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Drip Irrigation as a Potential Alternative to Traditional Irrigation Method for Saline Water Usage in Vegetable Crops- A Review

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Abstract

The aim of this review was to understand the response of various vegetable crops to different salinity and nitrogen levels under drip and traditional methods of irrigation. Effective methods of irrigation water application are important that would allow the proper use of poor-quality water for sustainable production. Drip irrigation is an economically feasible technology for water-saving (40%) and increasing the yield (30–40%) in different crops. Various research studies found that the salt concentration of irrigation water was negatively correlated with growth, fruit yield and quality parameters of vegetable crops. Further, the plants which received 100% of recommended dose of fertigation under saline water irrigation showed a better performance in terms of higher nutrient uptake of nitrogen (150.09–226.26 kg ha^{-1}), phosphorous (13.67–74.64 kg ha^{-1}), and potassium (155.70–302.05 kg ha^{-1}) with highest water use efficiency (11.9–61.68 kg ha^{-1} m^{-1})**.** We made an attempt to review and compile the ill effects of saline water application and also summarise management strategies to manage poor quality water in vegetable production, especially in arid and semi-arid regions. The review also highlighted the importance of drip irrigation as an alternative to conventional methods for efficient use of poor-quality water without adversely affecting the quality and productivity of vegetable crops.

Keywords: Drip, fertigation, fertilizer use efficiency, saline water, yield

1. Introduction

India has about 18% of the world's population and 4% of the world's freshwater, out of which 80% is used in agriculture (Anonymous, 2017). In the current situation of the water scarcity, irrigated agriculture is facing the problem of adequate availability of freshwater resources for producing crops in arid and semi-arid regions. To surpass the good-quality water deficit, it is prudent to make efficient use of poor-quality water, such as brackish or saline water, and lead more area under modern techniques of irrigation and improved water management practices (Feikema et al., 2010; Verma et al., 2012; Arvind et al., 2018). Therefore, proper use of poor-quality water and improved irrigation technologies such as drip irrigation plays a prominent role to conserve water resources in arid areas associated with brackish groundwater for attaining improved crop quality and high yield over the traditional irrigation method (Hanson and May, 2011).

Controlled irrigation methods such as drip irrigation is typically the most efficient method of water/fertilizer distribution which allows precise timing, controlled distribution of water and applied nutrients than traditional methods (surface flooding and furrow irrigation) because it applies frequent irrigation to crops in root zone and reduces adverse effects of over irrigation and water stress problems (Godara et al., 2013; Pandey et al., 2013). Irrigation and fertilizer management have contributed immensely in increasing the yield and quality of crops in the intensive agriculture. In arid and semi-arid regions, the method of fertilizer and irrigation application affects the efficiency of these inputs. Many researchers had reported improved yield (30-40%) in different crops and quality of crop along with increase in water and nutrient use efficiency and water-saving (40%) (Tiwari et al., 2003; Singandhupe et al., 2007; Jha et al., 2017). Drip irrigation has been extensively used for many vegetable crops, such as okra (Soomro et al., 2012), chillies (Pandey et al., 2013), cabbage (Vasu and Reddy, 2013), eggplant (Aujla et al., 2007), potato (Jha et al., 2017), and tomato (Ughade et al., 2016).

Vegetables play a significant role in human health and nutrition being sources of vitamin C, thiamine, niacin, pyridoxine, folic acid, minerals, and dietary fibres. Nutritional disorders such as micronutrient deficiencies are mainly associated with low vegetable intake (Schneider et al., 2000). Though, vegetable crops have high productivity per unit of water applied and economic value compared to the field crops. Further, vegetables can be grown in small areas, under intensive cultivation techniques (Machado et al., 2017). Therefore, vegetable production has an extensive opportunity for increasing the economic returns of marginal and small farmers. In the present scenario, vegetable crop production mainly depends on the availability of water and nutrient (Vijayakumar et al., 2010). During 2017–2018, the area under vegetables was 10.26 mha with an annual production of 184.40 MT in India (Anonymous, 2018). The majority of the existing commercial vegetable crops have a low salt tolerance for saline water applied for an elongated period of time. These were further classified into the different types of classes of salt tolerance i.e., sensitive, moderately sensitive, moderately tolerant, tolerant and unsuitable for crops. Most of the vegetable crops are categorized under sensitive or moderately sensitive to salinity (Maas, 1984; 1990; Hanson et al., 2006).

As limited information is available on the impact of application of saline water and nutrients through drip system for vegetable production in India, an attempt was made to review the interactive effect of saline water and fertilizer application under drip and traditional irrigation methods in vegetable crops.

2. Impact of Saline Water and Nitrogen Application

2.1. Effect of saline water and N-application on yield and yield attributes

Various growth and yield parameters i.e., height of plant, primary and secondary branches plant^{-1}, fruits plant^{-1} and fruit weight and size are the important factors for realizing higher fruit yield in vegetable crops. Kadam et al. (2007) observed that the plant height of brinjal was highest of 71.3 and dry matter accumulation of 112.6 g plant^{-1} with canal water irrigation (ECiw: 0.21 dS m^{-1} with 100% RDN), but plants were stunted with saline water irrigation (ECiw: 2.0 dS m^{-1} with 100% RDN) at 90 DAT. Malash et al. (2008) applied two types of water management practices i.e., cyclic and mixed supply of canal and saline water through drip and furrow (traditional) method on tomato (*Solanum lycopersicum* L.) crop. Maximum plant height (93.4 cm), leaf area (1.29 cm^2), dry matter accumulation of plant (187.4 g plant^{-1}) and yield (86.3 t ha^{-1}) were obtained with irrigation of ECiw: 2.0 dS m^{-1} (blended water) under drip irrigation. Maximum WUE of 77.29 kg m^{-3} was recorded with blended water (ECiw: 2.0 dS m^{-1}) applied by drip irrigation. Drip irrigation system resulted in an 11% yield and 30% WUE advantage over the traditional method with blended and cyclic fresh and saline water.

Unlukara et al. (2010) reported the highest fruit yield (566 g pot^{-1}) under control treatment (tap water, T_0) and the lowest yield under treatment of EC_{iw}: 7.0 dS m^{-1}, T_5. The percent of yield reduction under different irrigation water treatments with EC_{iw}: 1.5, 2.5, 3.5, 5 and 7 dS m^{-1} were observed 13, 31, 36, 47, and 63% as compared to the control. Soomro et al. (2012) studied the effects of good quality water (EC_{iw}: 0.5 dS m^{-1}) and marginal quality groundwater (EC_{iw}: 2.9 dS m^{-1}) on crop yield and yield parameters in Okra (*Abelmoschus Esculentus*). Crop yield, plant height and water use efficiency were recorded higher under freshwater (18.90 t ha^{-1}, 91.2 cm and 2.7 kg m^{-3}) over marginal quality water (16.96 t ha^{-1}, 89.9 cm and 2.4 kg m^{-3}). Jha et al. (2017) laid out an experiment to investigate the comparable effects of saline water on various growth parameters of potato (*Solanum tuberosum*) under drip and traditional irrigation method. Mean tuber yield was found higher under drip irrigation (26.61 t ha^{-1}) with average increase of 24.7% over the furrow irrigation method (20.0 t ha^{-1}) with increasing salinity levels. The lowest tuber yield of 18.8 t ha^{-1} was observed under ECiw: 8 dS m^{-1} and weight of tubers per plant (291.7 g) with ECiw: 6 dS m^{-1} under furrow irrigation. Al-Zubaidi (2018) carried out a comparative study on two cultivars (Threa and Barcelone) of eggplant for determining their performances under different salinity stress levels (control, EC_{iw}: 4, 8, and 12 dS m^{-1}). Results revealed that height of the plant tended to decrease as the concentrations of salt in irrigation water increased. The highest reduction in plant height was under EC_{iw}: 12 dS m^{-1} of 35.66 cm with Threa variety and Barcelone variety recorded 39.81 cm under EC_{iw}: 12 dS m^{-1}, as compared with the control. Furthermore, saline irrigation with EC_{iw}: 12 dS m^{-1} resulted in a maximum loss on leaf number of 38.30 and 36.66 varieties Barcelone and Threa, respectively. The brinjal yield decreased with increasing the saline irrigation levels which recorded lowest total fruit yield (1.89 kg) under saline water of EC_{iw}: 12 dS m^{-1} as compared to control treatment (3.26 kg) with Barcelone variety.

Aujla et al. (2007) experimented to examine the interactive effects of various levels of N (N: 75, 100, 125, and 150% of RDN and amount of water applied (R_{EF}- ridge each furrow irrigation, R_{AF} -ridge alternate furrow irrigation, $D_{1.0}$, $D_{0.75}$ and $D_{0.50}$ of pan evaporation) through drip and traditional method of irrigation on yield, nitrogen and water use efficiency in brinjal crop. The results revealed that the yield of brinjal was 23% higher under $D_{0.75}$ at N_{125} and resulted in 25% of water and 30 kg N ha^{-1} of fertilizer saving as compared with the maximum yield obtained at each furrow irrigation at N_{150}. Drip irrigation produced a 4% higher yield at N_{150} with 50% of irrigation water as compared to the furrow irrigation. Badr et al. (2010) recorded the higher tomato yield (74.87 t ha^{-1}) with 100% NPK fertigation and attributed it to the maximum number of fruits plant^{-1} and a larger fruit size as compared to the traditional method of fertilizer application. Imamsaheb et al. (2011) studied the effect of different levels of fertigation (50, 75, 100% recommended NPK) on productivity and nutrients uptake of tomato. The study showed that the number of fruits per plant (40.71), number of flowers bunch^{-1} (6.30), fruit weight (60.89 g), fruit setting percentage (78.24%), number of fruits per bunch (4.82) and yield (56.98 t ha^{-1}) were observed significantly higher for 100% NPK recommendation. Ertek et al. (2012) investigated the influence of irrigation intervals and nitrogen application treatments on tomato plants under trickle irrigating system. Treatment levels involved - irrigation at 5 days and 10 days intervals with plant coefficients (Kcp1-0.50, Kcp2-0.75 and Kcp3-1.00) and nitrogen levels (N0-0, N1-80 and N2-160 kg ha^{-1}). For 5 days irrigation interval, the highest marketable yield (95.61 t ha^{-1}) was recorded in Kcp3 with N2 and the lowest yield (23.32 t ha^{-1}) was recorded in Kcp1 with N0. Maximum nitrogen use efficiency (NUE) was recorded as 1.00 t kg^{-1} in Kcp1 with N1 and Kcp3 with N1. In 12 days, interval, the highest marketable yield (78.23 t ha^{-1}) was recorded in Kcp3 with N2 and lowest yield (12.83 t ha^{-1}) was recorded in Kcp1 with N0. Maximum NUE recorded was 0.75 t kg^{-1} in Kcp1 with N1. Chauhan et al. (2013) observed that the drip irrigation at 1.0 ET resulted in 30.95% higher brinjal fruit yield with 24.62% of water-saving over conventional irrigation method. Drip irrigation along with 80% of the recommended dose of N & K fertilizers significantly increased the fruit yield of brinjal. Singh and Pandey (2014) observed that the drip with 100% recommended dose of NPK resulted in higher average fruit weight, fruit yield per plant and total fruit yield as compared to 2/3rd recommended dose of NPK fertilizer applied through drip irrigation. Gupta et al. (2015) revealed that irrigation at 80% ET with 60% recommended NPK through drip significantly improved the fruit yield (989.3 q ha^{-1}), water use efficiency (49.9 q ha^{-1} cm^{-1}) and fertilizers use efficiency (10.9, 18.3, and 27.4 q kg^{-1} N, P & K).

2.2. Effect of saline water and N application on nutrient uptake

Nitrogen fertilization plays a significant role on crop productivity in saline soils. The salt stress impairs the uptake of nitrogen and numerous studies revealed that excess salts can reduce the nitrogen content in plants (Wahid et al., 2004; Yin et al., 2007). Tumbare and Bhoite (2002) reported that nutrient application through fertigation resulted in 51% of water-saving along with 30% of N and 20% of P and K of fertilizer saving. They found fertilizer application through drip was effective than traditional method (soil application) in improving crop yields. Kadam et al. (2007) studied the influence of saline water and fertigation on the concentration of nutrients in brinjal fruit and plant. They concluded that the concentration of NPK in plant was higher under canal water with 100% RDF (1.60, 0.46 and 2.87%) as compared to the saline water treatment with 100% RDF (1.20, 0.38 and 2.46%). The interaction effect due to the different treatment of fertilizer level and irrigation (canal water and saline water) level was not found significant. Uptake of nitrogen, phosphorous and potassium (150.09, 13.67, 155.11 kg ha^{-1}, respectively) was recorded higher with 100% recommended NPK in different tomato (*Solanum lycopersicum* L.) crop varieties (Jat et al., 2011).

Ughade et al. (2016) studied the response of different fertigation levels on tomato and observed higher uptake of nitrogen (226.26 and 218.42 kg ha^{-1}), phosphorus (74.64 and 69.26 kg ha^{-1}), and potassium (302.05 and 291.02 kg ha^{-1}) with 100% RDF as compared to the other treatments. Ankush et al. (2017) conducted an experiment to study the response of tomato (*Solanum lycopersicum* L.) under drip fertigation scheduling and revealed that NPK content in the plant (1.88%, 0.42%, 1.94%) and fruit (2.55%, 0.61%, and 2.72%) significantly increased with irrigation up to 100 % PE (Pan evaporation). Nutrient content in fruit i.e., nitrogen (2.56%), phosphorus (0.63%) and potassium (2.78%) and plant i.e., nitrogen (1.91%), phosphorus (0.43%) and potassium (1.95%) were also significantly higher under 100% RDF through fertigation.

2.3. Effect of saline water and N application on nutrient and water use efficiency

Yield of squash (scientific name) was observed higher under fertigation due to more N uptake, fertilizer N utilization efficiency, and percent N derived from fertilizer as compared to soil application (Mohammad, 2004). Solaimalai et al. (2005) reported that drip fertigation resulted in higher input use efficiency, minimum losses of N due to leaching, optimum nutrient concentration in soil solution, nutrient supply to the root zone in available forms, and reduced cost of application. Goswami et al. (2006) reported that yield of the brinjal was higher under drip with fertigation and led to water-saving of 37−49% compared to surface irrigation. Aujla et al. (2007) found that water-saving up to 50% can be attained via drip irrigation with a 4% increase in yield compared to the furrow irrigation accompanied by the maximum water use efficiency (WUE) of 11.9 kg ha^{-1} m^{-1} in eggplant. Shedeed et al. (2009) observed that the fertilizer use efficiency (FUE) was considerably higher with 100% NPK (138 kg yield kg^{-1} NPK) with fertigation compared to furrow irrigation (81 kg yield kg^{-1} NPK), 50% NPK fertigation (114 kg yield kg^{-1} NPK) and 75% NPK fertigation (127 kg yield kg^{-1} NPK). This might be due to more availability of moisture and nutrients throughout the growth stages in trickle system contributing to better uptake of nutrients and yield of tomato fruits.

Vjekoslav et al. (2011) conducted a field experiment for tomato (*Solanum lycopersicum* L.) crop with five experimental treatments: drip irrigation with fertigation (after 2 days), drip irrigation with fertigation (after 4 days), drip irrigation with fertigation (after 6 days), drip irrigation with conventional fertilization, furrow irrigation with conventional fertilization. The drip fertigation treatments (after 2, 4 and 6 days) gave results significantly higher tomato yields in comparison to drip with conventional fertilizer and furrow with conventional fertilizer. After three years of studies, WUE was observed 28% more in trickle irrigation in comparison with the combination of trickle irrigation with soil application of fertilizer and it was 87% higher than the furrow irrigation with soil application of fertilizers. Dingre et al. (2012) found that the fertilizer application through drip resulted in the increase of onion seed productivity by 12 to 74% over the traditional method. The total amount of water applied through surface and drip system was 840 mm and 520.45 mm indicating 39% of water saving and 2.5 times more WUE under drip fertigation over control. Soomro et al. (2012) reported that the quantity of tap (T1) and groundwater (T2) applied through the drip system to okra (*Abelmoschus esculentus*) crop was of equal volume i.e., 6989.7 m^3 ha^{-1}. However, higher water use efficiency was recorded with EC_{iw}: 0.5 dS m^{-1} (2.7 Kg m^{-3}) over EC_{iw}: 2.9 dS m^{-1} (2.4 kg m^{-3}). Vasu and Reddy (2013) conducted an experiment regarding the response of drip fertigation on yield, quality, nutrient uptake, fertilizer, and water use efficiency in cabbage (*Brassica oleracea*). They reported the highest cabbage yield (16.92 t ha^{-1}) associated with the higher content of N (3.18%) and K (4.60%) under daily fertigation of N and K (100% recommended dose) followed by 125% recommended dose. The Highest N (100.50 kg kg^{-1}) and K (131.31 kg kg^{-1}) FUE was recorded in daily fertigation of 75% RDF of N and K whereas higher water productivity (7.92 kg m^{-3}) for 100% RDF in daily fertigation.

2.4. Effect of saline water and N application on quality and physiological parameters

The application of irrigation water of different salinity and nitrogen fertilizer levels has a crucial role in the quality and physiological parameters of vegetable crops. Sifola et al. (1995) studied the effect of increasing salinity (EC_{iw}: 2.3, 4.43, 8.46, and 15.73 dS m^{-1}) on the quality of eggplant fruit. They reported an increase in mesocarp firmness due to induced salinity which was associated with reduced water content in fruits of plants irrigated with saline water as compared to the control. They observed an increase in the titratable acidity, reducing sugars and mineral ash with the salinity stress, whereas the reduction of pH, total polyphenols, and ascorbic acid contents were reported under saline water irrigation. Kadam and Patel (2001) showed the effects of salinity water (EC_{iw}: 0.21 and 5 dS m^{-1}) through drip irrigation system on tomato (*Solanum lycopersicum* L.) quality and concluded that with an increase in salinity of water the values of acidity (0.51 to 0.69%), total soluble solid (4.20 to 5.22%), and lycopene contents (1.65 to 2.47 mg 100 g^{-1}) of tomato also increased. A field experiment was conducted by Kahlaoui et al. (2011) for studying the response of three tomato cultivars under drip and subsurface drip irrigation with saline water. They found a significant reduction in chlorophyll content of the cultivars irrigated with saline water (ECiw: 6.57 dS m^{-1}) under drip irrigation. This significant reduction in chlorophyll content under DI was due to the increase of the evaporation rate near the surface led to the more accumulation of salts. Shaheen et al. (2013) determined the salt-induced changes in physio-biochemical attributes of the eggplant. With varying, sodium chloride levels (0, 50, 100, and 150 mM) under greenhouse condition. They found that the varying saline regimes significantly reduced the shoot and root lengths, shoot and root dry weights, relative water content, stomatal conductance, soluble proteins, total phenolic content, the activity of superoxide dismutase (SOD), peroxidase (POD) and catalase, photosynthetic rate, water-use efficiency, chlorophyll *a* and *b* pigments, leaf and root K, leaf water and osmotic potential in all eggplant plants shown in Figure 1 a and b.

Zhai et al. (2015) revealed that the saline water with a salinity <4 dS m^{-1} had no obvious impact on tomato LAIm and chlorophyll content, however, they found that LAIm decreased by 2.86% ~12.50% and chlorophyll content by 4.00% ~15.0% at salinity of 5.5 dS m^{-1}. A positive relation between the quality traits of tomato and salinity was observed as the total soluble solids, total acid, vitamin C, and sugar-acid ratio increased by 38.2~54.2%, 25.9~43.1%, 36.5~50.2%, and 34.9~43.3%, respectively, under the high-saline water (5.5 dS m^{-1}) treatment. Gupta et al. (2015) obtained higher total soluble solids (TSS) (4.920 brix) and total sugar (3.77%) under I2F2 (80% ET+60% RDF through drip) treatment i.e., 80% ET through drip irrigation+80% RDF (recommended dose of fertilizer) through drip irrigation. Vasu and Reddy (2013) observed the highest values of TSS (4.66%) and ascorbic acid (118.37 mg 100 g^{-1}) content in cabbage at 125% RDF under daily fertigation of N and K as compared to the 75% and 100% RDF treatments in drip the system.

AL-Zubaidi (2018) study also indicated that the phenotypic data i.e., leaf area, dry weight of shoot, an average of fruit number, an average of fruit weight showed a high decrease for saline water of EC_{iw}: 8 and 12 dS m^{-1}. The proline content (7.81 mcg g^{-1}) and root dry weight (141.89 g) showed a positive response toward increasing water salinity and were recorded higher under salinity stress level of EC_{iw}: 12 dS m^{-1} as compared to control (3.21 mcg g^{-1} and 131.57 g) with Threa variety of egg plant. Brenes et al. (2020) experimented on two species of

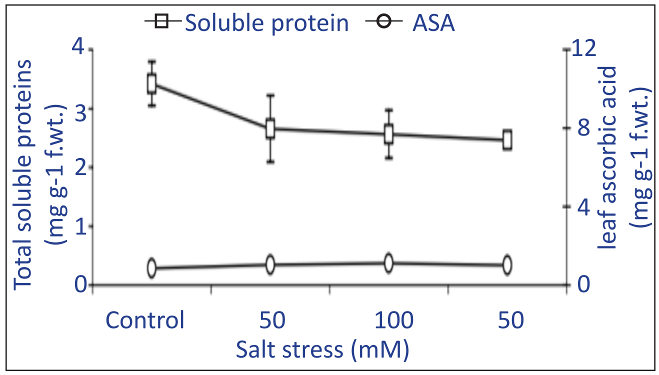

Figure 1a: Total soluble proteins and leaf ascorbic acid of eggplant (*Solanum melogena* L.) plants grown under varying NaCl levels

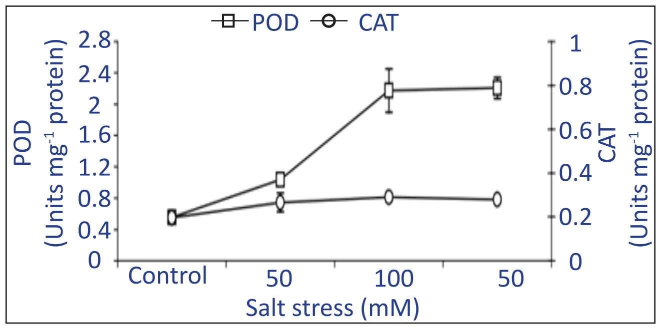

Figure 1b: Peroxidase (POD) and catalase (CAT) of eggplant (*Solanum melogena* L.) plants grown under varying NaCl levels (Source: Shaheen et al; 2013)

eggplant (*Solanum melongena* MEL and *Solanum insanum* INS) with an irrigation solution containing NaCl at concentrations of 0 (control), 50, 100, 200, and 300 mM. Proline, total soluble sugars, total phenolics, and total flavonoids were quantified for both species. Leaf proline levels of both the species of eggplant responded significantly positive to the salt stress treatments. Proline content was lower in *S. melongena* than in *S. insanum* at different salinity levels, proline content decreases at 300 mM NaCl but highest levels were estimated in the presence of 200 mM NaCl. Proline content in *S. insanum* increased ten-fold higher than the control at 300 mM NaCl (shown in Figure 1a). They concluded that the no correlation was found between total soluble sugars (TSS) and degree of salt tolerance shown in Figure 1b. Antioxidant compounds total phenolic and total flavonoids contents slightly decreased in response to increasing salinity in plants of the two species although the differences with the non-stressed controls were not statistically significant in *S. melongena* species. The improved quality of vegetable fruits with conjunctive use of poor-quality water and fertilizers through drip irrigation might be due to the efficient use of fertilizers under drip system for better usage of water and nutrients and reduced leaching losses.

3. Conclusion

There is an utmost concern over the increasing demand of irrigation water for food production to feed the ever-growing population of the world and the non-availability of good quality water all over the world. Hence, a sustainable approach to water resources and salinity management has become imperative. As compared to traditional approaches drip irrigation offers most suitable alternative for productive utilization of marginal or poor-quality water for crop production, higher fertilizer and water use efficiency especially in vegetable crops. The present review study indicates that the primary goals of irrigation management strategies in arid and semi-arid regions are optimising water use efficiency, fertilizer use efficiency, reducing salinity effects, maximising yield and quality of crops, especially, horticultural and vegetable crops.

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