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Optimal design of flow rate in drip irrigation system to enhance the tomato cultivation

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ABSTRACT

Tomato is the second most important vegetable crop next to potato. As far as conservation of soil and water is concerned, drip irrigation offers the most practical and effective alternative to regular surface irrigation among all the irrigation technique known today in the world. Researchers throughout the world are kin to obtain the optimal flow rate through drip irrigation for overall development of crop. In this study, attempt has been made to analysis the growth rate and yield of tomato plant at various flow rate of drip irrigation, and to determine the effect of fertigation through drip irrigation on growth and yield of tomato. In this study "Samartha F1 hybrid" variety of tomato seed was selected and cultivated over the farm size of 6×5 m^2. The selected farm area was divided into two sections i.e. fertigation section and non-fertigation section. Three rows having ten plants in each row was transplanted in both sections. Growth of tomato plants in term of height and canopy was measured and compared with different flow rates. The average increment in the height of tomato plants at flow rate of 2 L/hr, 4 L/hr and 8 L/hr were estimated as 68%, 60% and 52% respectively. Yield of tomato in terms of fruits was estimated for three different flow rates of 2 L/hr, 4 L/hr and 8 L/hr. The yield of tomato is optimal when drip irrigation with 2 litres per second has been used for irrigating the farm land. Significant effect of fertigation through drip irrigation has been found on growth and yield of tomato plants.

Highlights

- Optimal flow rate of drip irrigation has been determined for tomato cultivation
- 'Samartha F1 hybrid' tomato variety has been used for experimentation
- Effect of Fertigation through drip irrigation has also been studied.
- Optimal flow rate of 2 litres per second through drip irrigation maximizes the profit.

Keywords: Drip irrigation, tomato, fertigation, flow rate, Samartha F1 variety

Demand for methods and techniques for efficient use of water has become the need of the hour due to increase in water shortages all over the world. Scientific management of irrigation water is highly desirable keeping in view the fact that water, as a resource in agriculture, has become a limiting factor especially in arid and semi-arid regions, as rainfall distribution in these regions is uncertain and erratic in time and space. Drip irrigation is one of the most valuable innovations in modern agriculture, because it offers the most practical and effective alternative to regular surface irrigation (Singh *et al.*, 2013). An extensive outline for drip irrigation was presented by Camp in 1998. He concluded that "Drip irrigation provides a more efficient delivery system, but the realization of this increased application efficiency will depend upon how well the application is matched to crop water and nutrient requirements". Judicious use of the available water resources through drip irrigation under conditions of protected cultivation becomes necessary to enhance the yield and water use efficiency. Water management by drip irrigation provides daily requirement of water to a portion of the root zone of each plant, and maintains a high soil matric potential in the rhizosphere to reduce plant water stress (Afolayan *et al.*, 2014, Kennedy *et al.*, 2013, Nakayama and Bucks 1986, Wan *et al.*, 2013). Irrigating agricultural field with drip irrigation technique has many advantages. For example, adopting this technique will utilize every drop of water economically. Further, as water is applied only in plant root zone, leaching is minimum and hence, fertilizer/nutrient loss can also be minimized using drip irrigation as compared to other techniques of irrigation. Growth of weeds can also be controlled as no water is available in there root zone. Moreover, once the system is installed in the field, operational cost will be low for the next subsequent cropping seasons. Soil erosion can also be controlled because the lateral movement of water is only limited within the root zone of the crop. As far as constraint on topology of the field is concerned, this technique is best because irrigation through drip can be provided to irregular shaped land also (Kumar and Singh 2014). Thus, leveling of field before irrigation is not necessary. Also, if drip irrigation is properly used in the field, seed germination will improve. Furthermore, energy cost can be reduced as it can operate on lower pressure than other irrigation methods. Thus, yield of crops can be maximized using this technique. Researchers like Al-Ghobari (2014), Kuscu *et al.*, (2014), Noshadi *et al.*, (2014) and Fontes *et al.*, (2014) worked extensively on drip irrigation and identified some of the major advantages of drip irrigation such as: reduced tillage, reduced weed control inputs, enhanced fertility management, reduced water and energy use, and increased yield. Heermann (1996) did research on irrigation scheduling on tomato cultivation. They defined irrigation scheduling as the science of specifying future irrigation timing and amount in the implementation of a water management strategy. S. Lakshmi (1997) to observe the vegetables crop yield capacity with different levels of fertigation of nitrogen, phosphorous and potassium. He recommended that nitrogen phosphorus and potassium should be used at the rate of 75 kg/ha and 60 kg/ha and 60 kg/ha respectively for maximum yield.

In the present study, irrigation in tomato cropping is controlled by using the drip irrigation method. Tomato is the second most important vegetable crop next to potato. World production of tomato is about 152.9 million ton with a value $74.1 billion (FAOSTAT, 2009). India stands second in the world in terms of tomato production of 16.82 million ton (IHD, 2012). The tomato is botanically known as Lycopersicum esculentum and it belongs to the Solanacae family. The fruits are harvested as red for consumption. Tomato is a rapidly growing crop with a growing period of 90 to 150 days. Optimum mean daily temperature for growth is 18 to 25ºC with night temperatures between 10 and 20ºC. Fereres *et al.*, (2003) and de Aguiar *et al.*, (2014) worked on the irrigation management in processing tomato production. He concluded that successful irrigation management is very important in maximizing plant productivity; where water is limiting, yield and quality of agricultural crops can be greatly affected.

Fertigation is the application of fertilizers, soil amendments, or other water-soluble products through an irrigation system. Fertigation is a more efficient and effective way to fertilize the crops, saving time and money and improving yields. Good results can be achieved by using a 'little and often' principle to enhance plant growth and also its health along with more dry matter per unit wet mass of crop. Fertigation involves mixing the fertilizer in the irrigation water by suitable arrangement. To ensure uniform distribution of water and fertilizers, the irrigation system must be properly designed and operated. The selection of suitable fertilizers is also very important and must be based on several factors like nutrient form, purity, solubility and cost. Fertilization in agricultural field is one of the important steps to increase the productivity of a cropped field. The drip system can be used for fertilizing crop through the system of fertigation. Some arid countries in Western Asia already use irrigation to simultaneously dispose of municipal wastewater effluent and resolve the demand for irrigation water by farmers. Bar-Yosef (1999) reported a number of potential agronomic advantages for fertigation with drip irrigation (DI) .These advantages included nutrient application to the center of the root system, and the utilization of nutrient rich secondary municipal effluents.

Drip irrigation is an interesting technology for arid and semi-arid countries, to enhance the safe disposal of wastewater while maintaining or increasing yields (Camp, 1998). Optimum yield of crop can be obtained when needed primary nutrients (N, P and K) and others are injected precisely through the drip irrigation system (Godara *et al.*, 2013). Khalilian *et al.*, (2000) conducted the research on row crop using the different irrigation method and they found that drip irrigation is one of the most economical methods of water application to agronomic row crops such as corn, peanuts, and cotton. Sijali (2001) worked on drip irrigation system and reported that higher crop yield may be obtained by using the drip irrigation system since is applied in regular basis.Keeping in view the above points, the present study has been focused on determining the effect of drip irrigation system and fertigation on growth and yield of tomato with the following specific objectives:

- To analysis the growth rate of tomato plant at different flow rates of drip irrigation.
- To compare the yield of tomato at different flow rate of drip irrigation.
- To determine the effect of fertigation through drip irrigation on growth and yield of tomato.

Materials and Methods

The details of the project site, preparation of seedling, drip irrigation system, fertigation system, preparation of field, material used and the methods followed to evaluate the effect of drip irrigation system and fertigation on growth and yield of tomato plant are presented in this section.

A rectangular farm area of 6×5 m^2 was selected as a project site to determine the effect of drip irrigation system and fertigation on growth and yield of tomato plant. Farm was situated just beside the Department of Agricultural Engineering, Assam University Silchar. In the present study, "Samartha F1 hybrid" variety of tomato has been selected on the basis of environment, sustainability, adaptability and availability in local market. One high-density polyethylene (HDPE) container was used to prepare the seedling of tomato. HDPE container was filled with rich soil to prepare about 20 cm thick soil bed. Sufficient amount of farmyard manure (FYM) was mixed with soil. Before sowing, soil bed was converted in to loosen state by digging or ploughing 3-4 times.

The land (experimental field) for growing tomato was prepared to fine tilth by digging the soil surface 4-5 times. Recommended amount of FYM (10 tone/ha) was mixed with soil before 15 days of transplanting. Liming has been done before transplanting; liming was done to raise the soil pH to optimum range (5.5 to 6.8). Total six numbers of small ridges having length of 4 meters was constructed. Each ridge was constructed uniformly maintaining the interval of 75 cm. Transplantation of seedling was carried out after 28 days of sowing when seedling height was 10-15 cm. Total sixty tomato plants were planted manually on the six small ridges. In one ridge total ten numbers of seedlings were planted by maintaining the plant to plant distance of 30 cm (Anonymous, 2010.

In drip irrigation system, water is supplied to the plants at its root zone through a network of pipes. A drip irrigation system consists essentially of over head tank or pump, mainline, sub mains, lateral, drippers, filters and other small fittings and accessories like valves, pressure regulators, pressure gauge, fertilizer application components etc. The design and layout of drip irrigation system adversely affect the growth and yield of cultivated crops and it also leads to the wastage of water and fertilizer. The layout of drip irrigation system was prepared, which is shown in Figure 1.

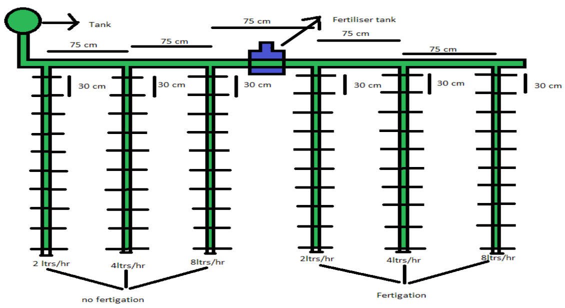


Figure 1. Layout of drip irrigation system

The actual site of drip irrigation is shown in Figure 2. The recommended level of primary fertilizers (nitrogen: 75kg/ha, potassium: 60 kg/ha and phosphorus: 60 kg/ha) were applied in tomato crop (Lakshmi; 1997). Nitrogen was given in split doses. Half nitrogen and full phosphorous were given at the time of transplanting and remaining nitrogen was given after 30 days and 60 days of transplanting. The availability of Primary fertilizers (nutrient) in soil was estimated by soil testing. The deficit value of primary fertilizers has been full filled in only three ridges of tomato crop by fertigation through drip irrigation.

Three different types of dippers having flow rate of 2 L/hr, 4 L/hr and 8 L/hr were successively provided in different sub laterals of the drip irrigation system (Figure 1). At an interval of seven days, growth of tomato plant for individual flow rate was measured for 85 days. Length and diameter of stem, number of branches and canopy spread were considered as growth parameters in present study. Length and diameter of stem of tomato plant were measured by scale and vernier- caliper respectively, while number of canopy was counted manually. The yields of tomato at different discharges of drippers were measured separately in terms of kg/ha and yield of tomato at different flow rate was further compared.

Canopy (crown) spread was measured by Cross-method. The mathematical expression used to estimate the average crown spread is provided in equation 1. The growth parameters were compared with different flow rates.

$$S_a = \frac{(S_l + S_{lc})}{2} \quad \ldots (1)$$

Where, Sa is the average crown spread; Sl is the longest spread; Slc is the longest cross spread

To study the effect of fertigation through drip irrigation method on the overall growth of tomato crop, the experimental farm area has been divided into two sections which are shown in Figure 1. To compare the effect of fertigation, one section of the

Figure 2. A view of tomato plants with drip irrigation system

farm area has been irrigated with addition of fertilizer, while the other section has not been fertigated. Keeping it in view, fertigation was not provided in the first section. On the other hand, fertigation was provided only to those plants, which was in second section. In second section, fertilizer was mixed with water and further it was applied through drip irrigation. Growth and yield of tomato plants in both sections has been measured and further the effect of fertigation through drip irrigation was estimated.

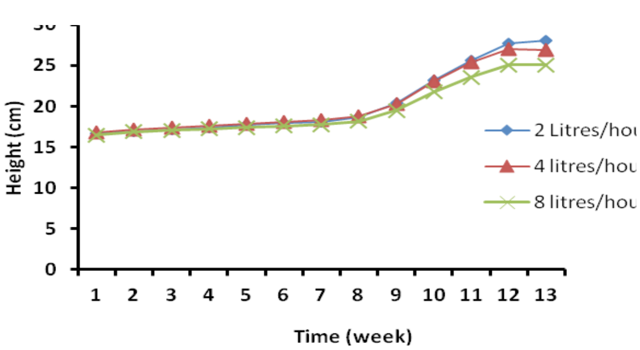
Results and Discussion

In this section, analysis of growth rate of tomato plant at different flow rates, effect of fertigation on growth and yield of tomato and comparison of yield of tomato at different flow rate of drip irrigation are presented and discussed.

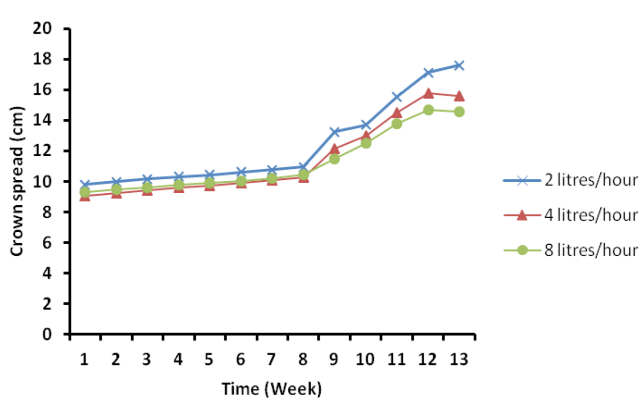
Growth rate of tomato plant at different flow rates of drip irrigation

Water flowing through drip irrigation is in the form of drops and the rate at which these drops are absorbed by soil is one of the factors responsible for healthy growth of plant. In this study, irrigation through drip at different flow rate is closely analyzed. Growth of tomato plants in terms of height and crown spread were measured in weekly basis for each flow rate of emitter. Variation of plant's height with time for different flow rate (2 L/hr, 4 L/hr and 8 L/hr) can be seen in Figure 3a. The initial height of tomato plant at the beginning of transplantation in study area is almost same. Further, the height of plants with varying flow rate is critically studied and it is shown in Fig 3a. For healthy growth of a plant, it is necessary that adequate amount of soil moisture is present in the root zone. Figure 3a also depict that 2 litres per hour provide the perfect soil moisture zone for the healthy growth of plant. Thus, the row of tomato plantation which was getting 2 litres per second water through drip irrigation has better growth rate than other two flow rate. The maximum average heights of plants were measured as 28, 26.8 and 25 cm for the flow rate of 2 L/hr, 4 L/hr and 8 L/hr respectively after thirteenth week of transplantation. The average increment in the height of tomato plants at flow rate of 2, 4 and 8 L/hr were estimated 68%, 60% and 52% respectively.

Further, the average crown spread of each row of tomato plants were estimated which is shown graphically in Figure 3b. At the time of transplantation, the average initial crown spread was estimated as 9.8, 9 and 9.3 cm for the flow rate of 2 L/hr, 4 L/hr and 8 L/hr respectively. However, maximum average crown spread were calculated as 17.6, 16 and 14.6 cm for the flow rate of 2 L/hr, 4 L/hr and 8 L/hr respectively. The total increases in average crown spread were recorded as 7.8, 6.5 and 5.3 cm for flow rate of 2 L/hr, 4 L/hr and 8 L/hr respectively. So flow rate of 2 L/hr has better crown spread area.



(a) Variation of tomato plant height at different flow rate



(b) Variation of crown spread at different flow rate

Figure 3. Variation in physical features of tomato plantation at different flow rate of drip irrigation

Yield of tomato at different flow rate of drip irrigation

Yield of tomato in terms of fruits of tomato was estimated for three different flow rates (2 L/hr, 4 L/hr and 8 L/hr) of drip irrigation. Number of fruits in tomato plants for different flow rate of drip irrigation is shown in Fig.4. It can be seen from Figure 4 that fruiting of tomato plants has started from third week of transplantation for 2L/hr flow rate where as in case of 4 L/hr and 8 L/hr flow rate, fruiting started from fourth week of transplantation.

It can be depicted from Figure 4 that the highest number of fruit, i.e. 23 tomato fruits, has been observed in 11th week after transplanting in case of irrigation through 2 litres/ hour drip, whereas 15 and 13 numbers of fruits is the highest number of flowers in case of 4 litres/hour and 8 litres/hour. In 13 weeks, the total fruiting in the study area was 131, 93 and 79 for flow rate of 2 litres/hour, 4 litres/hour and 8 litres/hour respectively. Thus, the yield is maximum for 2 litres/hour.

The average growth rate of tomato plants in terms of heights and crown spread for each flow rate of drip irrigation was estimated. Height of fertigated tomato plant at different flow rate were presented in Table 1. It can be depicted from Table 1 that initial average height of tomato plants at 2, 4 and 8 L/hr of flow rate are 15.3, 14.2 and 14.6 cm respectively and average final height of tomato plants were measured 36.3, 29.2 and 26.6 cm at flow rate of 2, 4 and 8 L/hr respectively. The average increment in the height of fertigated tomato plants at flow rate of 2, 4 and 8 L/hr were estimated 137%, 106% and 81.6% respectively.

Crown spread/canopy spread of fertigated tomato plants for different flow rate were estimated and presented in Table 2. It can be seen from Table 2 that initial average canopy spread of fertigated tomato plant at 2L/hr, 4L/hr and 8L/hr were estimated as 8.3, 7.7 and 7.90 cm. Final increment in canopy spread of fertigated tomato plant at 2L/hr, 4L/hr and 8L/hr

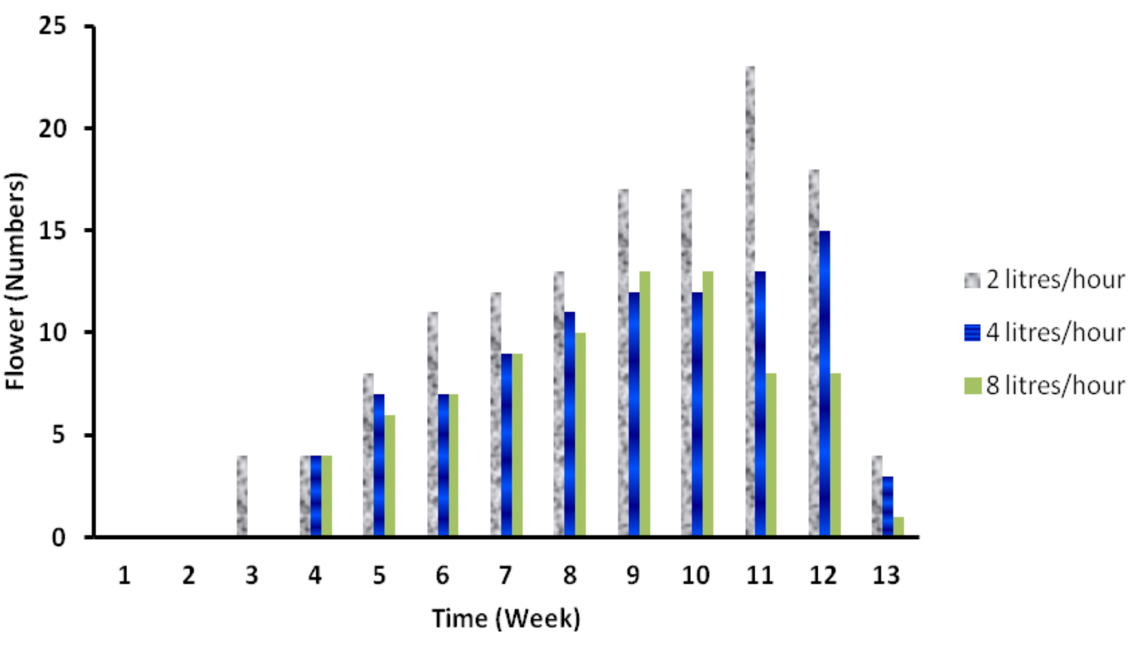


Figure 4. Fruiting of tomato plants at different flow rate

Table 1 Height of fertigated tomato plants at different flow rates

Flow rate (L/hr)	Time (Week)												
	1	2	3	4	5	6	7	8	9	10	11	12	13
	Average height of Fertigated tomato plant (cm)												
2	15.3	16.9	17.2	17.4	17.6	17.9	18.1	18.8	21.7	25.3	28.6	33.1	36.3
4	14.2	14.5	14.7	14.9	15.1	15.3	15.5	16.0	18.0	21.6	23.8	27.1	29.2
8	14.6	15.0	15.3	15.5	15.7	15.8	16.0	16.6	18.3	20.4	22.0	24.3	26.6

Table 2 Fertigated crown spread of tomato plant at different flow rate

Flow rate (L/hr)	Time (Week)												
	1	2	3	4	5	6	7	8	9	10	11	12	13
	Average Crown/Canopy Spread of fertigated plants of tomato (cm)												
2	8.3	8.5	8.6	8.6	8.8	9	9.2	9.4	11.9	14.5	17	21	22.4
4	7.7	7.8	8.0	8.2	8.3	8.5	8.6	8.9	11.4	13.9	17.1	18.9	20.1
8	7.9	8.1	8.2	8.4	8.5	8.7	8.8	9.0	11.1	13.3	15.8	17.5	18.5

Table 3. Fruiting of fertigated tomato plants at different flow rates

Flow rate (L/hr)	Time (Week)												
	1	2	3	4	5	6	7	8	9	10	11	12	13
	Flowering of Fertigated tomato plant in Number												
2	0.0	0.0	1.0	2.0	5.0	8.0	11.0	15.0	19.0	25.0	29.0	11.0	4.0
4	0.0	0.0	1.0	2.0	4.0	6.0	9.0	12.0	14.0	17.0	20.0	8.0	3.0
8	0.0	0.0	0.0	1.0	3.0	6.0	8.0	11.0	13.0	16.0	19.0	9.0	3.0

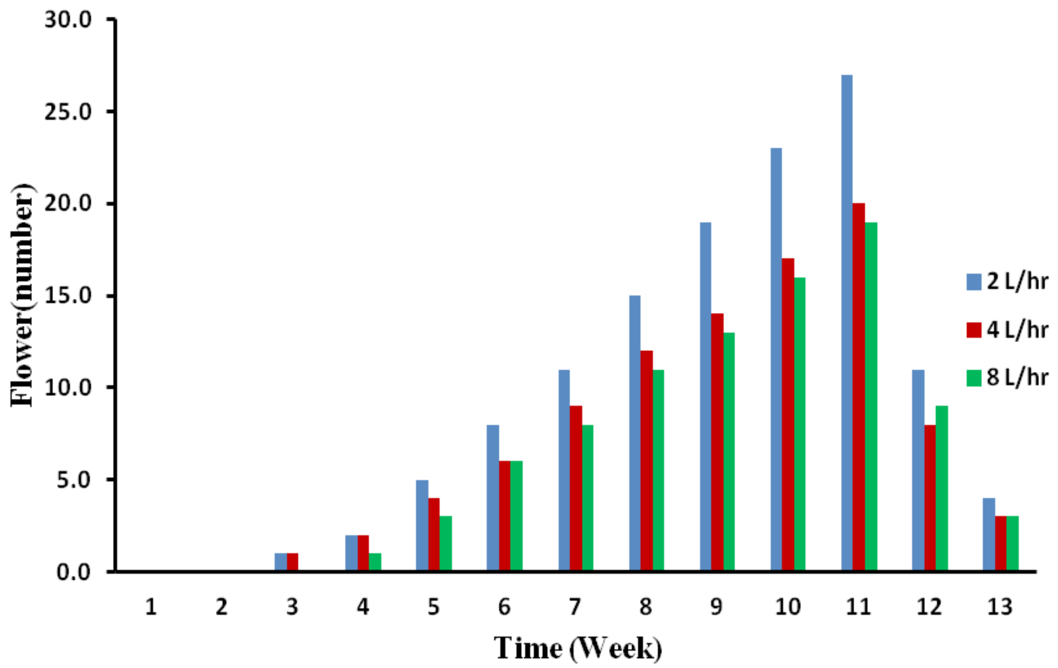


Figure 5. Variation of number of fruits of fertigated tomato plants at varying flow rate

were found by 169 %, 162 % and 134% respectively, which is more than the non- fertigated plants.

It can be seen from Table 3 that fruiting in fertigated tomato plants started from third week of transplantation for 2 L/hr and 4 L/hr of flow rate where as in case of 8 L/hr flow rate flowering start from fourth week of transplantation. Maximum 29, 20 and 19 number of flowers was counted at flow rate of 2 L/hr, 4 L/hr and 8 L/hr respectively. Details variation of fruiting with time for different flow rate of 2 L/hr, 4 L/hr and 8 L/hr are presented in Figure 5.

The yield of fertigated tomato plants at different flow rate of drip irrigation was estimated and presented in Table 4. Total yield of fertigated tomato plants 8.4, 6.1 and 5.2 kg was estimated at flow rate of 2L/hr, 4L/hr and 8L/hr respectively.

Table 4. Yield of fertigated tomato plants at different flow rates

Serial No.	Flow rate (L/hr)	Yield (kg)
1	2	8.4
2	4	6.1
3	8	5.2

The comparison of yield of ferigated tomato plants at different flow rates are presented in Figure 6.

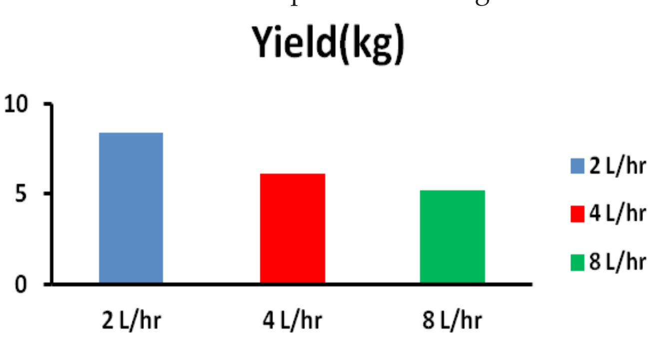


Figure 6. Yield of tomato (kg) at different flow rate

From Table 4 and Figure 6, it can be concluded that rate of application of irrigated water through drip irrigation plays a very vital role on the overall yield of the crop. If the flow rate will not be optimally decided, then there will be loss of fertilizer through leaching and also yield of the crop can reduce. In the present study, it has been shown that if the flow rate of water in dripper is up to 2 litres per hour, then the yield will be maximum. Also at this flow rate, uptake of fertilizers through the plant root zone will be maximum.

Conclusion

The primary goal of this study was to analysis the growth rate of tomato plant at different flow rates of drip irrigation, to compare the yield of tomato at different flow rate and to determine the effect of fertigation through drip irrigation on growth and yield of tomato. For experimentation, a rectangular farm area of 6 m×5 m was prepared for the cultivation of tomato through drip irrigation. The "Samartha F1 hybrid" variety of tomato seed was selected for this study on the basis of environment, sustainability, adaptability and availability in local market. Whole farm area was divided into two sections and each section having three ridges. The recommended fertilizer was provided in only one section with the three different flow rates of 2L/hr, 4L/hr and 8L/hr in three different ridges. Only irrigation was provided with three different flow rates of 2L/hr, 4L/hr and 8L/hr in three different ridges in other section. Growth of tomato plants in terms of height and crown spread (canopy) were measured in weekly basis for each flow rate. Effect of fertigation on growth and yield of tomato plants were estimated at different flow rate of drip irrigation. The results suggest that when tomato field is cultivated with irrigation of 2 litres per second, the overall development of the tomato crop as well as the yield is maximum. Moreover, controlled fertigation at the same flow rate enhance the productivity of the tomato cropping.

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