd (1996), the effectiveness of magnetic field for water treatment applications is still a controversial question, and the relevant phenomena cannot be clearly explained. The mechanism of magnetic applications has not been completely confirmed scientifically by researchers. Many papers describe different types of magnetic mechanisms, and several of them are even in conflict with each other. Potential of magnetic field in various environmental engineering applications, specifically, in water and wastewater treatment systems have been widely studied. However, magnetic treatment has remained a controversial process for antiscale treatment of industrial and domestic water treatment over the past many years. While the increase in the number of commercial magnetic treatment devices might seem to be an indicator of the effectiveness of magnetic fields in the control of scale, independent review of the performance of these devices has been highly controversial. Claims have been made that magnetic fields change the physiochemical properties of water, or prepared laboratory solutions (Zaidi et al., 2014; Ali et al., 2014; Teixeira da Silva and Dobránszki, 2014 and 2016; Aliverdi et al., 2015; Hozayn et al., 2016).

But the reproducibility of both laboratory and industrial trials has been poor, and conclusions drawn on the basis of laboratory work have sometimes been criticized. Higher magnetic field intensity may halt the bacterial activity, thus causing an adverse effect to the treatment performance. The past studies have indicated that there are possibly some positive effects of magnetic field on plant growth and yield improvement. However, water treatment by magnetic field is still a controversial subject, because the reported results have low reproducibility and little consistence and seldom accepted by physicists. Besides, there is no clear understanding yet on the mechanisms behind these effects and the changes that magnetic treatment brings in water and in the plant and seedling growth. By keeping all these points, an attempt has been made to study the effects of magnetic treatment of irrigation water types viz., normal irrigation water, saline water and hard water and its influence on the growth and yield parameters on different crops; influence on soil moisture and water properties.

2. Materials and methods

2.1. Study site

The study area of Kozhikode district is located in Kerala State, which is in southern part of India and it lies between North latitudes 11°08′ and 11°50′ and East longitudes 75°30′ and 76°8′. The district has a humid climate with a very hot season extending from March to May. The most important rainy season is during the South West Monsoon which sets in the first week of June and extends up to September. The North-East Monsoon extends from the second half of October through November. The average annual rainfall is 3240 mm. During December to March, practically no rain is received and from October onwards, the temperature gradually increase to reach the maximum in March, which is the hottest month of the year. The moisture stress is experienced in this district for the period of 4–6 months. This study comprises of pot experiment under green house, field experiment for soil moisture studies, field experiment with brinjal and laboratory studies during the period of 2011–2014.

2.2. Magnetic treatment

A permanent magnet having Magnet gauss strength of 1800–2000 G was used for treating the water. It contains two permanent magnets that are 120 mm in length and 130 mm width, separated by a distance of 30 mm. A static non-uniform mag-

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