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A REVIEW

Nitrate distribution pattern under conventional and trickle irrigation system

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Abstract : Nitrate is a highly mobile ions that moves with water. So that nitrate distribution around the driplines is strongly affected by irrigation and fertigation strategy. Nitrate movement under conventional flood irrigation system was observed 2 to 3.5 times faster as compared with trickle irrigation as well as NO_3^--N concentrations exceeded the threshold limit (*i.e.* 10 mg l^{-1}) under traditional irrigation method, while stayed below the threshold limit under micro irrigation methods. Nitrate distribution was influenced by hydraulic properties, drip discharge rate, soil layering, timing of nutrient application and irrigation frequency. To maintain larger amounts of nutrient nearby emitter in highly permeable coarse-textured soils, nutrients must be applied at the starting of an irrigation cycle so that it is less susceptible to leaching losses. Study revealed that higher transpiration raised the NO_3-N uptake by the plats. The study also revealed that urea moves promptly with irrigation water and urea–ammonium–nitrate fertilizer increased the nitrate concentration, near the drip line immediately after the drip fertigation due to the nitrification, while low concentrations was found near the periphery of the wetting zone.

Key Words : Conventional irrigation system, Drip line, Fertigation, Trickle irrigation, Nitrate Distribution Pattern

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INTRODUCTION

Nutritional element, nitrogen is the most important element for numerous metabolic processes and growth activity in cereals grains and other crops. Application of nitrogen fertilizer lead to nitrification and mineralization process that converts the organic N in to NO_3^- N and NH_4+, respectively which is termed as available nitrogen and absorbed and utilized by crops. In India, particularly in agriculturally developed states such as Andhra Pradesh, Maharashtra Punjab and Haryana, where application of fertilizers are very high, ground water tends to pollute due to nitrate leaching, which is becoming a serious problem in India,. Micro irrigation (drip and micro sprinkler irrigation system) has the capability for uniformly and precisely applying water and fertilizers throughout a field both in terms of quantity and place. This capability can results in water, fertilizer and chemical saving, higher yield, and can also saves the ground water from nitrogen leaching (Chen *et al.,* 2017, Bhowmik *et al.,* 2019, Xiang *et al.,* 2019). Fertigation is an efficient method in which water soluble fertilizers and micro nutrients are applied through irrigation water directly to the crop root zone and therefore the fertilizer use

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efficiency by the crop can be increased and leaching potential of mobile nutrients can be decreased (Sandal and Kapoor, 2015). Leaching of NO_3^--N below the root zone is exacerbated by over application of manure and inefficient irrigation (Thorburn *et al.,* 2003, Maheswari, 2018, Kumar and Kumar, 2018). In fine sand nitrogen fertilizers and water management practices influenced the residual NO_3^--N. At lower application rates of nitrogen fertilizers residual NO_3^--N was very low because this lower quantity of fertilizer was nearly equal to plant uptake. Water and solute distribution patterns are very important under subsurface drip irrigation system and are described by solutions of the governing flow equations (Thorburn *et al.,* 2000).

Results and Discussion

Bristow *et al.* (2000) revealed that distribution of nitrate under two fertigation strategies, involving application of solute at end and beginning of an irrigation cycle helped to maintain larger amount of nutrients near to and above the emitter, thereby less susceptible to leaching losses. While Sharmasarkar *et al.* (2000) reported that, rate of Nitrate movement under conventional flood irrigation system was 2 to 3.5 times faster as compared with trickle irrigation.

Cote *et al.* (2003) conducted a research on simulation of solute transport and soil wetting in subsurface drip irrigation. The study showed that wetting patterns and solute distribution were influenced by hydraulic properties, drip discharge rate, soil layering, timing of nutrient application and irrigation frequency. The study revealed that (1) plant water availability is improved by drip irrigation in medium and low permeability fine-textured soils, (2) if emitters are buried too deep than it difficult to wet the near surface zone as water and nutrients move rapidly downwards from the emitter in coarse textured highly permeable soils and (3) to maintain larger amounts of nutrient nearby emitter in highly permeable coarse-textured soils, apply nutrients at the starting of an irrigation cycle so that it is less susceptible to leaching losses.

Li *et al.* (2003) observed a uniform distribution of nitrate concentration in the soil in 15 cm around the point source for a given input concentration. The results indicated that there existed an extremely high ammonium concentration in the proximity of the point source (about 2.5-7.5 cm from the source). Hanson *et al.* (2004) reported that Nitrate is a highly mobile ions that moves with water. So that nitrate distribution around the driplines is strongly affected by irrigation and fertigation strategy.

Li *et al.* (2005) conducted field experiments to study the effects of fertigation strategies for wetting patterns and nitrogen distribution in the soil from a surface point source of ammonium nitrate (NH_4 N). The results revealed that the strategy of first applying water for one fourth of the total irrigation time, then applying fertilizer solution for half of the total irrigation time followed by applying water for the remaining one fourth of total irrigation time left the most nitrate close to the source. Higher transpiration raised the NO_3-N uptake as reported by Deb *et al.* (2005).

Hanson *et al.* (2006) conducted the research on evaluation of urea ammonium nitrate fertigation with drip irrigation using numerical modeling. Different micro irrigation systems in combination with different fertigation strategies were analyzed for various soil types using a nitrate-only fertilizer, clearly demonstrating the effect of fertigation strategy on the nitrate distribution in the soil profile and on nitrate leaching. The study concluded that urea moves promptly with irrigation water and urea–ammonium–nitrate fertilizer increased the nitrate concentration, near the drip line immediately after the drip fertigation due to the nitrification, while low concentrations was found near the periphery of the wetting zone.

Nitrate movement in the soil profile under irrigated agriculture was studied by Mirjat *et al.* (2008). Study consisted of different irrigation methods traditional flooding *i.e.* basins and furrows and micro irrigation *i.e.* drip and sprinklers. Study showed that NO_3^--N concentrations remained concentrated only in the top 30 and 60 cm depths under micro irrigation methods whereas high concentrations showed at all depths under traditional flooding method. Research also revealed that NO_3^--N concentrations exceeded the threshold limit (*i.e.* 10 mg l^{-1}) under traditional irrigation method, while stayed below the threshold limit under micro irrigation methods.

Li and Liu (2011) conducted a laboratory experiments to investigate the water and nitrate distributions from a subsurface drip irrigation system discharging an ammonium nitrate solution in uniform and layered-textural soils. It was reported that nitrate accumulated at the edge of the wetted volume while water accumulation approximated the input concentration for both uniform and layered soils.

Phogat *et al.* (2013) studied nitrate dynamics under drip irrigated orange tree. Study revealed that Concentration of NO_3^--N was higher at the center of the plume below the dripper, with a gradual decrease in N concentration towards the outer boundaries of the plume. Study also revealed that plant NO_3^--N uptake gradually reduced as the amount of irrigation increased as nitrate concentration at the higher depth (40 to 60 cm) is not available for plants as majority of active fibrous root zone are in the top of 15-30 cm depth.

Nutrient availability in the rhizosphere of rice grown under the drip irrigation was studied by Zhu *et al.* (2013). Experiment was conducted to measure the availability of soil Nitrogen, Phosphorus, Potassium, Zink and Manganese in two treatments T_1= conventional irrigation system and T_2= drip irrigation system with plastic film mulching. It was found that Soil ammonium N and exchangeable manganese concentrations were higher in the T_1 as compared to T_2, while concentrations of Nitrate N, available Phosphorus, Zink, and easily reduced manganese were lower in the T_1 as compared to T_2.

The increase in NO_3-N concentrations with increasing soil drying can be explained by NH_4+ nitrification in the soil as nitrification only occurs under aerobic conditions. The nitrification rate in the saturated zone is expected to be low, due to high sensitivity of the process to anaerobic conditions. As NO_3^--N concentration for drip irrigated guava was observed in above soil profile (0-15) as 19.3 mg/kg, 51.7 mg/kg and 92.1 mg/kg for after 8 hrs, 24 hrs and 48 hrs after fertigation Khan (2014).

Applicability of subsurface drip irrigation for increasing the rice production under climatic variability in India was studied by Rajwade *et al.* (2014).The rice variety 'Annada' was grown using four nitrogen fertilizer levels *i.e.* 0 kg ha^{-1}, 50 kg ha^{-1}, 75 kg ha^{-1} and 100 kg ha^{-1} and two drip lateral spacing's *i.e.* 40 cm and 60 cm in a strip-plot design. Among the drip irrigated rice treatments, the 75 kg N ha^{-1} through drip fertigation with 40 cm lateral spacing were recorded maximum rice yield of 4108 $kgha^{-1}$. Drip irrigated rice yield was lower by 11% and higher by 8.48% as compared to the irrigated puddle transplanted rice and rain-fed direct seeded rice, respectively under similar nitrogen application level. Also, the nitrogen uptake of the drip irrigated rice treatments increased by 16.2% and 12.5% compared to puddle transplanted rice and rain-fed direct seeded rice, respectively.

Sui *et al. (*2015) studied the nitrogen transport and water distribution under different nitrogen and irrigation applications for drip irrigated wheat crop during 2011–13. The study included four nitrogen (N) levels (120 kg·ha^{-1}, 140 kg·ha^{-1} and 190 kg·ha^{-1} in 2012 and 120 kg·ha^{-1}, 190 kg·ha^{-1} and 290 kg·ha^{-1} in 2013) and three water applications (*i.e.* 30 % evaporation, 50 % evaporation and 80 % evaporation). It was observed that, deep percolation at 1-m depth was constant at 50–80% evaporation with the same nitrogen rate as well as when nitrate rate increased from 120 - 140 kg·ha^{-1} or from 190 -290 kg·ha^{-1}. Nitrogen leaching 60 cm below the root zone of was only affected by irrigation scheduling and nitrogen rates.

Karandish and Simunek (2017) studied nitrogen dynamics for various N-managed strategies for maize. The field experiment consisted of five irrigation treatments that included a full irrigation (FI) treatment, two partial root-zone drying (PRD) and two deficit irrigation (DI) treatments. Higher irrigation levels along with higher nitrogen fertigation rates resulted in the higher NO_3^--N content in the top soil layers during the early maize growth stages while the NO_3^--N content in the deeper soil layers increased gradually as the season progressed. For irrigation level of 100%, reducing nitrogen rate from 400 to 250 kg ha^{-1} resulted in diminishing NO_3^--N leaching below 20 cm and 40 cm soil depths by 12.4–56.4% and 12.3–46.1%, respectively, while slightly reducing crop N uptake by 0.2–8.7%. How-ever, lower NO_3^--N leaching below 20 cm for PRD were up to 13.3% higher than as compared to drip irrigation, although N uptake only reduced by 0.3–5.9%, lowering nitrogen rate from 250 kg ha^{-1} to 200 kg ha^{-1} produced savings of 19.7–24.6% and 19.6–28.5% of NO_3^--N in the 0–20 cm and 0–40 cm soil layers, respectively.

Nitrate move gently at the soil depth and horizontally among the drippers and this may be due to the root distribution of crops at the surface layer consumes the nitrate from the soil solution. At the vertical distance between the dripline, the Nitrate N content increased. The peak concentration of Nitrate N was found 35 mg/kg at 0.6 m to 0.8 m soil depth. So that losses of nitrate was low under surface drip irrigation (Mahgoub *et al.,* 2017).

Nitrate N concentration increased with respect to time and it's because of hydrolysis and results of nitrification of ammonium, Nitrate accumulated in the soil profile and increased with time. Maximum nitrate concentration increased from 0.002 mg/cm^{-3} to 0.43 mg/

cm^{-3}, 0.076 mg/cm^{-3} to 0.223 mg/cm^{-3} among time periods between 0.6 days to 7.6 days and 10.5 days respectively. It was also observed that Nitrate N concentration decreased near to emitter between the irrigation period due to the redistribution and plant uptake. Eltarabily *et al.* (2019).

Shafeeq *et al.* (2019) conducted a research on Nitrate N distribution under conservation agriculture for wheat crop. Study showed that under permanent broad bed with residue, Nitrate N concentration was higher in upper soil layer (50 mg/l/cm^3) as compared with conventional tillage (40 mg/l/cm^3). Whereas in a lower depth (<45 cm), Nitrate concentration was higher under conventional tillage than conservation tillage agriculture. Study showed that Nitrate leaching beyond the rootzone was reduced in permanent broad bed with residue.

Xiao *et al.* (2019) reported that nitrate N leaching depends up on the precipitation and Nitrate N concentration. When the concentration is high, Nitrate N moved downward with the precipitation and irrigation water. Study also revealed that water saving irrigation mode can reduce the downward movement of nitrate thus leaching

Conclusion:

The nitrification rate in the saturated zone is expected to be low, due to high sensitivity of the process to anaerobic conditions. Nitrate N leaching depends up on the precipitation and Nitrate N concentration. When the concentration is high, Nitrate N moved downward with the precipitation and irrigation water. Study showed that NO_3^--N concentrations remained concentrated only in the top 30 and 60 cm depths under trickle irrigation, whereas high concentrations showed at all depths under conventional flooding method. Nitrate accumulated at the edge of the wetted volume. Plant NO_3^--N uptake gradually reduced as the amount of irrigation increased as nitrate concentration at the higher depth (40 to 60 cm) is not available for plants. Nitrate move gently at the soil depth and horizontally among the drippers and this may be due to the root distribution of crops at the surface layer consumes the nitrate from the soil solution. At the vertical distance between the dripline, the Nitrate N content increased. Nitrate N concentration increased with respect to time and it's because of hydrolysis and results of nitrification of ammonium, Nitrate accumulated in the soil profile and increased with time. It was also observed that Nitrate N concentration decreased near to emitter between the irrigation period due to the redistribution and plant uptake. Overall study showed that water saving irrigation mode can reduce the downward movement of nitrate thus leaching.

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