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Distribution of Water and Nitrogen in Soil under Drip and Microsprinkler Irrigation Fertigation of Garlic (*Allium sativum* L.) Crop

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ABSTRACT
Nitrogen (N) is an essential plant nutrient which is taken up by the crops throughout the growing season. Field experiments were conducted on microirrigation fertigation in garlic crop during the crop growing season of 2008-09 and 2009-10 year (both drip and micro sprinklers). Four levels of nitrogen treatments namely 0, 40, 80 and 120 kg N ha^{-1} with three replications were applied in both the methods of irrigation in Randomized Block Design (RBD). Water requirement of garlic crop was estimated by using Penman-Monteith method. Periodic soil samples were collected along the lateral (at emitter, 12.5 and 25 cm from emitter) as well as across the lateral (15 and 30 cm from the emitter) at three soil depths (0-15, 15-30 and 30-45 cm) in both methods of irrigation. The plant samples were also collected during the harvest in both the season. It was observed that the soil water content was relatively higher in upper profile and near the emitter in all the three observations at 24, 48 and 72 h after fertigation in both drip and microsprinkler irrigation. The results revealed that N concentration in active root zone (15-30 cm) in microirrigation was more than the initial N content. In the same layer adequate nitrogen availability was observed. Available nitrogen decreased from emitter to the boundary wetting zone in drip fertigation in contrary to microsprinkler fertigation. Nitrogen leaching was higher in drip fertigation than the microsprinkler due to more vertical movement of soil water leading to the movement of the nitrogen beyond the root zone. Nitrogen balance for the study indicated that leaching of nitrogen beyond the root zone increased with the level of nitrogen applied in both the methods of irrigation.

Key words: Drip irrigation, microsprinkler irrigation, nitrogen transport, nitrogen balance, fertigation, garlic

INTRODUCTION
There is a need for efficient application of nitrogenous fertilizer as mismanagement could lead to leaching and contamination of surface and ground water sources as well as soil degradation. Nitrogen is amongst the most important nutritional element in garlic and other crops and actively acts in numerous metabolic processes. The nitrogen content is directly related to the synthesis of proteins and carotenoids and would affect garlic fruit coloration and different plant organs at the skin as well as the bulb level (Romojaro *et al*., 2007).

Application of nitrogen fertilizer lead to mineralization and nitrification process that converts the organic N and NH_4^+ into NH_4^+ and NO_3^{2-}, respectively which are absorbed and utilized by crops and termed as available nitrogen. Microirrigation (drip and microsprinkler irrigation system) has the potential for precisely applying water and fertilizers throughout a field both in terms of amount and location. This potential can results in higher yield, water and fertilizer saving and can also reduce leaching of nitrogen to the ground water (Tripathi *et al.*, 2010). Various studies suggested that ground water pollution due to nitrate leaching is becoming a serious problem in India, particularly in agriculturally developed states such as Punjab, Haryana, Andhra Pradesh and Maharashtra, where fertilizer applications are high. Fertigation is the process of applying soluble fertilizer along with irrigation water. Fertigation is an efficient means of applying crop nutrients, particularly nitrogen and it may results in reduction of application of nitrogen fertilizers. Nutrients applied through fertigation can be applied directly to the wetted volume of soil where the majority of roots are located and therefore nutrient use efficiency by the crop can be increased and the leaching potential of mobile nutrients can be decreased (Thorburn *et al.*, 2003). Smika and Watts (1978) studied residual NO_3^--N in fine sand as influenced by nitrogen fertilizers and water management practices. They found that at lower application rates residual NO_3^--N was very low because it was nearly equal to plant uptake. They also concluded that the injected N application method with the proper water application management can greatly reduce the potential for NO_3^--N movement below the crop root zone in fine sandy soils.

Improved understanding of solute dynamics in the crop root zone should help to improve fertigation schedules for better microirrigation management (Mmolawa and Or, 2000). Instead of giving the recommended fertilizer in one dose, split application is appropriate method in fertigation as the nitrogen is most vulnerable to the leaching (Darwish *et al.*, 2003; Haynes, 1990). When N is used for crop production in sandy soils, method and time of application are of equal importance because of the potential for leaching losses of NO_3^--N through these soils during the growing season (Wolkowski *et al.*, 1995). The amount of N available for leaching and NO_3^--N leached beyond the root zone were affected by amounts of N fertilizer, the amounts of irrigation water and amounts of annual precipitation (Ersahin and Karaman, 2001). Therefore, careful management practices are required on particular soil in specific place.

Microirrigation system can be designed and operated such a way that water and nutrients are applied at particular rate, duration and frequency, so as to maximize crop water and nutrients utilization from the root zone of agricultural fields. After irrigation both soil moisture content and nitrogen concentration will be higher near the microirrigation application point but will redistribute thereafter as controlled by soil physical properties because of non-uniform wetting patterns of soil. However, it is possible that percolation of irrigation water below the root zone and nitrate leaching occurs despite that applied irrigation water is equal or less than crop evapotranspiration. Pawar *et al.* (1998) opined that microsprinkler method is suitable for irrigating close growing crops like garlic by closely spaced microsprinklers in terms of soil water distribution. However, the distribution of point source application of water and fertilizer would be different than the disc source of application as in the of case of microsprinkler system. The difference of water and nitrogen distribution in both (drip and microsprinkler) the method of irrigation will vary based on the soil type. The N uptake decreased and nitrogen volatilization and final soil nitrogen increased for the deficit irrigation treatments as compared to the full irrigation treatments in sprinkler. Therefore, in order to avoid nitrogen loss, the amount of nitrogen fertilizer application should be reduced in proportion to the severity of the existing water stress condition (Gheysari *et al.*, 2007).

Li *et al.* (2008) studied water and nitrogen distribution for summer maize under subsurface drip irrigation and reported that the initial nitrate content in sandy loam was significantly affected on the vertical distribution of nitrate following a fertigation event. The same study also revealed that the nonuniform distribution of water and nitrogen in the soil following a fertigation event was mainly caused by the spatial variation of soil properties, especially the initial distribution of soil water and nitrogen contents. The mobility of applied N through the drip irrigation system depends on the form (granular or powder) in which it is presented (Haynes, 1990). It has been reported that movement and transformations of fertigated urea were influenced significantly by the time of fertigation application in an irrigation cycle (Hou *et al.*, 2003).

Li *et al.* (2003) also studied influence of point source fertigation on water and nitrogen distribution in loam soil in China. They found that the effects of application rate and applied volume on nitrate distribution were not significant upto a radius of 15 cm, beyond which either a higher application rate or a smaller applied volume resulted in a higher nitrate concentration in the soil. Measurement of ammonium distribution revealed that an extremely high ammonium concentration in the proximity of the point source (about 2.5-7.5 cm from the source). The value of the peak ammonium concentration greatly depended on the input concentration. An increased input concentration produced a higher ammonium concentration around the point source.

Nitrate distribution in the soil for various fertigation strategies, soil types and methods of microirrigation was evaluated by Blaine *et al.* (2004). They found that injecting NO_3^- for a few hours at the beginning of an irrigation event could result in relatively nonuniform distributions of fertilizer in the root zone and may leach most of the NO_3^- beyond the root zone. On the other hand, injecting for several hours at the end of the irrigation event could result in most of the NO_3^- remaining near the drip line. Therefore, the timing of fertigation relative to the start and end of the irrigation event coupled with duration of fertigation event can affect crop NO_3 availability and leaching.

Very little information is available for water and nitrogen movements under microirrigation fertigation in garlic crop. There is a need to develop information based on water and nitrogen dynamics in the root zone for garlic crop to develop best fertigation design and management guidelines. This study was planned to develop database on water and nitrogen dynamics in garlic crop under microirrigation fertigation in order to develop design and management guidelines for microirrigation (drip and microsprinkler) fertigation.

MATERIALS AND METHODS

Field experiments were conducted on garlic (var., *Yamuna safed*) crop under microirrigation (drip and microsprinkler) fertigation on the farm of the Indian Agricultural Research Institute (IARI), New Delhi located between the latitudes of 28°37'22" N and 28°39' N and longitudes of 77°8'45" E and 77°10'24" E at an average elevation of 230 m above mean sea level. Climate of New Delhi is categorized as semi-arid, subtropical with hot dry summer and cold winter. The mean annual rainfall is 710 mm of which as much as 75% is received during monsoon season (June to September). Some winter showers are also received during December and March. Frost occurs occasionally during the months of December-January. Experiments were carried out in the garlic crop growing season of the years of 2008-09 and 2009-10.

Randomized block design was used with four levels of fertilizers treatments with three replications in drip and microsprinkler method of irrigation. The plot size was kept as 3×4 m. The fertilizer treatment imposed were N0 (0 kg ha^{-1}), N40 (40 kg ha^{-1}), N80 (80 kg ha^{-1}),

Table 1: Treatments details

Treatment	Drip irrigation	Microsprinkler irrigation
N0	No nitrogen	No nitrogen
N40	40% of recommended dose of nitrogen	40% of recommended dose of nitrogen
N80	80% of recommended dose of nitrogen	80% of recommended dose of nitrogen
N120	120% of recommended dose of nitrogen	120% of recommended dose of nitrogen

N120 (120 kg ha^{-1}). The field experiments consisted of design and installation of microirrigation fertigation system, field observations, samplings and analysis of soil and plant samples. Drip laterals were placed in the middle of the rows and spaced at 0.6 m to cover the two rows of the crop. Crop row to row spacing and plant to plant spacing was kept as 15 and 10 cm, respectively. Drip emitters were placed on the lateral line at a spacing of 50 cm. Two microsprinklers were placed in each plot with the spacing of 2 m. The drip and microsprinkler systems were operated for each treatment in all the replications at the same time. The details of experimental treatments were given in the Table 1.

Irrigation and fertigation schedule: Water requirement of garlic crop was estimated using the Penman-Monteith method. Previous five years (2002-2005) average daily reference evapotranspiration (ET_o) values were multiplied with the crop coefficients to estimate the daily crop water requirements of garlic crop. Irrigation requirement was estimated by subtracting corresponding rainfall during the crop season. Nitrogen fertilizer in the form of urea was applied with the interval of once in twenty days in four equal split doses. During each fertigation application, fertilizer was applied in the beginning of irrigation for 0.17 h. The amount of nitrogen fertilizer applied per dose was 150, 313 and 470 g in N40, N80 and N120 levels of nitrogen, respectively. Apart from nitrogen fertilizer, the recommended doses of P (50 kg ha^{-1}) and K (50 kg ha^{-1}) were applied after sowing as basal application.

Field observations and laboratory analysis: Soil samples were collected from different depths (0-0.15, 0.15-0.30 and 0.3-0.45 m) at emitter, 12.5 and 25 cm away from emitter along the lateral and 15 and 30 cm across the lateral periodically (before fertigation and 24, 48, 72 h after fertigation) in drip irrigation. In microsprinkler system soil samples were collected at 50, 100 and 150 cm away from the microsprinkler head along the lateral as well as across the lateral for three soil depths. Tube auger was used for collecting soil samples from the experimental area to determine spatial and temporal distribution of water and available nitrogen during the growing season. The soil samples were collected after each fertigation in both the methods of irrigation. These samples were analyzed to determine the gravimetric water content and available nitrogen. Kjeldahl method (Page *et al*., 1982) was used to estimate the ammonium and nitrate forms of the available nitrogen. In this method, distillation procedures for determination of NH_4^+ and NO_3^- involve steam distillation with MgO and Devarda alloy. Soil samples were shaken with 2 M KCl (10 mg g^{-1} of soil) for 1 h and the extract liberated by steam distillation was collected in $H_3BO_3^-$ indicator solution and determined by titration with standard (0.01 N) HCl. The plant samples were collected in all the treatments at the time of harvest. Water is removed from plant tissue to stop enzymatic reactions and to stabilize the sample. Removal of combined water also facilitates particle size reduction, homogenization and weighing. The plant samples were digested in the KEL PLUS digester block. Total nitrogen of the plant samples were determined by Kjeldahl method (Page *et al*., 1982).

RESULTS AND DISCUSSION

Water distribution in drip fertigation: The results of soil water content distribution in drip irrigation are presented in order of along and across the lateral in both the seasons. As the plant entered into the development stage (35 DAS) after two months, the root activity during this period will be more for uptake of water and nitrogen (Mohammad and Zuraiqi, 2003). So, the soil water distribution at 48 Days After Sowing (DAS) was taken for the discussion. Second dose of fertigation was completed at that time. Field capacity of various layers of the soil of experimental site was in the range of 20-27%. Soil moisture distribution pattern at 24, 48 and 72 h after fertigation along the lateral are presented in Fig. 1 and 2 in both the years for three places (at emitter, 12.5 and 15 cm from emitter). These figures revealed that 24 h after fertigation in the year 2008-2009 along the lateral soil water content in the vertical plane at emitter, 12.5 and 25 cm from emitter were 17.7-20.1, 16.5-19.5 and 14.1-18.2%. The figures also show that the variation in soil water content at various points in the first two layers (0-15 and 15-30 cm) was not much (1.3%). Similarly, water content in 48 and 72 h after fertigation in these layers varied from 12.1-17.2, 12.2-16.2 and 11.9-13.5%, respectively at emitter, 12.5 and 25 cm away from emitter. In contrary to these results Arulkar *et al.* (2008) reported that with increase in water application, the water content of soil increased horizontally and vertically in sandy loam soil. In this study, soil water content was relatively higher in upper profile (0-30 cm) and near the emitter in all the 3 cases after irrigation (24, 48, 72 h after fertigation) because of redistribution. Water content in all the soil layers decreased as the distance from the emitter with increase in the horizontal direction. Similar results were also reported by Chakraborty (1997) and Ajdary *et al.* (2007) in sandy loam soil.

Highest soil water content was observed at 24 h after fertigation in 12.5 cm along and 15 cm across the lateral in the soil layer of 0-15 cm. While highest soil water content was observed at 48 h after fertigation in 25 cm along and 30 cm across the lateral in 15-30 cm soil layer. Similarly, 72 h after fertigation, highest water content was observed in above said place (25 and 30 cm across the lateral) and layer (15-30 cm) as 48 h after fertigation. The results indicate that due to the redistribution, soil water content reached upto the 30 cm in horizontal as well as in vertical

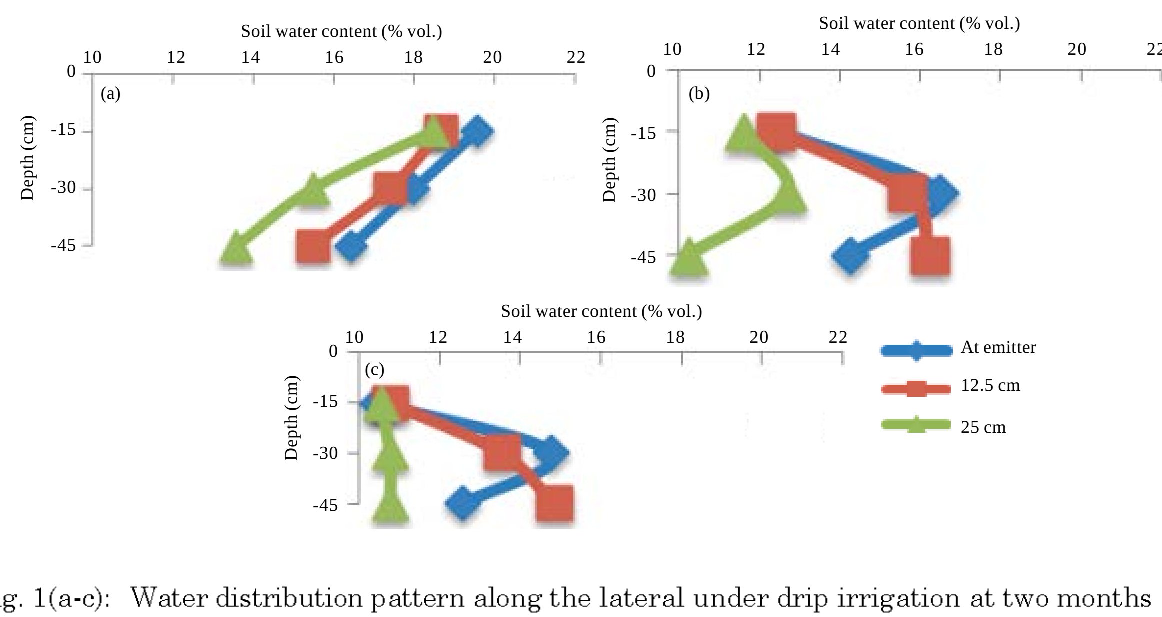

Fig. 1(a-c): Water distribution pattern along the lateral under drip irrigation at two months after sowing in 2008-2009 at (a) 24, (b) 48 and (c) 72 h

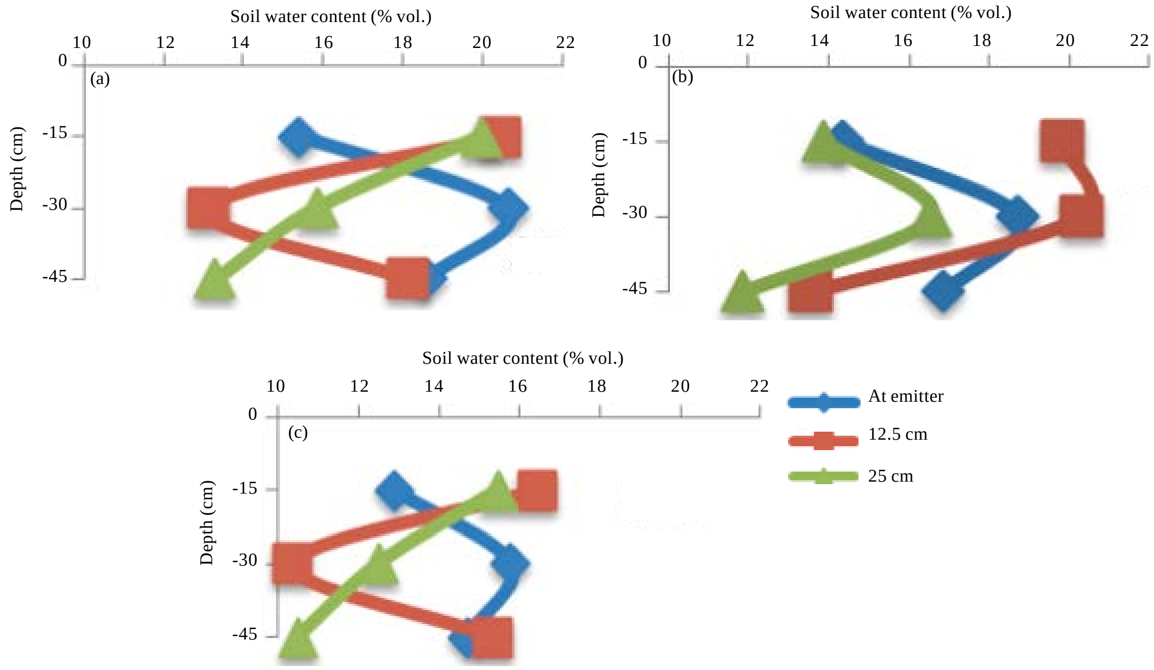

Fig. 2(a-c): Water distribution pattern along the lateral under drip irrigation at two months after sowing in 2009-2010 at (a) 24, (b) 48 and (c) 72 h

directions beyond emitter. Similar results were reported by Singandhupe *et al*. (2003) with clay loam soil. The soil water content in the root zone for garlic crop in medium textured soil should be maintained between 15-20% (Arulkar *et al*., 2008). The observations of present study also indicated that favorable water content was maintained in the root zone even after 72 h of irrigation. This concludes that lateral spacing could be taken as 60 cm for garlic crop under sandy loam soils.

Soil water distribution in microsprinkler: The results of soil water content in microsprinkler fertigation plots are presented in the order of along and across the lateral of microsprinkler in both the years. The water distribution along the lateral in three layers (0-15, 15-30, 30-45 cm), four places (at microsprinkler head, 50, 100 and 150 cm from microsprinkler head) and three times (24, 48 and 72 h after fertigation) are shown in the Fig. 3 and 4. It was observed that the water content at 24 h after irrigation was in the range of 11-17% in the year 2008-09 and 15-26% in the year 2009-2010, respectively. While at 48 h after irrigation, the water content ranged from 11-15% in the year 2008-2009 and 15-25% in the year 2009-2010, respectively. After 72 h of irrigation, the water content was in the range of 10-14% in the year 2008-2009 and 12-24% in the year 2009-2010. Figure 5 and 6 show the water distribution in microsprinkler across the lateral in three layers (0-15, 15-30, 30-45 cm), four places (at microsprinkler head, 50, 100 and 150 cm from microsprinkler head) and three times (24, 48 and 72 h after fertigation). The water content at 24 h after fertigation was observed in the range of 10-17% in the year 2008-2009 and 12-20% in the year 2009-2010, respectively. The water content at 48 h after irrigation was observed in the range of 10-15% in the year 2008-2009 and 10-21% in the year 2009-2010, respectively. The above results indicated that even after 72 h of irrigation favorable water content maintained in the root zone. Similar results were reported by the other researchers (Patel *et al*., 1996; Unlu *et al*., 2006)

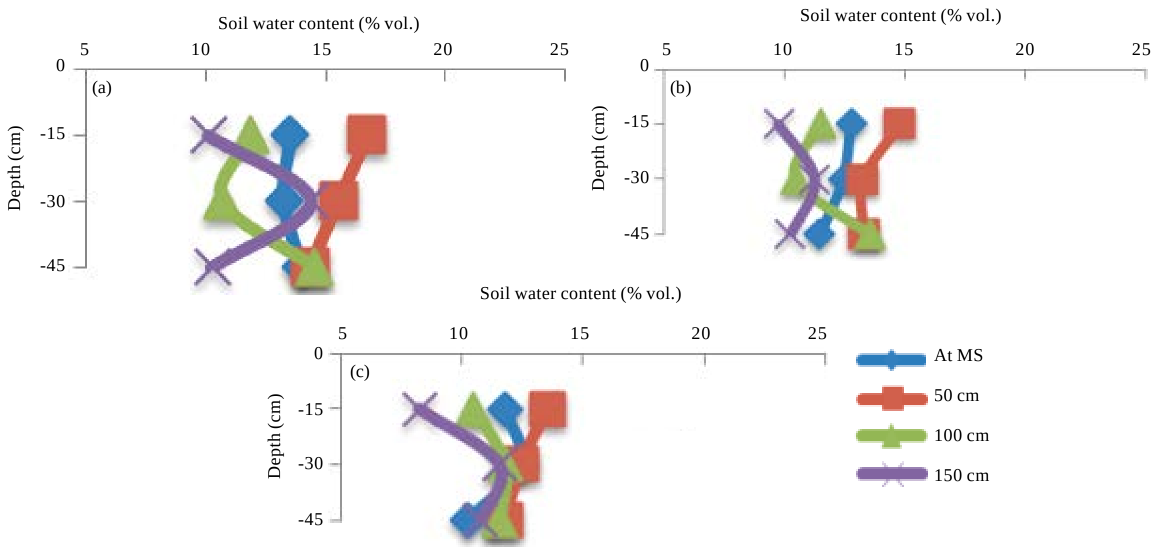

Fig. 3(a-c): Water distribution pattern across the lateral under microsprinkler at two months after sowing in 2008-2009 at (a) 24, (b) 48 and (c) 72 h

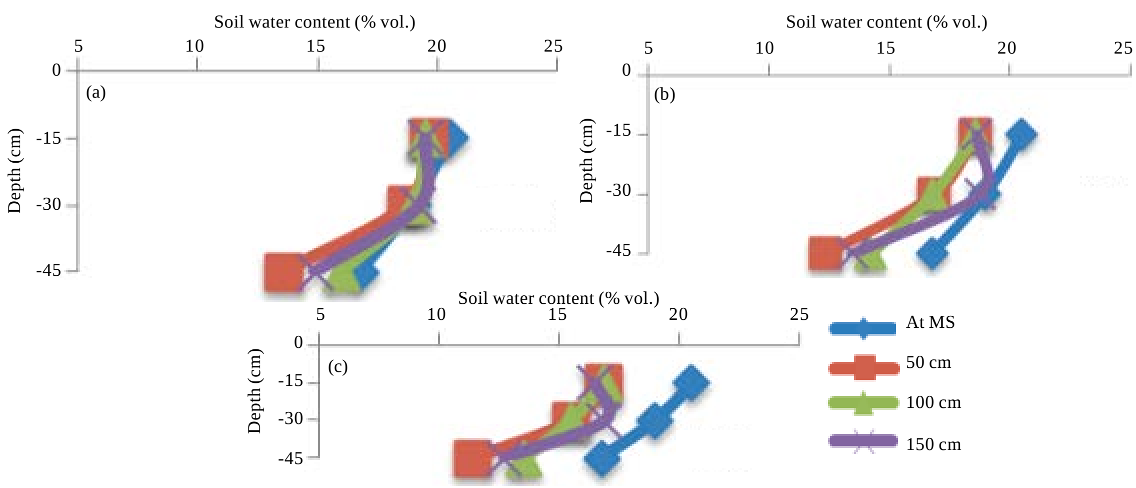

Fig. 4(a-c): Water distribution pattern across the lateral under microsprinkler at two months after sowing in 2009-2010 at (a) 24, (b) 48 and (c) 72 h

showing that the soil water distribution decreased from the point of application to periphery of wetted area. Comparison of the water distribution in both the methods revealed that horizontal distribution was more in microsprinkler than in drip irrigation. But in drip irrigation vertical distribution was more than in microsprinkler.

Nitrogen distribution in drip irrigation during growing period: The results of available nitrogen distribution are presented in order of along and across lateral under drip fertigated plots of garlic crop. Available nitrogen distribution at the end of second dose of fertigation in three soil

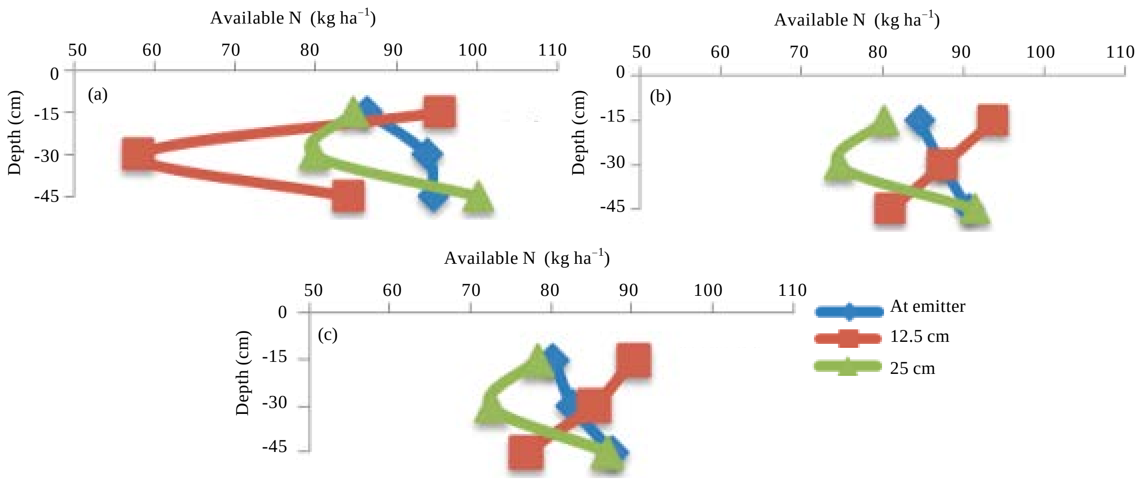

Fig. 5(a-c): Nitrogen distribution pattern along the lateral under drip irrigation at two months after sowing in 2008-2009 at (a) 24, (b) 48 and (c) 72 h

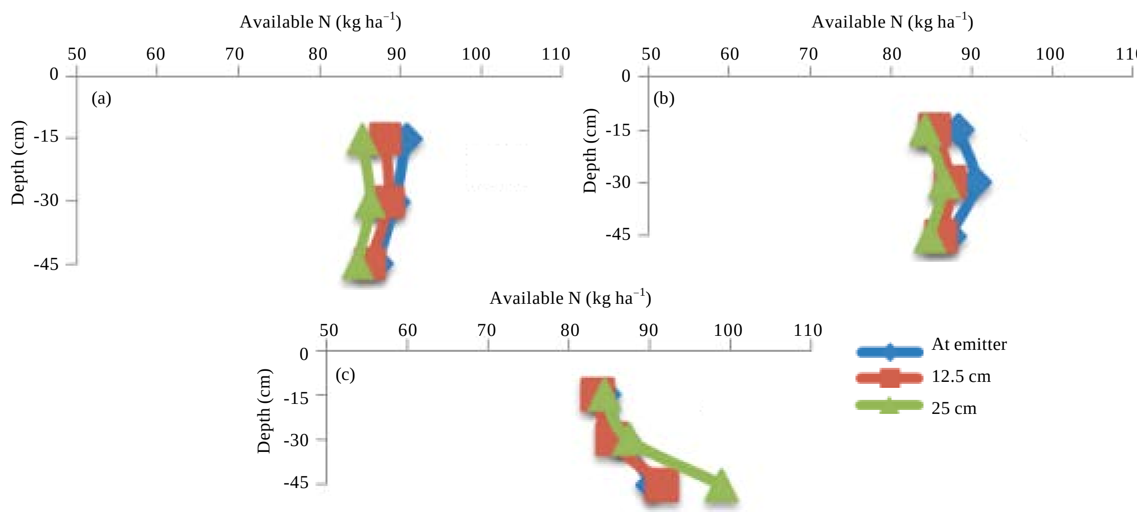

Fig. 6(a-c): Nitrogen distribution pattern along the lateral under drip irrigation at two months after sowing in 2009-2010 at (a) 24, (b) 48 and (c) 72 h

layers (0-15, 15-30 and 30-45 cm) at 24, 48 and 72 h after fertigation and at emitter, 12.5 and 25 cm from emitter are presented in Fig. 7-10 during both the seasons. Available nitrogen distribution along the lateral were in the range of 60-110, 70-95 and 70-96 kg ha^{-1} and 80-95, 80-90 and 80-100 kg ha^{-1}, respectively for both the year in three times (24, 48 and 72 h after fertigation). The available N across the lateral in the range was 80-110 kg ha^{-1} for all three timing in both the years.

In both the seasons in the treatment N80 i.e., 80 kg N ha^{-1} fertigation with drip irrigation, the maximum N content was observed as 98 kg ha^{-1}at 24 h after fertigation in 15-30 cm layer. It decreased with an increase in soil depth below the emitter. However, at 12.5 cm away from emitter

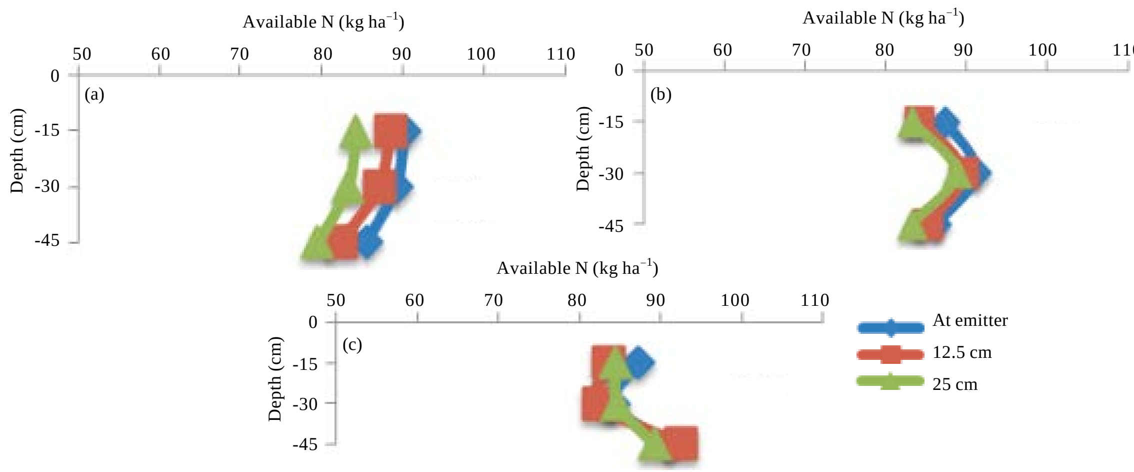

Fig. 7(a-c): Nitrogen distribution pattern across the lateral under drip irrigation at two months after sowing in 2008-2009 at (a) 24, (b) 48 and (c) 72 h

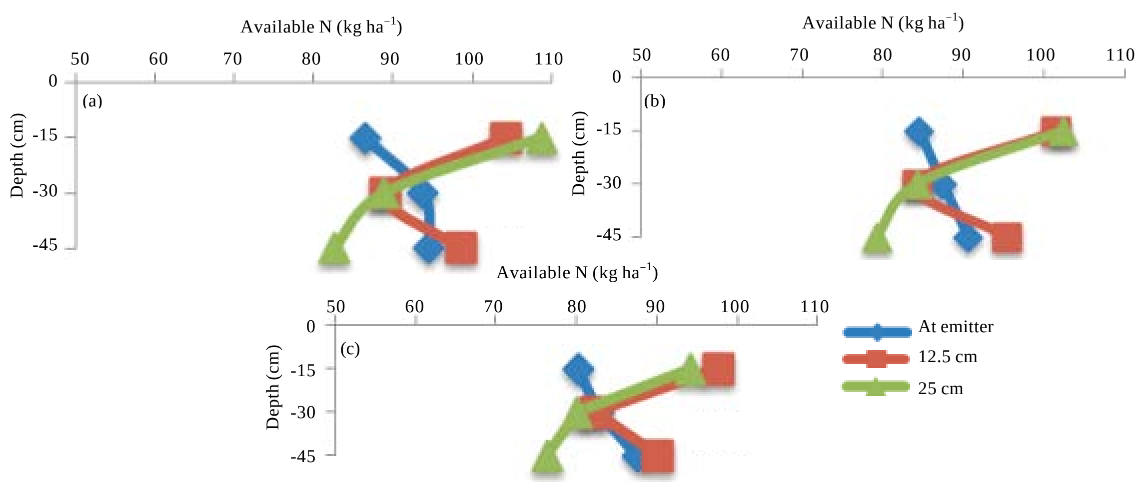

Fig. 8(a-c): Nitrogen distribution pattern across the lateral under drip irrigation at two months after sowing in 2009-2010 at (a) 24, (b) 48 and (c) 72 h

in the 0-15 cm soil layer the N content was maximum as 96 kg ha^{-1}. It decreased with increase in the depth. At 25 cm away from emitter the highest N content was recorded in 30-45 layers as 104 kg ha^{-1}. It was observed that the N moves with the water downwards and most of the N molecule accumulated in the third layer (30-45 cm) of soil. Similar result was reported by Hanson *et al.* (2003) in sandy loam soil.

Similar trend was observed at 48 h after fertigation and 72 h after fertigation. However, in 2009-10 at 24 h after fertigation, at emitter the maximum N (91 kg ha^{-1}) content was in 0-15 cm layer as compared to other lower layers. Due to this there might not be sufficient redistribution at this time. At 12.5 cm away from emitter the maximum N content (89 kg ha^{-1}) was observed in 15-30 cm layer. Similarly for 25 cm away from emitter, 15-30 cm soil layer recorded maximum N content (87 kg ha^{-1}). But at 48 h after fertigation, the trend was different from the values at

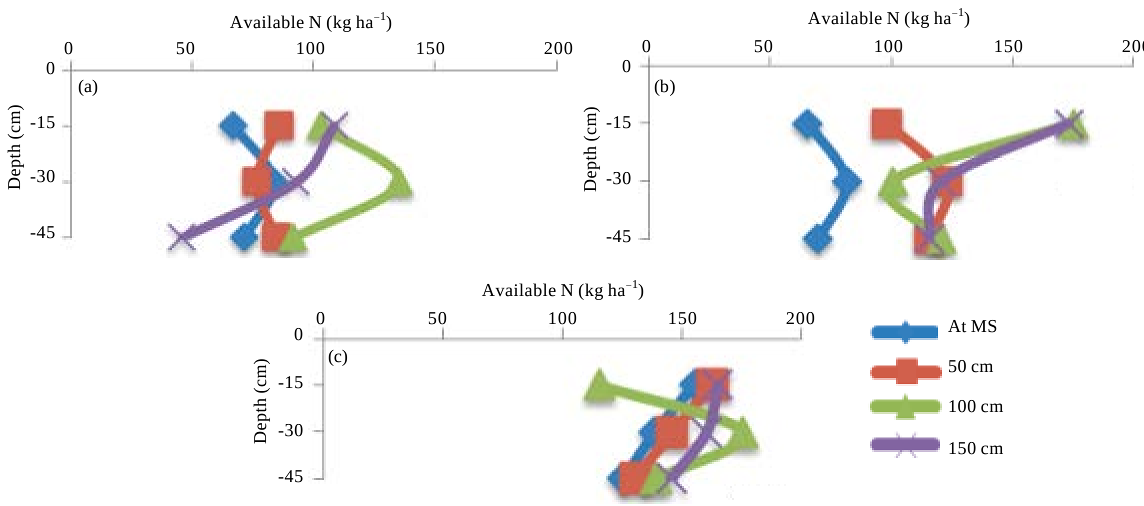

Fig. 9(a-c): Nitrogen distribution pattern along the lateral in microsprinkler at two months after sowing in 2008-2009 at (a) 24, (b) 48 and (c) 72 h

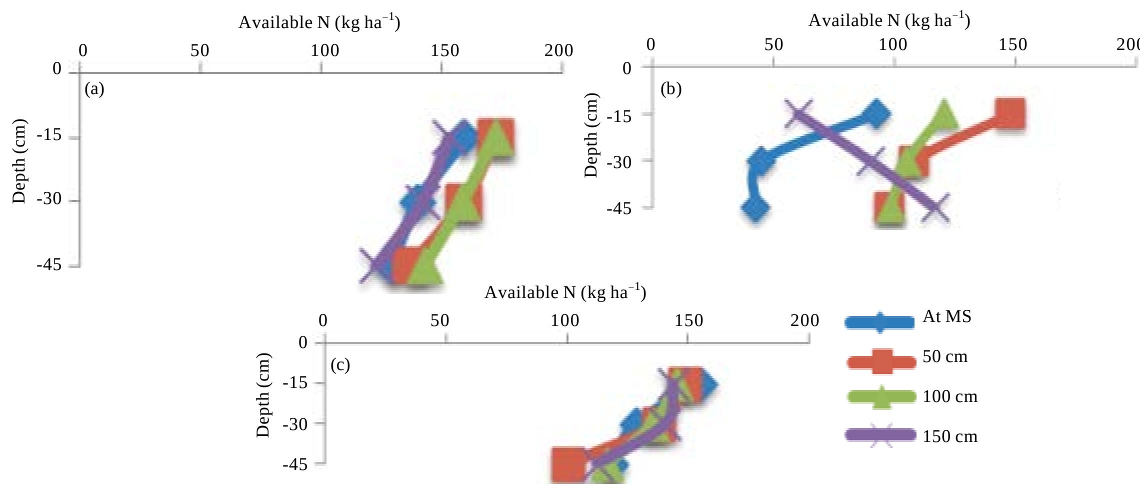

Fig. 10(a-c): Nitrogen distribution pattern along the lateral under microsprinkler at two months after sowing in 2009-2010 at (a) 24, (b) 48 and (c) 72 h

24 h after fertigation. In this case, the maximum N content in all three places such as at emitter (91 kg ha^{-1}), 12.5 cm from the emitter (87.5 kg ha^{-1}) and 25 cm from the emitter (87 kg ha^{-1}) were observed in 15-30 cm depth layer. At 72 h after fertigation, the 0-15 cm layer observed highest N content as 85 kg ha^{-1} for all three points such as at emitter 12.5 and 25 cm away from emitter. Similar trend was observed in both the year in across the lateral in 24, 48 and 72 h after fertigation at emitter, 12.5 and 25 cm away from the emitter. Gardenas *et al*. (2005) observed that fertigation at the beginning of the irrigation cycle tended to increase seasonal nitrate leaching while fertigation events at the end of the irrigation cycle reduced the potential for nitrate leaching. Leaching potential increased as the difference between the extent of the wetted soil volume and

rooting zone increased. The results indicated that available nitrogen decreased from emitter to the boundary wetting zone. That means horizontal distribution decreased while going along and across the lateral.

In general, N concentration in active root zone (15-30 cm) in drip irrigation varied from 79-103 kg ha^{-1} which was more than the initial N content in the same layer before sowing indicating adequate nitrogen availability in the active root zone. Similar results were reported by the Arulkar *et al*. (2008).

Figure 5 and 6 illustrate the distributions of available N in the sandy loam soil in vertical plane for the four applied fertigation doses. Comparison of Fig. 1, 2, 11, 12 and 13, 14, 3 and 6 revealed

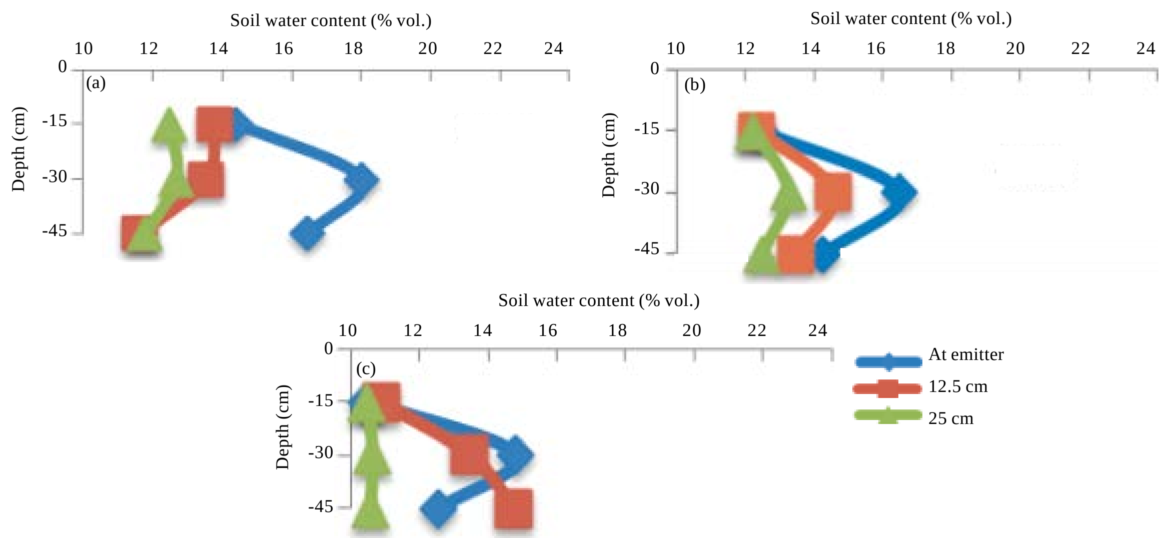

Fig. 11(a-c): Water distribution pattern across the lateral under drip irrigation at two months after sowing in 2008-2009 at (a) 24, (b) 48 and (c) 72 h

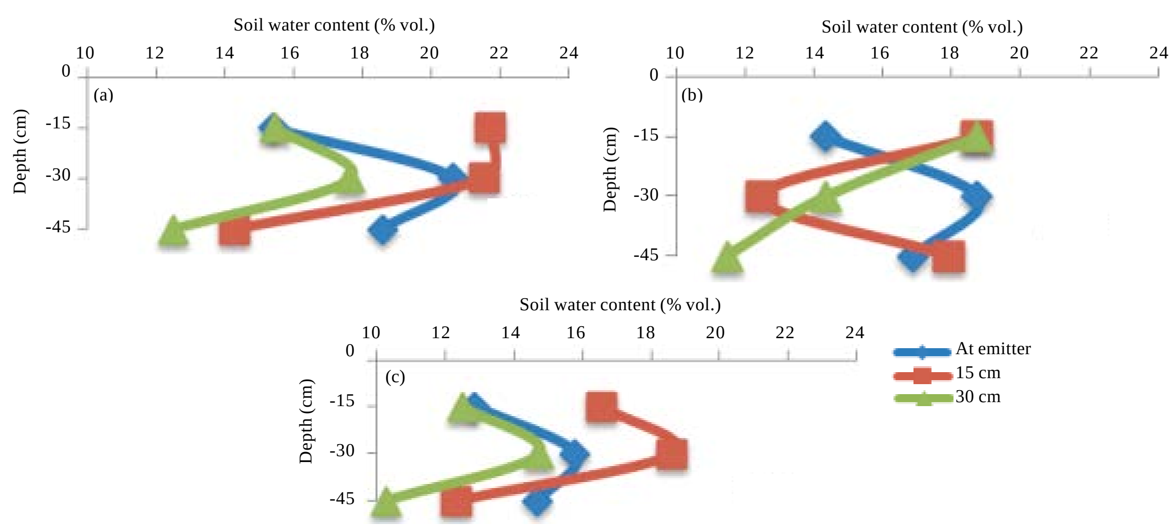

Fig. 12(a-c): Water distribution pattern across the lateral under drip irrigation at two months after sowing in 2009-2010 at (a) 24, (b) 48 and (c) 72 h

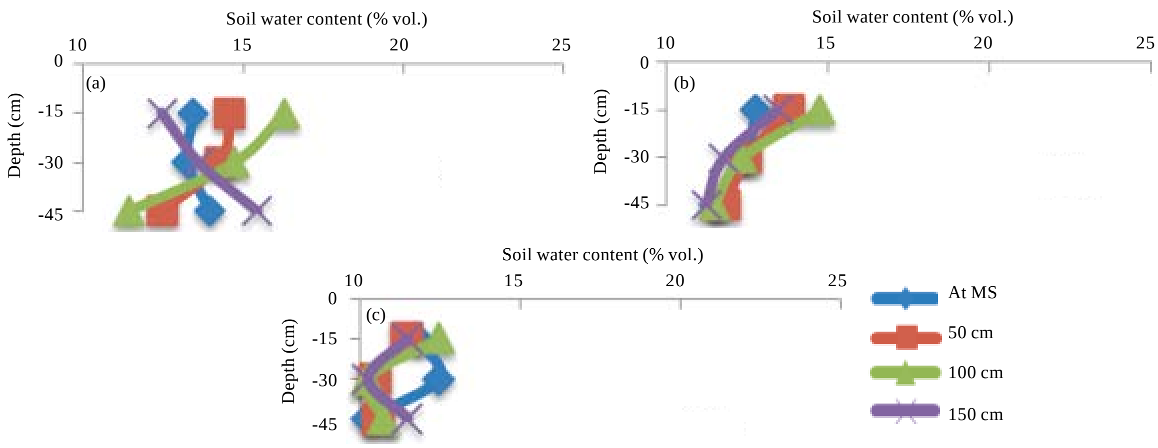

Fig. 13(a-c): Water distribution pattern along the lateral under microsprinkler at two months after sowing in 2008-2009 at (a) 24, (b) 48 and (c) 72 h

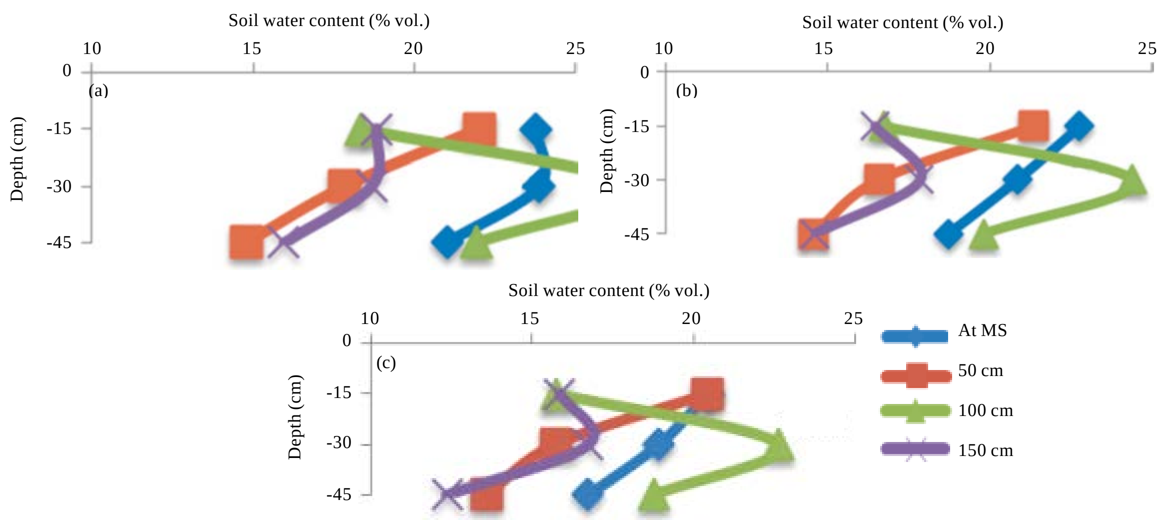

Fig. 14(a-c): Water distribution pattern along the lateral under microsprinkler at two months after sowing in 2009-2010 at (a) 24, (b) 48 and (c) 72 h

that N moves with water during soil water movement. The accumulation of N towards the boundary of the wetted volume was observed at 72 h after fertigation. The N availability in boundary (75, 78 and 82 kg ha^{-1}) was low at emitter source in all three depths (94, 97 and 110 kg ha^{-1}). In contrary to these results in a study of the simultaneous transport of water and chloride, reported that the apparent diffusion coefficients of chloride are less than 0.01 cm min^{-1} that is slower than relative rate of water movement. This means that once a soluble non-reactive ion like NO_3^- begins to move with water its back diffusion is slow which means that ion and water are closely coupled.

The amounts of N in case of N40, N80 and N120 treatments were 89, 92 and 104 kg ha^{-1}, respectively in the 0-15 cm layer. This could be attributed to higher water content resulting in more ammonical N in this layer. To find out the leaching trend in the treatments, N concentration in the last layer (30-45 cm) was compared with the 0-15 and 15-30 cm layers (Fig. 7-10). It was observed that the lowest amount of N (79 kg ha^{-1}) in the 30-45 cm layer was in treatment N40 and the highest amount of N (95 kg ha^{-1}) was in treatment N120. This indicates that the chance of more nitrogen in treatment N120 in the last layer may be due to application of more nitrogen. Lowest amount of N content in case of N80 was due to the fact that in this treatment only 80% of recommended dose of N was applied. The above results indicated that nitrogen availability decreased with increasing horizontal distance in drip fertigation. Also, it was observed that application of more nitrogen as compared to plant requirement leads to more leaching.

Nitrogen distribution in microsprinkler fertigation: Figure 9 and 10 show the N distribution in microsprinkler along the lateral at four places, three depths and three occasions of observations. The available N distribution at 24 h after fertigation was found to be in the range of 50-150 and 120-170 kg N ha^{-1} in the year 2008-2009 and in the year 2009-2010, respectively. At 48 h after fertigation the range of available N distribution was observed as 55-170 kg N ha^{-1} in the year 2008-2009 and 50-150 kg N ha^{-1} in the year 2009-2010. At 72 h after fertigation the available N range was observed as 100-170 kg N ha^{-1} in the year 2008-2009 and 100-150 kg N ha^{-1} in the year 2009-2010. In contrary to drip fertigation the results indicated that the available nitrogen was increasing with increase in time due to redistribution.

Figure 15 and 16 show the available N distribution in microsprinkler across the lateral. At 24 h after fertigation, the range of N was observed as 94-99 kg N ha^{-1} in both the years. At 48 h after fertigation the range of N distribution was 95-105 kg N ha^{-1} in both the years. While at 72 h after fertigation the N distribution range was 91-107 kg N ha^{-1} in both the years. It was observed from the above results that most of the available N was present in the 15-30 cm layer indicating adequacy of N in the active root zone. Similar results were found in the drip fertigation; however, insufficient redistribution time leads to decreasing N content while increasing time. The highest soil water content in microsprinkler was observed in the second layer (15-30 cm).

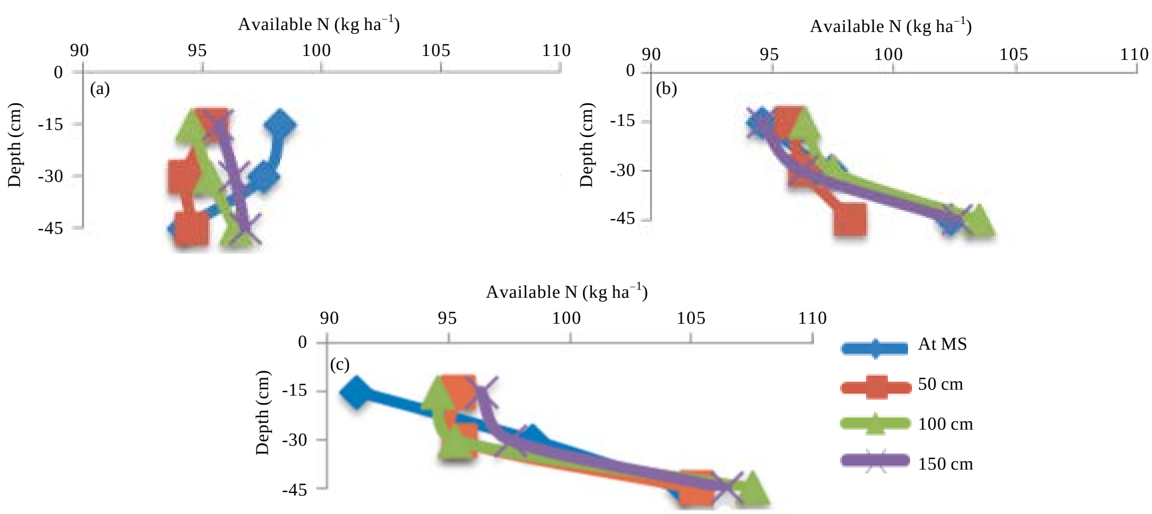

Fig. 15(a-c): Nitrogen distribution pattern across the lateral under microsprinkler at two months after sowing in 2008-2009 at (a) 24, (b) 48 and (c) 72 h

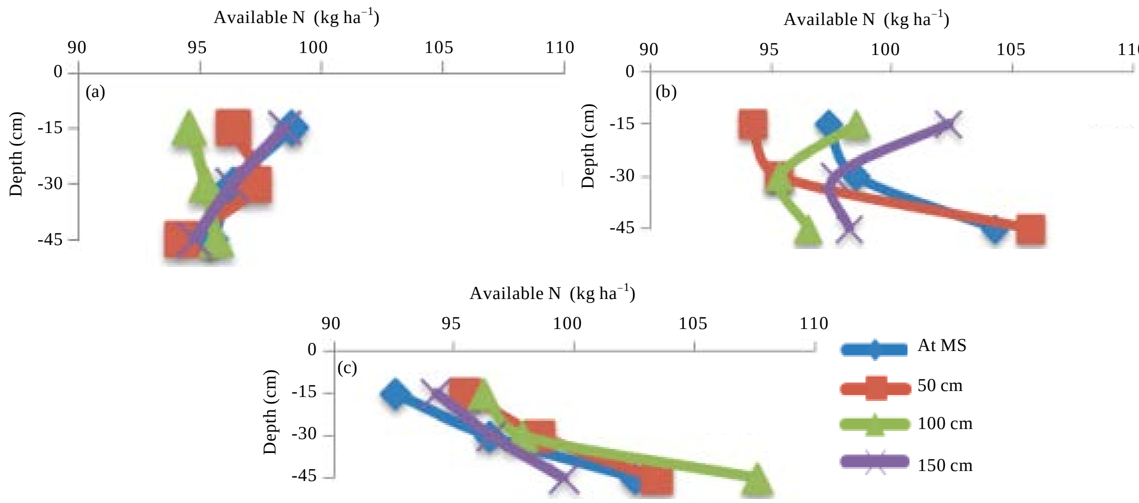

Fig. 16(a-c): Nitrogen distribution pattern across the lateral under microsprinkler at two months after sowing in 2009-2010 at (a) 24, (b) 48 and (c) 72 h

Table 2: Nitrogen balance in drip in both the years

Nitrogen balance (kg N ha^{-1})	2008-2009 N40	2008-2009 N80	2008-2009 N120	2009-2010 N40	2009-2010 N80	2009-2010 N120
Available N	74.22	74.22	74.22	69.34	69.34	69.34
Nitrogen applied	40.00	80.00	120.00	40.00	80.00	120.00
Plant uptake	21.34	36.74	64.23	22.47	38.65	67.34
Soil residue	73.64	85.24	95.34	72.87	88.47	94.13
Leaching	19.24	32.24	34.65	14.00	22.22	27.87

While comparing the N distribution in both the methods of irrigation, horizontal distribution of N was more than the vertical distribution due to the non-uniform distribution of water due to disc through of water in microsprinkler which is contrary in the drip irrigation. As most of the water and nitrogen is available in the active root zone (15-30 cm) in microsprinkler, this is most suitable for the shallow rooted crops like garlic to facilitate crop uptake of water and nitrogen as compared drip irrigation. The above results indicated that more N is available horizontally in active root zone (15-30 cm).

Nitrogen balance in microirrigation fertigation during 2008-2009 and 2009-2010: Nitrogen balance was computed using the available N, applied N, plant uptake and soil residue N contents. The available N was estimated from the samples taken before the sowing. Plant uptake and soil residue were measured from the samples taken from after harvest. By deducting the N output from the N input quantity the balance was assumed as leached beyond the root zone depth. Table 2 shows the N balance in the drip fertigation after harvest in both the years in all the treatments. It revealed that the maximum plant uptake was in 120 kg ha^{-1} (90.47 kg ha^{-1}) and the minimum N content was in 40 kg N ha^{-1} (58.24 kg ha^{-1}). The highest N by the plant uptake, soil residue and

Table 3: Nitrogen balance in microsprinkler in both the years

Nitrogen balance ($kg\ N\ ha^{-1}$)	Years 2008-09 N40	N80	N120	2009-10 N40	N80	N120
Available N	74.22	74.22	74.22	70.24	70.24	70.24
Nitrogen applied	40.00	80.00	120.00	40.00	80.00	120.00
Plant uptake	20.14	32.47	67.53	22.74	42.13	64.47
Soil residue	75.45	93.42	96.47	76.64	90.34	104.34
Leaching	18.63	28.23	30.22	14.86	21.77	25.43

leaching, was found to be in the treatment of 120 kg N ha^{-1} in both the seasons. It may be due to the reason that N applied was more than the recommended dose leading to more plant uptake causing higher vegetative development. This could be corroborated with the lower bulb yield in the N120 treatment as compared to the N80 treatment.

Table 3 shows the N balance in microsprinkler in both the years after harvest. Similar to the drip fertigation the leaching beyond the root zone depth was estimated. It was observed that the plant uptake was higher in N120 (67.53 and 64.47 kg N ha^{-1}) in both the years. Similarly, soil residues (96.47 and 104.34 kg N ha^{-1}) and leaching (30.22 and 25.43 kg N ha^{-1}) were highest in N120 treatment in both the years. It can be inferred from the table that the leaching increased with increase in the nitrogen applied.

In both the methods of fertigation despite the available N and applied N were same, from plant up take and leaching points of view these were higher in drip fertigation than microsprinkler. Also results in research study I indicated that drip fertigation was giving the highest yield and quality. So, the drip irrigation was better than the microsprinkler. However, microsprinkler facilitates to increase the horizontal distribution, thereby decreasing the leaching than drip fertigation.

CONCLUSION

It can be concluded that proper management of microirrigation with appropriate amount of water and nitrogen significantly enhances the yield and quality of garlic with maximum water and nitrogen use efficiency. In drip fertigation, soil water content was relatively higher in upper soil layer (0-30 cm) and near the emitter in all the 3 cases after irrigation (24, 48, 72 h after fertigation) because of redistribution. Water content in all the soil layers decreased as the distance from the emitter increased in the horizontal direction. The soil water distribution decreased from the point of application to periphery of wetted area. The favorable water content was maintained after 72 h after irrigation in the active root zone. Comparing the water distribution in both the methods, more horizontal movement was observed in microsprinkler than drip fertigation. But, in drip irrigation vertical distribution was more than microsprinkler. The present study revealed that water in both the methods of irrigation was maintained in the range of 15-25%.

It can be concluded from the study that available nitrogen decreased from emitter to the boundary of wetting zone in drip fertigation. Nitrogen availability decreased with increasing horizontal distance in drip fertigation contrary to microsprinkler fertigation.

In both the methods of irrigation, leaching of nitrogen increased with an enhancement in rate of nitrogen application. However, nitrogen leaching was higher in drip fertigation than the microsprinkler due to more vertical movement of soil water leading to the movement of the nitrogen beyond the root zone. Nitrogen balance for the study indicated that leaching of nitrogen beyond the root zone increased with the level of nitrogen applied in both the methods of irrigation. Present study demonstrated that fertigation through drip fertigation is more suitable for growing of shallow rooted crop like garlic in terms of yield and its quality and root uptake.

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