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RESEARCH ARTICLE

FERTIGATION SCHEDULING IN TOMATO BASED ON THE HYDRAULICS AND NUTRIENTS UNDER POINT SOURCE OF WATER APPLICATION

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ABSTRACT

Drip irrigation with fertigation is the most efficient way to supply water and nutrients to the plant as it saves significant amounts of water and nutrients and enhances the quality and quantity of vegetable and fruit crops. The effect of soil moisture movement and nutrient dynamics on the growth and yield of tomato was studied. Tomato (Indo-American hybrid var. Rashmi) crop was transplanted and the movement of waterfront and the distribution of soil moisture and nutrients (N, P_2O_5 and K_2O) in soil under alternate day, weekly, fortnightly and monthly fertigation frequency were monitored. Lateral pipe having drippers of 4.0 l h^{-1} discharge at a distance of 40 cm was used for applying water. Tomato is 180 days duration crop and is divided in four stages namely, initial (35 days), developmental (45 days), middle (70 days) and late stage (30 days). The water requirement of tomato varied from 2.1 to 7.0 l day^{-1} m^{-2} from early stage to peak demand period. The total amount of water needed to irrigate 1.0 ha of tomato crop was estimated as 66.4 cm. To meet the nutritional requirement of tomato crop, 50 t ha^{-1} farm yard manure, 180 kg ha^{-1} nitrogen (N), 230 kg ha^{-1} phosphorous (P_2O_5) and 190 kg ha^{-1} potassium (K_2O) were applied. NO_3-N, NH_4-N, P_2O_5 and K_2O concentration around the point of application (at 0.0 cm from lateral pipe) were found more than at 15 and 45 cm away from lateral pipe throughout the crop season. The maximum NO_3-N, NH_4-N, K_2O and P_2O_5 concentration was found in upper soil profile. Crop quality and yield of tomato crop was improved by fertigation significantly. The maximum yield of 96.2 t ha^{-1} was observed under alternate day fertigation and the minimum yield of 72.5 t ha^{-1} under treatment monthly fertigation. The comparison among the four treatments showed that the adoption of alternate day or weekly fertigation was more profitable as compared to the fortnightly and monthly fertigation.

INTRODUCTION

Tomato (*Lycopersicon esculentum*) is a member of Solanaceae family and one of the most widely grown vegetables in the world, which thrives well in temperature 10 to 30 ^{0}C with optimum range of temperature of 21 to 24 ^{0}C. Present world production of tomatoes is about 100 million tons fresh fruit from 3.7 million ha (FAOSTAT, 2001). Tomato is important source of vitamins A and C. One hundred eighty gram of tomato contains 2.0 g protein, 1.0 g fat, 8 g carbohydrates and 15 g sodium, besides enriched in Vitamins A and C. Tomato crop prefers deep, well drained sandy loam soil because they are sensitive to water logging. Tomato crop prefers a pH range of 6.0 to 7.0. Pressure on agriculture is increasing due to population growth, necessitating efficient utilization of all inputs to agriculture. India needs to produce about 300 million tones by 2020 to feed its growing population. As there is not much scope to expand the net cultivated area (142.5 mha), the future requirement has to be met through vertical growth by intensification of agriculture. The per capita per annum water availability at present is about 2001 m^3 which will reduce to the stress level of 1700 m^3 per capita per annum in the next 2-3 decades. The present allocation of water for agriculture is about 85 % but is likely to reduce by 10-15 % to meet the growing vital demand for drinking water and industrial use. Drip irrigation is the most effective way to supply water and nutrients to the plant as it saves significant amounts of water and nutrients and increases the quality and quantity of vegetable and fruit crops. The characteristics of soil moisture movement and nutrient dynamics influence the growth and yield of crop substantially. Fertigation is an efficient method of fertilizer application and savings in the consumption of fertilizers up to 50 % are reported by many workers (Miller *et al*., 1976; Patel and Rajput, 2000; Rajput and Patel, 2001). The growth of the active roots remains restricted to the top soil and the nutrient reserves within this volume is depleted due to crop uptake (Sweeney *et al*., 1987; Haynes, 1988). Sixty per cent saving in the fertilizer use through fertigation in production of tomato was also reported by Prasad (1997).

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Fertilizers should be applied in a form that becomes available in synchrony with crop demand for maximum utilization of nitrogen from fertilizers (Boyhan *et al*., 2001). Frequent fertigation of crops by low-volume irrigation systems is often advocated in the technical and popular literature (Bar- Yosef and Sagiv, 1982; Stark *et al*., 1983). But there is limited evidence of the benefits of high-frequency fertigation in field. A review of the literature did not reveal any previous investigations of the effects of fertigation frequency on the yield of drip-irrigated tomato. The present experiment was conducted to study the influence of frequency of fertigation and irrigation management on the movement of nitrogen (NO_3-N and NH_4-N), potassium and phosphorous in the soil and on the yield of tomato. The purpose of this study was to observe the distribution of nutrients nitrogen (NO_3-N and NH_4-N), potassium and phosphorous under four fertigation frequencies and their effect on tomato yield.

MATERIALS AND METHODS

Location and soil of experimental field plot

The experiment was conducted at the experimental farm of Water Technology Centre, Indian Agricultural Research Institute, New Delhi, India during the month of October to May for 3 years (1999-2002). The soil of the research farm comprised of deep, well-drained sandy loam with the texture (53.18 % sand, 30.1 % silt, and 16.72 % clay). The bulk density of soil is 1.48 g cm^{-3}, field capacity 0.173, and saturated hydraulic conductivity 1.17 cm h^{-1}.

Raising of seedlings and transplanting

The tomato (Indo-American hybrid var. Rashmi) seeds were sown in the raised nursery beds prepared in a ploy house in the first week of October. After sowing, the nursery bed was covered with thin layer of sand and then with straw. The seed bed was moistened with water. After germination of seed, straw cover was removed. After 15 days of germination, Thiodan (2.5 g l^{-1}) and Dithane (2.5 g l^{-1}) were sprayed over tomato seedlings. One month old tomato seedlings were transplanted at the spacings of 40cm x 40cm. One lateral line was provided for every two rows of tomato. Lateral pipe having in-line drippers of 4 l h^{-1} discharge at a distance of 40 cm was used for applying the irrigation water.

Estimation of water requirement and irrigation application

Reference crop evapo-transpiration was estimated using Penman-Monteith method using weather data collected from Automatic Weather Station, 100 m away from the field site. The actual evapo-transpiration was estimated by multiplying reference evapo-transpiration with crop coefficient (Kc) (Allen et. al. 1998) for different months based on crop growth stages. Tomato is 180 days duration crop and was divided in four stages namely, initial (In) (35 days), developmental (Dev) (45 days), middle (Mid) (70 days) and late stage (Late) (30 days). Crop coefficient at initial stage (Kc in) was based on wetting event, irrigation frequency and soil type. Crop coefficient for middle growth (Kc mid) stage was based on the crop height, wind speed and relative humidity. Kc mid was adjusted for semi arid region according to wind speed. Crop coefficient at developmental stage (Kc dev) and late stage (Kc late) were estimated by using the relationship suggested by Allen *et al*. (1998). The water requirement of tomato varies, respectively, from 2.1 to 6.95 l $day^{-1}m^{-2}$ (1999-2000) from early stage to peak demand period. The drip irrigation system was operated to supply irrigation water to meet the estimated irrigation water requirement of plants. Amount of water applied in different treatments were same and duration were adjusted according to the size of the field. The total amount of water needed to irrigate 1.0 ha of tomato crop was estimated as 66.6 (1999-2000), 64.3 (2000-01) and 68.3 (2001-02) cm, respectively.

Nutrient management

To meet the nutritional requirement of tomato crop, 50 t ha^{-1} farm yard manure, 180 kg ha^{-1} N, 230 kg ha^{-1} P_2O_5 and 190 kg ha^{-1} K_2O were applied. To meet the nutritional requirement of tomato crop, 50 t ha^{-1} farm yard manure, Fertigation was started 15 days after transplanting and was closed 30 days prior to the end of the crop period. During the remaining 112 days of the crop duration fertigation was alternate day (VA), weekly (VW), fortnightly (VF) and monthly (VM) fertigation with irrigation. To determine the moisture distribution and nutrients in the crop growth season, soil sampling was done along the lateral pipe as well as across the lateral pipe. Soil samples were collected fortnightly from 0-15, 15-30, 30-45, 45-60, 60-75, 75-90 and 90-120 cm soil depths at distances of 0, 15, 30 and 45 cm from the lateral pipe. Available phosphorous (P_2O_5), potassium (K_2O), ammonical-nitrogen (NH_4-N) and nitrate-nitrogen (NO_3-N) were estimated by colorimetric method (ascorbic acid), ammonium acetate method and potassium chloride extract method, respectively. Flame photometer and spectrophotometer were used for analysis of soil samples.

RESULTS AND DISCUSSION

Soil moisture distribution

Sandy loam soil needed frequent irrigation with less amount of water per irrigation. Tomato is deep- rooted crop and in deep soils, some roots penetrate up to 1. 5 m. The maximum rooting depth is reached about 60 days after transplanting (FAOSTAT, 2001). Over 80 percent of the total water uptake occurs in the first 0.5 to 0.7 m and 100 per-cent of the water uptake of a full grown crop occurs from the first 0.7 to 1.2 m therefore soil moisture content up to depth of 120 cm was measured. Change in volumetric water content at 0-15, 15-30, 30-45, 45-60, 60-75, 75-90, 90-120 cm soil depths at 0, 15, 30 cm away from lateral (in all treatments) were monitored fortnightly. With growth of crop the root system of plant develops, water requirement of crop increases and soil moisture was increases in lower soil profile. Uptake of moisture was more up to developmental stage. But after developmental stage the soil moisture starts moving from upper profile to lower profile (Fig. 1). Distributions of soil moisture at middle growth stage of crop are illustrated in Fig 2. Because of frequent irrigations, the soil moisture was high at about field capacity ($\simeq$ 25.6 %) near the dripper. Soil water content just below the dripper i.e. 0 cm away from lateral was more throughout the crop season i.e. 25.6, 25.5 and 25.6 %, in treatments VA, VW, and VF, respectively. Soil water content did not decrease significantly with the increasing depth of soil from 15 to 120 cm. Soil water content was found decreasing with increasing distance from the lateral pipe (Fig. 2).

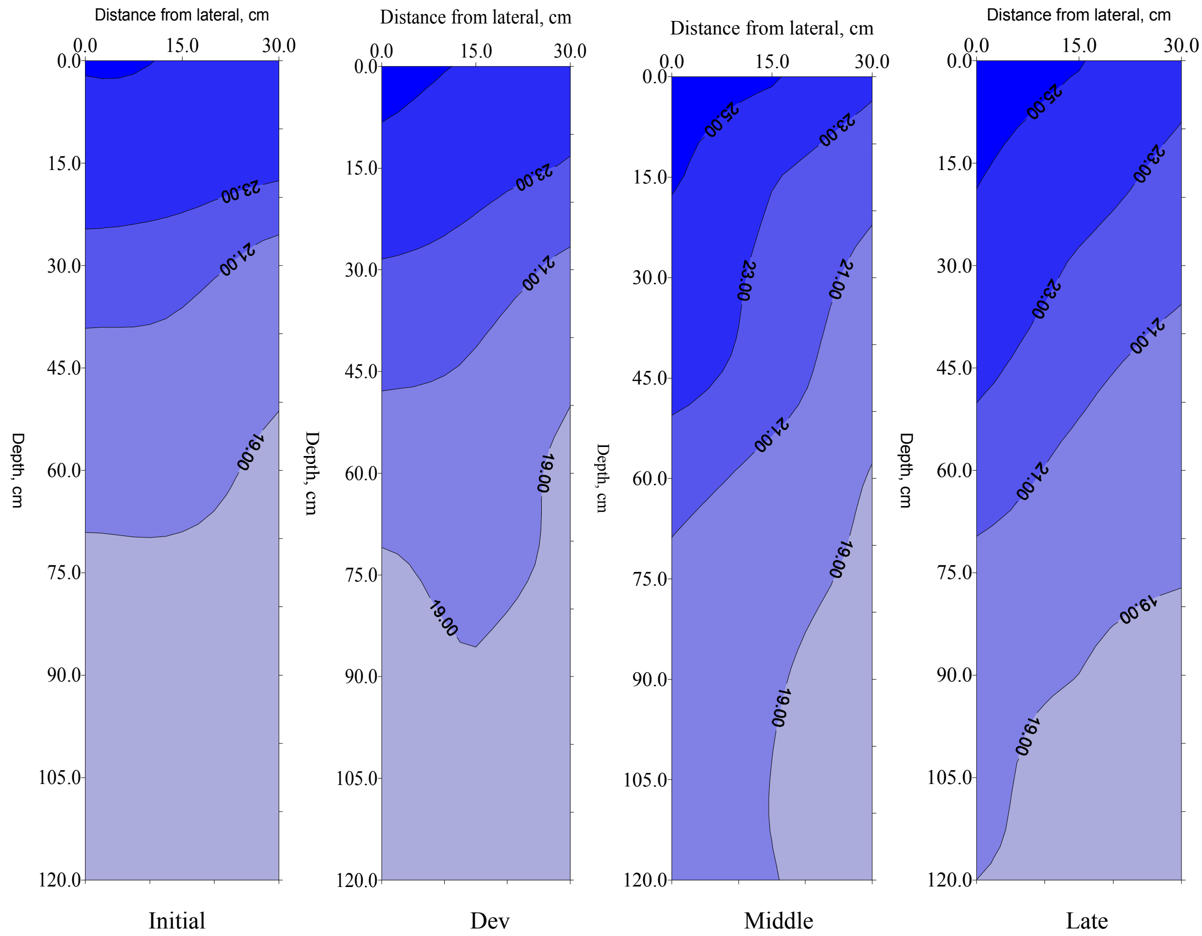

Fig. 1 Soil moisture distribution in treatment VA at initial, developmental, middle and late growth stage of tomato

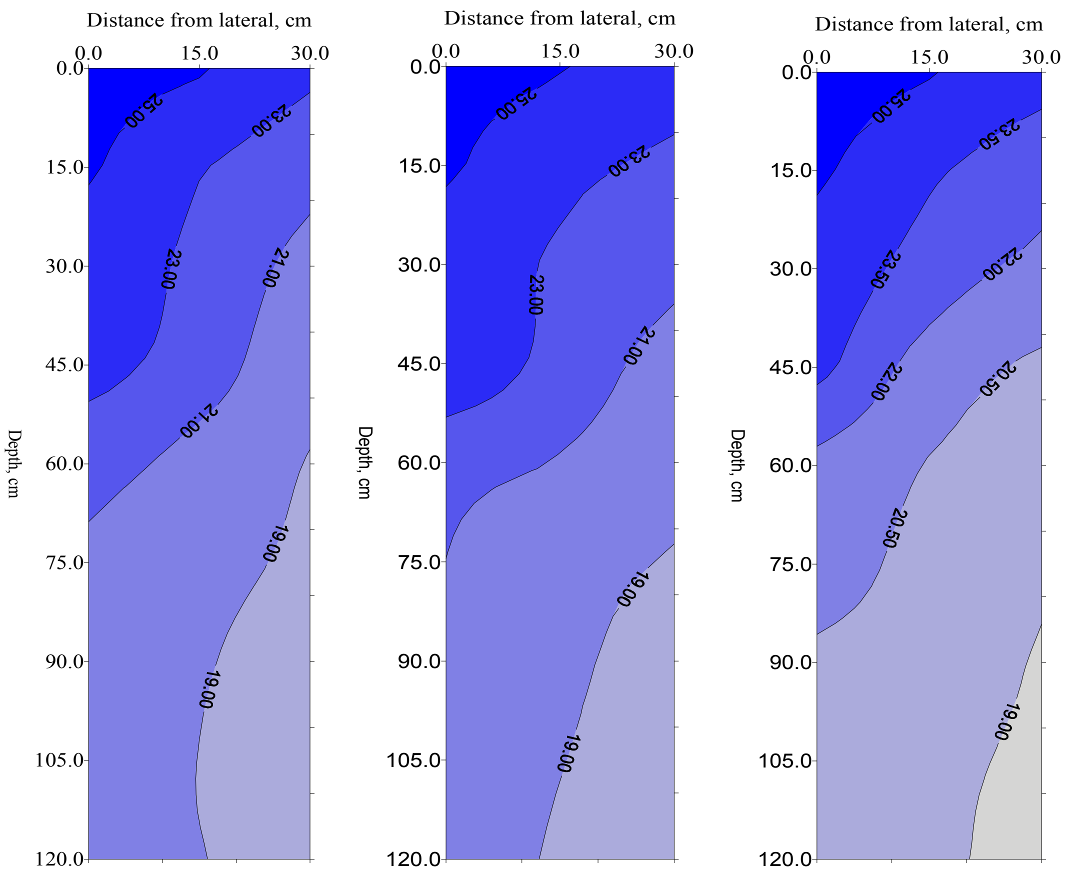

Fig. 2. Soil moisture distribution in treatments VW, VF and VM at middle stage

Effect of fertigation frequency on distribution of NO_3-N, NH_4-N, K_2O and P_2O_5

NO_3-N was observed in all four-fertigation frequencies i.e. VA, VW, VF and VM. In the treatment VD, NO_3-N concentration first increases in 0-15 cm soil depth from 50.1 to 86.37 mg Kg^{-1} of soil (ppm) (initial and developmental stage) then starts decreasing from 86.37 to 41.13 ppm. NO_3-N concentration in 0-15 cm soil depth was found more than in 30, 45 and 60 cm soil depth at initial and developmental stage. The soil samples were collected to determine the initial NO_3-N status of the field. Initially, the maximum NO_3-N concentration 28.6 ppm was present at surface but decreased downward up to the depth of 60 cm depth (below the ground surface). It was observed that after 45 DAT the tomato the maximum NO_3-N concentration of 46.8 ppm at 15-0 cm, 29.5 ppm at 30-15 cm and 44.2 ppm 30-15 cm was observed under treatments VA, VW, VF and VM, respectively.

After 90 DAT of tomato the maximum NO_3-N concentration was found 99.4 ppm at 15-0 cm, 115.9 ppm at 0-0 cm and 97.0 ppm at 0-0 cm in treatments VA, VW, VF and VM, respectively. It was observed that after 90 DAT of the tomato crop was not able to consume the total NO_3-N applied and hence the concentration of NO_3-N in soil was found to be increasing. After 150 DAT of tomato the maximum NO_3-N concentration of 123.6 ppm at 0-0 cm, 108.4 ppm at 30-60 cm and 52.2 ppm at 15-30 cm was observed in treatments VA, VW, VF and VM, respectively. But the NO_3-N concentration below the top layer is continuously decreasing, which may be due to the fact that fertigation was stopped after 90 DAT. The maximum NO_3-N concentration was found at 60 cm soil depth at 120 DAT. It was found from the field experiments that neither NO_3-N moved and ended up to the wetted periphery nor NO_3-N leached beyond the root zone. The distribution of NH_4-N in the soil at 15, 30, 45 and 60 cm soil depths at 0, 15 and 30 cm away from lateral pipe for throughout the crop season was estimated. It was observed that as distance from lateral pipe increases from 0 to 30 cm the concentration of NH_4-N decreases significantly throughout the crop season. NH_4-N concentration decreases as depth increase from 15 to 60 cm depth.

It was observed from the experiment that maximum NH_4-N concentration was accumulated around the dripper at 15.0 soil depth and at 15.0 cm away from lateral pipe. Immobile fertilizer ions of NH_4-N applied with irrigation water were absorbed in the soil close to the source of application, which was considered as the primary reason for the extremely high NH_4-N concentration close to the source. Beyond 30 cm soil depth, the NH_4-N concentration remained almost at its initial values in point source of water application. With growth of crop, the NH_4-N concentration increases in the lower soil depth i.e. from 15 to 30 cm. Higher concentration of NH_4-N near the dripper i.e. at 15 and 30 cm soil depth in treatment VA. After 45 cm soil depth, there is tendency to increase in the NH_4-N concentration. K_2O concentration and its distribution in the soil profile were determined on 45, 60, 75, 90, 120 and 150 DAT of tomato crop. It was observed that the throughout the crop season the maximum K_2O concentration of about 55 ppm was found at 15 cm soil depth except at 150 DAT when maximum potassium was found at 30 cm soil depth. As distance from dripper increases from 0 to 30, the concentration of K_2O decreases significantly at all soil depth. It was observed that with growth of crop the K_2O concentration tends to increase in lower soil depth. It was found that at 0 cm away from lateral pipe and at 30, 45 and 60 cm soil depth, the potassium concentration at 45 DAT was found 35.9 ppm, 18.8 ppm and 14.0 ppm respectively, while on 120 DAT, the concentration increases from 35.9 to 48.5 ppm, 18.8- 37.1 ppm and 14.0 to 16.4 ppm. P_2O_5 concentration and its distribution in the soil profile were determined on 45, 60, 75, 90, 120 and 150 DAT. It was observed that after 45 DAT, the maximum P_2O_5 concentration of 18 ppm at 15 cm soil depth. There is no specific trend was found in the distribution of P_2O_5 in the soil profile. But with depth, the P_2O_5 concentration decreases with increase in soil depth.

Effect of fertigation frequency on tomato yield

Crop quality and yield of tomato crop improved by fertigation significantly. The maximum yield of 96.2 t ha^{-1} was observed with treatment VA and the minimum yield of 82.17 t ha^{-1} in treatment VM. The effect of the fertigation scheduling on the yield of tomato is shown in the Fig. 3. The comparison among the four treatments showed that the adoption of alternate day or weekly fertigation was more profitable as compared to the fortnightly and monthly fertigation.

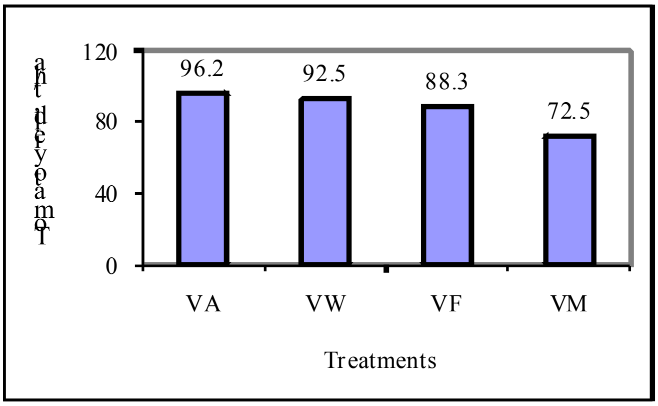

Fig. 3. Effect of fertigation frequency on tomato yield

Conclusions

Analysis of soil profiles in VA, VW, VF and VM shows that nutrients in lower soil profiles (30-60 cm soil depth) was marginally affected. The total available nutrient in soil in all fertigation frequency is almost same. The distribution of nutrients in soil profile is very greatly influenced by fertigation frequency in sandy-loam soil. However, fluctuations of nutrients in 0-15, 15-30, 30-45 and 45-60 cm were more in monthly fertigation frequency. The level of soil nutrients after the crop season shows that more NO_3-N leached through the profile in monthly fertigation frequency. Approximately 66.4 cm water is needed for growing tomatoes. The maximum yield of 96.2 t ha^{-1} was observed with treatment VA and the minimum yield of 82.17 t ha^{-1} under treatment VM.

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