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Viewpoint

Poor quality water utilization for agricultural production: An environmental perspective

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ABSTRACT

Agriculture is the largest water user and consumes over 70% of the abstracted freshwater globally. The continuous increase in global population and simultaneous decrease in good quality water resources emphasize the need of using poor quality irrigation water for agricultural production. However, the injudicious use of poor quality irrigation water for crop production can be detrimental to the environment. Irrigation water quality has been considered as a serious environmental factor for the assessment of sustainable development during the last few decades. This paper highlights the need and advantages and disadvantages of long-term application of poor quality water on the soil and plant health. The overall environmental concerns of the approach are discussed in the paper which could be useful for all the stakeholders.

Background

The global population is rising continuously and is expected to touch the 9.5 billion mark in 2050 from the current 7.2 billion (United Nations, 2012). This increase in population needs about 60% additional foods to feed them (FAO, 2013). Against the backdrop, the sustainability of water resources is a critical issue for fulfilling the rising water demands of various competitive sectors including agriculture, which is the largest water user and consumes over 70% of the abstracted freshwater globally (Singh, 2015). The issue has become more challenging in the light of dwindling resource base due to urbanization, contamination, and climate change impacts. Furthermore, improved living standards (Mariolakos, 2007) and changing dietary habits make the issue even more severe. The properly managed irrigated agriculture will provide more food in future as its share in world food production will rise to over 45% by 2030 (Faures et al., 2007) from the current level of 40%. However, without proper planning and management, the intensification of irrigated agriculture can result in declining biodiversity and other environmental problems in agro-ecosystems (Krebs et al., 1999; Tilman et al., 2002; Singh, 2010). For instance, more than one-third of the world's irrigated land is affected by salinization/waterlogging and this condition poses a threat for food security and environmental conservation (Wichelns and Oster, 2006; Singh, 2013). During the recent past, irrigation water quality has been considered as a serious environmental factor for the assessment of sustainable development (Cordoba et al., 2010; Gaudino et al., 2014).

The use of poor quality water for crop production is necessary because availability of good quality water over time and space may not be adequate to fulfill the entire crop water demands (Sharma and Rao, 1998; Harou and Lund, 2008; Nevill, 2009; Venot et al., 2010; Harmancioglu et al., 2013; Elagib, 2014; Guo et al., 2014). The simultaneous use of poor and good quality waters for irrigation is referred as conjunctive use (Foster and van Steenbergen, 2011). Though, it is not necessary that two water sources are used continuously all the time. It involves the planned and coordinated management of different quality water sources to maximize their efficient use (Khare et al., 2006; Yang et al., 2009). Conjunctive use improves the water use efficiency and regional environment of irrigated areas by improving the availability and reliability of water (Cosgrove and Johnson, 2005; Cheng et al., 2009; Liu et al., 2013). The major benefits of conjunctive water use are the economic advantage and reduction of the adverse environmental impact by minimizing the crop stress during the critical growth stages (Marques et al., 2010). The conjunctive use of different quality water for irrigation improves the overall crop production and helps in achieving the food security. The successful utilization of poor quality water for crop production has been reported from worldwide (Prendergast et al., 1994; Datta et al., 2002; Oster and Grattan, 2002; Ahmadi and Ardekani, 2006; Malash et al., 2008; Rasouli et al., 2013).

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Application modes

The poor quality water can be used conjunctively with the good one by either of the two available modes, i.e., mixing and cyclic (Rhoades et al., 1992; Hamilton et al., 2007; Dudley et al., 2008; Kulkarni, 2011). The poor quality water is mixed with good quality water in a certain proportion before applying to the field in the mixing mode, while, two water sources are used alternately in the cyclic mode (Ayers and Westcot, 1985). The mixing is possible in areas where good quality water can be made available in adequate quantities at the time of its requirement. Several researchers compared mixing and cyclic uses of two quality waters and concluded that higher irrigation efficiency can be achieved with cyclic use when good quality water is applied at the initial stages and poor quality water is used at the later stages when plants can tolerate the salts better (Bradford and Letey, 1992; Naresh et al., 1993; Yadav et al., 2004). The use of poor quality water for crop production in arid regions was reported by Ben-Gal et al. (2009). They concluded that the saline water can be used safely for increasing crop yields and reducing negative environmental consequences of using poor quality water.

The interrelations between field and regional level irrigation management for the case of Israel were examined by Kan and Rapaport-Rom (2012). The study provided the guidelines for planners regarding the blending of fresh and poor quality water for irrigation.

Various previous studies confirmed that for similar salt input, cyclic applications have an advantage over mixing the water supplies, particularly when the better quality water is used initially at crop establishment (Minhas et al., 2007). However, some studies have shown that with temporal variation in salinity, crop yield responds to the average salinity of the soil during the growing season (e.g., Bielorai et al., 1978; Hoffman et al., 1989; Singh and Panda, 2012). Practically, the mixing of two quality waters can result in the loss of consumable water and more crop production can be achieved from the same total water supply if the two components are used alternately (Rhoades, 1999). Moreover, the cyclic use has operational advantage over mixing, as the latter requires the creation of additional facilities for mixing the two water supplies.

Management of resources problems

The introduction of large scale irrigation in arid and semiarid regions has increased agricultural productivity and production. On the other hand, it causes the twin menace of waterlogging and soil salinization (Sheng and Xiuling, 2007; Singh, 2011, 2012). The problem of waterlogging is particularly serious in the areas where groundwater quality is poor. Waterlogging creates shortage of air in the rootzone which affects plant growth by reducing the physiological activity, resulting in reduced nutrient availability and gaseous exchange (Smedema, 1990). The conjunctive use of poor quality groundwater can control waterlogging problems up to some extent by increasing the ground water utilization (Sharma et al., 1994; Bakr et al., 2012; Kazmi et al., 2012). However, its excessive use can lead to higher concentrations of salts in the soil profile. In coastal areas the lowering of watertables can lead to seawater intrusion and can degrade groundwater quality, making it unsuitable for irrigation. The lower watertables also increase pumping costs, and the depletion of aquifers raises questions about the sustainability of irrigated agriculture (Qureshi et al., 2008).

Subsurface drainage systems are installed in many irrigated areas to lower the watertable and remove excess salts from the rootzone. But the disposal of poor quality drainage water poses a serious environmental problem (Sharma et al., 1993). The conjunctive use of drainage effluent allows the development of irrigated agriculture and also solves its disposal problem (Rhoades, 1987; Westcot, 1988; Sharma et al., 1991). The adoption of salt tolerant crops is suggested, while utilizing the poor quality groundwater, as it reduces the harmful effects of salts on plant growth (Singh et al., 2010). Crops differ much in their ability to tolerate salinity. For example, crops like mustards, wheat, and cotton are relatively tolerant to irrigation water salinity as compared to rice, sugarcane, and forages (Sharma and Minhas, 2005; Chauhan et al., 2008; Kahlown et al., 2009). The soil texture also plays an important role in salinity tolerance and high salinity waters can be used in coarse textured soils with good leaching efficiency. Thus, the combination of several factors, i.e., climate, soil, rainfall, crop, watertable conditions, and water management practices determine salinity buildup in the rootzone from the application of poor quality water (Singh and Poonia, 1980).

Cautious note

The utilization of poor quality water for crop production is challenging despite offering several advantages. Because it is indiscriminate and unplanned use can cause serious threats to the agricultural sustainability and food security by accumulating salts in soil profile (Yadav et al., 2007). With either mode of application, the saline water irrigation causes some sort of salinity buildup in the rootzone (Minhas, 1996; Beltran, 1999; Rahmanipour et al., 2014). The problem is particularly serious in the areas which have no natural/artificial drainage systems. For example, an irrigation application of 1912 mm/yr with the even good quality water of 0.3 dS/m salinity will add 3.7 t/ha/yr salts to the soil profile in no drainage condition (Ritzema et al., 2008). The salt accumulation is directly related to the proportion of saline water used in various irrigations. However, little difference can be noticed between mixing and cyclic use (Chauhan et al., 2007). Salinity in the upper portion of rootzone is more harmful to plant growth as compared to the lower portion (Rhoades et al., 1989). It has been shown in previous studies that a high level of salinity in the lower portions of the rootzone has a minor influence on yield if the upper portion is maintained at relatively low levels of salinity (Minhas and Gupta, 1993). The reports of salt accumulation in soils due to irrigation with poor quality water have come from worldwide (Bajwa and Josan, 1989; van Hoorn and van Alphen, 1994; Jalali, 2007). Thus, for the long-term use of poor quality water for irrigation, the top layer of the soil profile should be kept salt free by allowing proper leaching and drainage because this is a prerequisite for achieving the agricultural sustainability and food security and protect the environmental degradation.

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