Plant Archives Vol. 24, No. 2, 2024 pp. 299-306 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org

DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2024.v24.no.2.040

INFLUENCE OF MICRO IRRIGATION AND MULCHING ON THE GROWTH ATTRIBUTES, ROOT MORPHOLOGY AND NUTRIENT UPTAKE OF TOMATO IN RAIN SHELTER

N.S. Saniga[1]*, T. Sajitha Rani[2] and P. Merin Jose[3]

[1,3]Department of Agronomy, College of Agriculture, Vellayani, Kerala Agricultural University, Thrissur (Kerala), India.
[2]College of Agriculture, Padannakad, Kerala Agricultural University, Thrissur (Kerala), India.
*Corresponding author E-mail : saniga697@gmail.com

(Date of Receiving-20-02-2024; Date of Acceptance-08-05-2024)

ABSTRACT

A field experiment was conducted at the Instructional farm, College of Agriculture, Vellayani, Kerala, during February-May 2021 to evaluate the efficacy of micro irrigation and mulching on the growth and root parameters of tomatoes grown in rain shelter. The treatments include different types of micro irrigation (i_1- rain hose; i_2 -surface drip; i_3-sub surface drip at 10 cm; i_4-sub surface drip at 15 cm; i_5-sub surface drip at 20 cm) as the main plot treatments and mulching (m_1-no mulch and m_2-organic mulch) as sub plot treatments. Dry banana leaves @10 t ha^{-1} was applied as organic mulch. The results revealed that the sub surface drip irrigation at a depth of 10 cm (i_3) significantly influenced the growth parameters of tomato such as plant height, number of branches, dry matter production, and root-shoot ratio. Plant height, number of branches, dry matter production were the highest in the treatment (i_3) sub surface drip irrigation at 10 cm depth. The root parameters of tomato such as root depth and root volume were significantly influenced by types of micro irrigation. Sub surface drip irrigation at 20 cm (i_5) recorded the highest root depth whereas the highest root volume was obtained in sub surface drip irrigation at 10 cm depth (i_3). The uptake of nutrients viz., N, P and K was highest in sub surface drip irrigation at 10 cm depth (i_3). Between mulches, organic mulching with dry banana leaves @ 10 t ha^{-1} increased the growth, root attributes and nutrient uptake in tomato compared to no mulch.

Key words : Micro irrigation, Tomato, Sub surface drip, Rain hose, Surface drip, Organic mulch, Root depth, Root volume, Nutrient uptake.

Introduction

Tomato (*Lycopersicon esculentum* Mill.), also referred to as "poor man's orange," is a well-liked solanaceous vegetable that is grown throughout the world's tropics and subtropics. Due to its broad adaptability to various agroclimatic conditions, it is grown extensively in almost all regions of India. In terms of area and processing, tomatoes are the second most significant vegetable crop in the world. Tomato is regarded as protective food because they are rich sources of vitamins A and C, dietary fibers, minerals and organic acids. The natural antioxidants, lycopene and carotene found in tomatoes are proven to lower cancer and cardiovascular disease risks; hence consuming one tomato per day is extremely beneficial to human health (Singh *et al*., 2021).

Tomatoes are always in high demand to satisfy the requirements of the culinary and processing industries. Considering the high demand, the productivity of tomato needs to be boosted. The major impediments to enhanced tomato production technology include the unavailability of improved seed at the time of sowing, lack of irrigation water, high cost of irrigation, lack of disease resistant varieties, and lower prices at harvesting time (Jat *et al*., 2012). Water is one of the major constraints that have a considerable impact on the quality and output of tomato. Use of good quality seeds and fertilizers even fails to achieve their full potential, if the crop does not receive optimum irrigation. Being a tropical plant, it requires a constant supply of water and hence scarcity of water can adversely affect crop growth and yield (Kumar and Khanna, 2019).

Water is a critical input in developing countries like India. The pressure on water resources increases as population grows and development calls for larger allocations of groundwater and surface water for the domestic, agricultural, and industrial sectors. The agriculture sector alone consumes approximately 83 per cent of all available water. About 50-70 per cent of water is wasted through conveyance, evaporation, and field losses in conventional irrigation methods. As a result, water resources should be utilized more efficiently and productively. This could be accomplished by implementing improved irrigation techniques and better water management strategies (Kumar and Kumar, 2020). Micro irrigation is one such approach that is gaining momentum to address water scarcity.

Micro irrigation, also known as localised irrigation, is a novel method of irrigation that ensures a consistent supply of water in the crop zone, resulting in water savings of 30 to 70 per cent in various orchard crops and vegetables along with 10 to 60 per cent increases in yield compared to conventional methods of irrigation (Zaman *et al*., 2001). Drip irrigation is the practise of slowly dripping a tiny amount of water into the soil surface or directly onto the root zone of plants using a network of valves, pipes, tubing, and emitters (Kumari and Kaushal, 2014). Drip irrigation can be made more versatile for irrigating a variety of agronomic, horticultural, and fruit crops by putting the laterals below the soil surface, which is known as sub surface drip irrigation. Rain hose irrigation, also known as rain pipe irrigation, is a new low-cost spray irrigation that delivers water in precise amounts, ensuring a consistent water flow. It's simple to set up, and it's less expensive to run than drip and sprinkler irrigation systems. Other advantages include reduced leaching losses, less clogging, increased water efficiency and portability from one location to another (Ayyadura *et al*., 2020).

In addition to the improvement of irrigation systems and schemes, the assessment of crop management strategies can also lead to more efficient and sustainable agricultural water management (Mancosu *et al*., 2015). Mulching is one of the water management strategies proposed to boost water use efficiency. Organic mulches are eco-friendly, provide organic matter to the soil, maintain the ideal soil temperature, minimize soil erosion, prevent weed growth and reduce unproductive evaporation from the soil surface (Ranjan *et al*., 2017). Crop residues from previous crops are readily available in fields, so mulching is cost effective and farmers can benefit from organic mulch in a variety of ways. Hence, there is a wide scope for the practice and usage of organic mulching in crop production for the conservation of natural resources like soil and water. Keeping the above aspects in consideration, a field trial was undertaken to evaluate the efficacy of different micro irrigation methods and mulching on the growth and root parameters of tomato.

Materials and Methods

A field experiment was conducted at the Instructional Farm, College of Agriculture, Vellayani, Thiruvananthapuram, Kerala, from February to May, 2021. The farm is situated at 8.5^0 North latitude and 76.9^0 East longitudes at an altitude of 29 m above mean sea level. The soil of the experimental site was found to be sandy clay loam, high in organic carbon (1.21%), medium in available N (252 kg ha^{-1}), high in available P (68.2 kg ha^{-1}) and medium in available K (242 kg ha^{-1}) and had slightly acidic pH (6.1), with field capacity of 19.25% and permanent wilting point of 7.63%. The tomato variety Vellayani Vijai, released from the College of Agriculture, Vellayani was used as the test crop for the study. The experiment was laid out in split plot design with five types of micro irrigation, i_1 (surface drip irrigation), i_2 (rain hose irrigation), i_3 (sub surface drip irrigation at 10 cm), i_4 (sub surface drip irrigation at 15 cm) and i_5 (sub surface drip irrigation at 20 cm) as main plot treatments and two mulching materials m1 (no mulch) and m^2 (organic mulch) as sub plot treatments replicated four times. Dried banana leaves @ 10 t ha^{-1} were used as organic mulch.

Irrigation was scheduled on a daily basis based on the crop's water requirement, which was calculated using the following relationship,

$V = Ep \times Kc \times Kp \times Wp \times Sp$

Where, V- Water requirement (litre/day/plant)

Ep - Maximum pan evaporation (8 mm/day)

Kc – Crop coefficient

(Initial stage-0.40; Development stage-0.70; Maturity stage-0.90; End stage-0.85)

Kp - Pan coefficient (0.7)

Wp - Wetted area (0.9 m^2 for closely spaced crops)

Sp - spacing of crops in m^2 (0.6m × 0.6m).

One month old 'Vellayani Vijai' tomato seedlings were transplanted, keeping row to row and plant to plant spacing of 60 and 60 cm, respectively. All treatments received a total of 264:130:281 kg NPK ha^{-1} as fertigation at a three-day interval. The fertilizers applied were urea and polyfeed (19:19:19) as a N source, mono ammonium phosphate as a P source and potassium nitrate as a K source. For mulching, dried banana leaves @ 10t ha^{-1} were spread over the prepared beds. Lateral drip lines having an emitter spacing of 2 Lh^{-1} were placed below the mulch.

The observations on the growth attributes of tomato plant height, number of branches per plant, and dry matter production were recorded. The height of tomato plant was measured in centimeters from the base of the plant to the top of the plant with the help of a scale. The number of primary branches per plant at final harvest was recorded from the tagged observational plants and their mean was calculated. Total dry matter production was calculated at the final harvest of tomato. The samples were dried to a constant weight in a hot air oven at 60 ± 5^0C and dry weights were recorded and expressed in kg ha^{-1}. Root characteristics of tomato plants, including root depth and volume, were assessed at the time of harvest. Root depth was determined in five randomly chosen sample plants from each treatment, separating and cleaning the root portion, and measuring its length. The average length was then calculated and expressed in centimeters. Root volume was assessed utilizing the water displacement method proposed by Misra and Ahmed (1987), employing a graduated cylinder, with the volume expressed in cubic centimeters (cm^3). Nutrient content was assessed through various methods. Nitrogen (N) content was determined using the distillation and titration method outlined by Jackson (1973). Phosphorus (P) content was determined by diacid digestion of plant samples, followed by measurement using the Vanadomolybdo phosphoric yellow colour method described by Jackson (1973). Potassium (K) content in the diacid digest was estimated using a flame photometer as per Jackson (1973). The uptake of N, P and K was then calculated by multiplying the content of these nutrients by the plant dry weight and expressed in kilograms per hectare (kg ha^{-1}). Data generated from the experiment were subjected to statistical analysis by applying ANOVA for split plot design and significance was tested (Snedecor and Cochran, 1980).

Results and Discussion

Effect on growth attributes : Growth attributes of tomato such as plant height, number of branches per plant, root shoot ratio and dry matter production, were significantly influenced by the types of micro irrigation and mulching as shown in Table 1.

At 30 DAS, the maximum plant height was recorded in sub surface drip irrigation at 10 cm depth (i_3) (55.76 cm) and the lowest plant height was recorded in sub surface drip irrigation at 20 cm depth (i_5) (40.29 cm). At 60 DAT, plant height was significantly higher in sub surface drip irrigation at 10 cm depth (i_3) (90.91 cm). The treatment sub surface drip irrigation at 15 cm depth (i_4) was on par with sub surface drip irrigation at 20 cm depth (i_5). The lowest plant height was recorded in rain hose irrigation (70.56 cm). At 90 DAT and at harvest, the maximum plant height was recorded in the treatment sub surface drip irrigation at 10 cm depth (i_3) (107.41cm, 114.98 cm) respectively and it was on par with sub surface drip irrigation at 15 cm depth (i_4). The treatment sub surface drip irrigation at 15 cm depth (i_4) was in turn on par with sub surface drip irrigation at 20 cm depth (i_5). The lowest plant height was recorded in the treatment rain hose irrigation (i_2) (87.74 cm, 101.57 cm) and was on par with surface drip irrigation (i_1). Sub surface drip irrigation at 10 cm, 15 cm and 20 cmdepths resulted in taller plants compared to surface drip irrigation and rain hose irrigation. Higher availability and uniform distribution of water and nutrients immediately in the vicinity of the root zone for sub surface drip irrigation at different depths might have accelerated cell division, cell elongation, and metabolic activities of the plant throughout the growth phases resulted in taller plants. Different types of micro irrigation significantly influenced the number of branches per plant at 50 per cent flowering and at harvest. At 50 per cent flowering and at harvest, the maximum number of branches per plant was produced in (i_3) sub surface drip irrigation at 10 cm depth (8.01, 13.61) respectively and it was on par with sub surface drip irrigation at 15 cm depth (i_4). The lowest number of branches per plant was produced in the treatment rain hose irrigation (i_2) (5.22, 11.15) respectively and it was on par with surface drip irrigation (i_1). The distribution of water and nutrients at the appropriate time in sub surface drip irrigation systems might have resulted in better vegetative growth, leading to higher number of branches per plant.

The root-shoot ratio at harvest was significantly influenced by the types of micro irrigation. The maximum root-shoot ratio was obtained in sub surface drip irrigation at 10 cm (i_3) (0.27) and it was on par with sub surface drip irrigation at 15 cm (i_4) and the lowest root-shoot ratio was recorded in surface drip irrigation (i_1) (0.18) and was on par with rain hose irrigation (i_2).

The biological efficiency of any crop species would be reflected in the amount of dry matter it produces (Singh *et al.*, 2020). The dry matter production was recorded at harvest and sub surface drip irrigation at 10 cm depth (i_3) (4751 kg ha^{-1}) obtained significantly higher dry matter production followed by sub surface drip irrigation at 15 cm depth (i_4) (4423 kg ha^{-1}) and sub surface drip irrigation

Table 1 : Growth attributes of tomato influenced by types of micro irrigation and mulching.

Treatments	Plant height (cm)				Number of branches per plant		Root- shoot ratio	Dry matter production (kg ha^{-1})
	30 DAP	60 DAP	90 DAP	At harvest	50 per cent flowering	Harvest	At harvest	At harvest
Types of micro irrigation (I)								
i_1 Surface drip irrigation	45.07	76.69	89.69	104.10	5.31	11.27	0.18	3867
i_2 Rain hose irrigation	44.40	70.56	87.74	101.57	5.22	11.15	0.20	3761
i_3 Sub surface drip irrigation at 10 cm	55.76	90.91	107.41	114.98	8.01	13.61	0.27	4751
i_4 Sub surface drip irrigation at 15 cm	52.38	85.66	102.32	112.00	7.69	13.04	0.27	4423
i_5 Sub surface drip irrigation at 20 cm	40.29	83.75	98.30	110.02	6.44	12.84	0.24	4153
SE m (±)	0.87	1.39	1.72	1.02	0.22	0.39	0.01	77.31
CD (0.05)	2.839	4.533	5.616	3.336	0.010	1.290	0.024	250.37
Mulching (M)								
m_1 No mulch	45.00	79.33	95.42	106.85	6.01	11.88	0.21	4138
m_2 Organic mulch	50.16	83.70	98.76	110.22	7.07	12.88	0.26	4244
SE m (±)	0.78	0.50	0.46	0.52	0.01	0.13	0.01	12.22
CD (0.05)	2.449	1.586	1.457	1.636	0.726	0.415	0.020	38.520
Interaction (I × M)								
i_1m_1	40.67	74.07	87.07	100.77	4.44	10.10	0.15	3874
i_1m_2	49.48	79.30	92.30	107.42	6.19	11.55	0.21	3861
i_2m_1	41.59	68.40	86.17	99.87	4.67	10.18	0.18	3719
i_2m_2	47.21	72.72	89.32	103.26	5.78	12.11	0.23	3802
i_3m_1	53.66	90.40	106.90	112.71	7.66	13.33	0.23	4666
i_3m_2	57.85	91.43	107.93	117.26	8.37	13.88	0.31	4835
i_4m_1	51.20	86.72	101.38	111.71	7.48	12.33	0.26	4352
i_4m_2	53.57	88.60	103.26	112.30	7.89	13.74	0.29	4494
i_5m_1	37.88	81.04	95.59	109.19	5.78	12.55	0.21	4077
i_5m_2	42.70	86.45	101.00	110.85	7.11	13.13	0.27	4229
SE m (±)	1.74	1.12	1.03	1.16	0.22	0.29	0.01	27.33
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	86.134

at 20 cm depth (i_5) (4153 kg ha^{-1}), respectively. The lowest dry matter production was obtained in the treatment rain hose irrigation (i_2) (3761 kg ha^{-1}) and it was on par with surface drip irrigation (i_1). Sub surface drip irrigation at optimum depth had a key role in maintaining leaf and stem growth throughout the growth period of tomato resulting in increased dry matter output (Prabhakara, 2008). More vegetative growth, due to increased plant height, number of branches per plant and better leaf production might be the contributing factor for higher dry matter production in sub surface drip irrigation systems.

At all phases of plant development, mulching had a significant influence on different growth attributes of tomato. Significantly higher plant height was recorded for organic mulch (m_2) at 30 DAT (50.16 cm), 60 DAT (83.70 cm), 90 DAT (98.76 cm), and at harvest (110.22 cm). The maximum number of branches per plant at 50 per cent flowering and at harvest were obtained in the treatment with organic mulch (m_2) (7.07, 12.88) respectively compared to no mulch (m1). Mulching had a significant influence on root-shoot ratio at harvest. The root-shoot ratio was higher in the treatment organic mulch (m^2) (0.26) compared to no mulch (m_1). Between mulches, the treatment organic mulch (m_2) obtained higher dry matter production (4244 kg ha^{-1}) and was superior to the treatment no mulch (m_1). The interaction between the types of micro irrigation and mulching did not have a significant influence on plant height, number of branches and root-shoot ratio, except dry matter production. The treatment combination sub surface drip irrigation at 10 cm depth with organic mulch (i_3m_2) obtained significantly higher dry matter production (4835 kg ha^{-1}) and the lowest dry matter production was recorded in the treatment combination rain hoseirrigation with no mulch (i_2m_1) (3719 kg ha^{-1}). Sub surface drip irrigation delivers nutrients precisely to the crop root zone, reducing leaching, while organic mulch suppresses weed growth and avoids competition for moisture and nutrients. All this might have led to enhanced nutrient availability and uptake by the plants and improved the translocation of assimilates from source to sink, resulting in higher dry matter production in the treatment combination of sub surface drip at 10 cm depth with organic mulch

Effect on root parameters : The different types of micro irrigation and mulching significantly influenced the root depth and root volume at harvest as shown in Figs. 1 and 2, respectively. Sub surface drip irrigation at 20 cm (i_5) recorded the highest root depth (46.46 cm), when compared to rest of the treatments. The lowest root depth was obtained in rain hose irrigation (i_2) (30.95 cm) and it

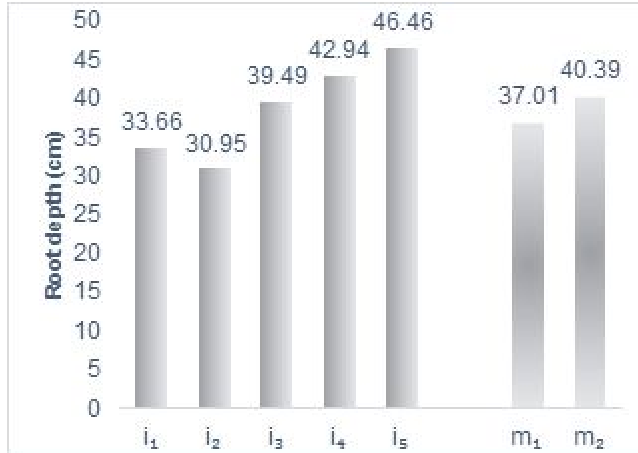

Fig. 1 : Effect of types of micro irrigation and mulching on root depth (cm).

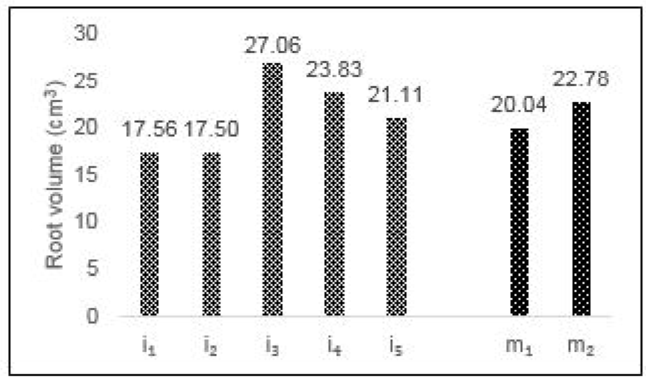

Fig. 2 : Effect of types of micro irrigation and mulching on root volume (cm^3).

was on par with surface drip irrigation (i_1). Sub surface drip irrigation can restrict the size of the root system to the wetted volume of soil (Fereres and Soriano, 2007). In sub surface drip irrigation, as the depth of the emitter increases, the root growth will also increase by balancing the moisture in the crop root zone (Al Harbi *et al*., 2008). The availability of moisture under sub surface drip fertigation might have aided effective absorption and utilization of nutrients and better proliferation of roots, resulting in higher root depth. Due to the non-uniform root distribution in the vertical direction, more roots were observed in the surface layer. This might have resulted in lower root depth in surface methods of micro irrigation.

The highest root volume was obtained in sub surface drip irrigation at 10 cm depth (i_3) (27.06 cm^3) and the lowest root volume was obtained under rain hose irrigation (i_2) (17.50 cm^3) and was on par with surface drip irrigation (i_1). Sub surface drip irrigation at 10, 15 and 20 cm depth recorded the highest root volume than the surface methods of micro irrigation such as rain hose and surface drip. Sub surface drip irrigation facilitates better availability of water and nutrients within the active crop root zone that leads to a greater number of primary roots

Table 2 : Influence of types of micro irrigation and mulching on nutrient uptake in tomato.

Treatments	Nutrient uptake (kg ha^{-1})		
	N uptake	P uptake	K uptake
Types of micro irrigation (I)			
i_1 Surface drip irrigation	47.77	14.46	62.85
i_2 Rain hose irrigation	47.28	13.82	61.01
i_3 Sub surface drip irrigation at 10 cm	59.09	21.43	85.94
i_4 Sub surface drip irrigation at 15 cm	57.48	18.61	77.94
i_5 Sub surface drip irrigation at 20 cm	53.84	16.69	71.49
SE m (±)	1.16	0.26	1.63
CD (0.05)	3.770	0.849	5.314
Mulching (M)			
m_1 No mulch	50.29	16.17	68.69
m_2 Organic mulch	55.89	17.83	75.00
SE m (±)	0.27	0.91	0.49
CD (0.05)	0.858	0.288	1.538
Interaction (I × M)			
i_1m_1	45.84	13.43	59.66
i_1m_2	49.70	15.50	66.04
i_2m_1	45.13	12.99	58.26
i_2m_2	49.43	14.66	63.76
i_3m_1	56.92	20.12	82.45
i_3m_2	61.26	22.73	89.44
i_4m_1	54.26	18.19	74.68
i_4m_2	60.70	19.03	81.21
i_5m_1	49.33	16.14	68.41
i_5m_2	58.35	17.24	74.57
SE m (±)	0.61	0.20	1.09
CD (0.05)	1.920	0.643	NS

and greater root density below the emitter and this could volume than the surface methods of micro irrigation such as rain hose and surface drip (Fereres and Soriano, 2007). Sub surface drip irrigation facilitates better availability of water and nutrients within the active crop root zone that leads to more number of primary roots and greater root density below the emitter and this could explain the significant difference in root volume compared to surface methods of micro irrigation (Al Harbi *et al.*, 2008).

Between mulches, organic mulch recorded the highest root depth (40.39 cm) and root volume (22.78 cm^3) than no mulch. It may be due to the increased soil moisture content that enhanced root proliferation in mulched treatments. The interaction between types of micro irrigation and mulching on root depth and root volume were not significant.

Effect on nutrient uptake : The effects of treatments on N, P and K uptake by the plants have been studied and shown in Table 2.

The N uptake was significantly influenced by the types of micro irrigation. Among the different types of micro irrigation, N uptake was the highest for sub surface drip irrigation at 10 cm depth (i_3) (59.09 kg ha^{-1}) and it was on par with sub surface drip irrigation at 15 cm depth (i_4), which was in turn on par with sub surface drip irrigation at depth 20 cm (i_5). The lowest N uptake was recorded in rain hose irrigation (i_2) (47.28 kg ha^{-1}) and was on par with surface drip irrigation (i_1).

The P and K uptake was the highest in the treatment sub surface drip at 10 cm depth (i_3) (21.43 kg ha^{-1} and 85.94 kg ha^{-1}) respectively, which was significantly superior to other types of micro irrigation. The lowest P uptake was observed in rain hose irrigation (i_2) (13.82 kg ha^{-1}) and it was on par with surface drip irrigation (i_1), whereas lowest K uptake was observed under rain hose irrigation (i_2) (61.01 kg ha^{-1}).

Sub surface drip irrigation involves precise application of water and nutrients at frequent intervals in the root zone coupled with the crop demand. This reduced the variations in nutrient concentration, increases their availability and reduces the leaching beneath the root zones, which ultimately improved the uptake of nutrients by the crop. Enhanced biomass production due to the constant availability of water and nutrients to the crop also resulted in increased nutrient uptake for sub surface drip fertigation compared to surface methods (Abou-Seeda *et al*., 2022).

Mulching had a significant influence on N, P and K uptake. The treatment organic mulch (m_2) registered higher N, P and K uptake (55.89 kg ha^{-1}, 17.83 kg ha^{-1}, 75.00 kg ha^{-1}), respectively than no mulch (m^1). The efficient utilization of nutrients under mulch treatments could be because of the active root growth conditioned by favourable moisture and thermal regimes, resulting in higher uptake of nutrients by plants under mulch.

The interaction between types of micro irrigation and mulching also showed a significant difference in N and P uptake. The treatment combination sub surface drip irrigation with organic mulch (i_3m_2) obtained higher N uptake (61.26 kg ha^{-1}) and it was on par with sub surface drip irrigation at 15 cm depth with organic mulch (i_4m_2). In case of P uptake, the combination of sub surface drip at 10 cm depth with organic mulch (i_3m_2) recorded the highest P uptake (22.73 kg ha^{-1}). The lowest N and P uptake was obtained for rain hose irrigation without mulch (i_2m_1) (45.13 kg ha^{-1}, 12.99 kg ha^{-1}) respectively and it was on par with surface drip irrigation without mulch (i_1m_1). The optimum moisture content and frequent availability of nutrients in the soil as a result of irrigation and mulching, combined with the high dry matter production, might be the reason for high nutrient uptake in sub surface drip irrigation at 10 cm depth with organic mulch. The interaction between the treatments did not have any influence on K uptake.

Conclusion

The present investigation revealed that growth attributes of tomato such as plant height, number of branches per plant, root shoot ratio, and dry matter production was significantly influenced by types of micro irrigation and mulching. From the results, it is found that among the different types of micro irrigation, sub surface drip irrigation at 10 cm depth (i_3) recorded higher plant height (114.98 cm), number of branches per plant (13.61), root-shoot ratio (0.27), dry matter production per plant (4751 kg ha^{-1}). Among mulches, organic mulching with dry banana leaves @ 10 t ha^{-1} (m_2) recorded higher plant height (110.22 cm), number of branches per plant (12.88), root-shoot ratio (0.26) dry matter production per plant (4244 kg ha^{-1}) at harvest. The treatment combination sub surface drip irrigation at 10 cm depth with organic mulch (i_3m_2) obtained significantly higher dry matter production per plant (4835 kg ha^{-1}). Sub surface drip irrigation at 20 cm (i_5) recorded the highest root depth (46.46 cm), whereas sub surface drip irrigation at 10 cm depth (i_3) recorded the highest root volume (27.06 cm^3). Among the mulches, organic mulch with dry banana leaves @ 10 t ha^{-1} recorded the highest root depth (40.39 cm) and root volume (22.78 cm^3). The uptake of nutrients viz., N, P and K was highest in the treatment sub surface drip irrigation at 10 cm depth (i_3) (59.09 kg ha^{-1}, 21.43 kg ha^{-1} and 85.94 kg ha^{-1}), respectively. Among mulches, organic mulch with dry banana leaves @ 10 t ha^{-}1 (m_2) recorded the highest N, P and K uptake (55.89 kg ha^{-1}, 17.83 kg ha^{-1}, 75.00 kg ha^{-1}), respectively.

Future scope

A long-term study is necessary to determine the durability and efficiency of sub surface placement of laterals. Standardization of the depth of lateral placement in various vegetables under rain shelter needs to be emphasized.

Acknowledgement

I extend my sincere gratitude to my major Advisor, Dr. T. Sajitha Rani, for the support throughout the study. I also thank College of Agriculture, Vellayani, Kerala Agricultural University, Thrissur, Kerala, for providing all facilities for the successful.

References

Abou Seeda, M.A., Hammad S.A., Yassen A.A. and Abou El-Nour E.A. (2020). Evaluation and optimization of subsurface irrigation system: A review. *Middle East J. Appl. Sci.*, **10(3)**, 508-538.

Al-Harbi, A.R., Al-Omran A.M. and El-Adgham F.I. (2008). Effect of dripirrigation levels and emitters depth on okra (*Abelmoschus esculentus*) growth. *J. Appl. Sci.*, **8(15)**, 2764-2769.

Ayyadurai, P., Shanmugam P.S. and Sangeetha M. (2020). Rain hose irrigation technology in groundnut-A new innovation in irrigation system. *Biotica Res. Today*, **2(8)**, 842-843.

Fereres, E. and Soriano M.A. (2007). Deficit irrigation for reducing agricultural water use. *J. Exp. Bot.*, **58(2)**, 147-159.

Jat, J.R., Singh S., Lal H. and Choudhary L.R. (2012). Constraints faced by tomato growers in use of improved tomato production technology. *Rajasthan J. Ext. Educ.*, **20**, 159-163.

Kumar, J. and Kumar M. (2020). Effect of drip irrigated mulch on soil properties and water use efficiency-A review. *J. Soil Water Conserv.*, **19(3)**, 300-309.

Kumar, R. and Khanna R. (2019). Comparative study of different irrigation methods on tomato crop (*Lycopersicon esculentum*) in western Uttar Pradesh. *Int. J. Chem. Stud*., **7(3)**, 59-64.

Kumari, R. and Kaushal A. (2014). Drip fertigation in sweet pepper: A review. *Int. J. Eng. Res. Appl*., **4(8)**, 144-149.

Mancosu, N., Snyder R.L., Kyriakakis G. and Spano D. (2015). Water scarcity and future challenges for food production. *Water*, **7(3)**, 75-99.

Prabhakara, B.N. (2008). Effect of Frequency, Methods and Levels of Fertigation on Growth, Yield and Quality of Green Chilli. *Ph.D. Thesis*, University of Agricultural Sciences, Bengaluru, Karnataka, 2008. 351 pp.

Ranjan, P., Patte G.T., Prem M. and Solanke K.R. (2017). Organic mulching-a water saving technique to increase the production of fruits and vegetable. *Curr. Agric. Res. J*., **5(3)**, 371-380.

Singh, D.K., Singh R.M. and Rao K.V.R. (2020). Standardization of lateral placement depths for subsurface drip irrigation with varying discharge rates of emitters in vertisols. *J. Pharmacogn. Phytochem*., **9(3)**, 148-153.

Singh, G.H., Bahadur A., Chaurasia S.N.S. and Singh S. (2021). Performance of tomato under subsurface drip irrigation laterals placed at various depths in inceptisols. *J. Agri Search*, **8(1)**, 26-29.

Snedecor, G.W. and Cochran W.G. (1980). *Statistical methods*. 7th Edn. Iowa State University Press, Ames Iowa, 225pp.

Zaman, W.U., Arshad M. and Salem K. (2001). Distribution of nitrate nitrogen in the soil profile under different irrigation methods. *Int. J. Agric. Biol*., **2**, 208-209.