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Research Article
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Effects of Soil Moisture Regime on Tomato Yield

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Abstract

In agriculture, understanding the role of moisture on crop growth and yield and establishing a proper moisture regime are prime factors for production. This research was conducted in the Horticulture Farm of Lamjung Campus in June-September 2019 to evaluate the effect of four irrigation regimes (25%, 50%, 75% and 100% based on field capacity) in flowering, fruiting, and yield of tomato. Each treatment was replicated ten times, considering a Completely Randomized Design under the plastic house in the spacing of 60 cm × 75 cm fitted along with drips of holes at 30 cm for irrigation. A significant effect ($p<0.05$) of moisture regime was found in flower cluster per plant, flowers per cluster, fruit set percentage, fruits per cluster, fruits/plant/plot, and yield per plant. The results revealed that an increase in moisture regime positively affects the yield per plant and other flowering fruiting characteristics. The average number of fruits per cluster (5.54), total number of fruits per plant (19.6) and total fruit per plot (196) were found to be significantly higher under 100% FC. The highest yield, 426.26 g/plant, was obtained under the condition of 100% FC. Thus, for more flowers, fruiting and yield tomatoes should be grown under higher moisture conditions.

Keywords : Field capacity, Flowering, Fruiting, Irrigation, Moisture regime

Introduction:

Tomato (*Solanum lycopersicum L.*), a warm-season herbaceous crop, belongs to the Solanaceae family and is considered an important vegetable worldwide (Dobson et al., 2002). They have abundant vitamins, minerals, sugars, essential amino acids and dietary fibres, which are essential for a healthy diet (Toor, Savahe and Heeb, 2006; Erba et al., 2013). They contain a high amount of water, minerals (iron and phosphorus), vitamins (A and C), Beta-carotene, lycopene, and calories, playing an essential role towards ensuring food security and nutrition (Marković, Hruškar, & Vahčić, 2006; Dorais, Ehret, & Papadopoulos, 2008).

Tomatoes are native to tropical America, but they were later brought to Europe and introduced to different parts of the world, including eastern and southern Asia (Naika et al., 2005). They are generally cultivated in tropical, subtropical, and temperate climates. About 22,566 hectares (ha) of tomatoes are cultivated in Nepal, and around 406,434 metric tons of tomatoes are produced annually in the country, incurring a yield of 18.01 metric tons/ha (MoALD, 2020).

Srijana is a popular tomato variety grown in Nepal, which was registered in 2012 by the Nepal Agricultural Research Council (NARC, 2014). Srijana variety is popularly grown in plastic house tomato production technology, which farmers mostly prefer because of its wider adaptability, superior taste, off-season production, and tolerance to bacterial wilt disease (Chapagain et al., 2010). In general, the optimal mean daily temperature required for the growth of tomatoes is 18 to 25ºC with night temperatures between 10–20ºC. However, temperatures above 25ºC, high humidity, and strong wind result in reduced yield (Hebbar et al., 2004).

Similarly, irrigation is another critical management practice to improve productivity, especially in vegetable cultivation, which requires intensive management and a high amount of fertilizers and irrigation water (Thompson et al., 2007). Excess irrigation leads to waterlogging conditions, and lack of timely irrigation leads to water stress in plant tissues (Shedeed et al., 2009). This water deficit has reduced yield, while proper irrigation has increased the yield of crops (Mahendran & Bandara, 2000). So, a controlled amount of water is required for the plant to grow properly, as a lack or excess of water causes damage to the plant (Hasanuzzaman, Nahar, Gill, Fujita, and Tolerance, 2013). Shortage of water during the cultural cycle of tomatoes heavily affects yield.

Along with yield reduction, a decrease in quality and a physiological disorder such as the 'apical rot' of berries are prominent (Candido et al., 2000). Plants growing under sub-optimal water levels exhibit slow growth, and a continuous low water supply over an extended period causes stem dieback. These plants are also more susceptible to diseases (Osakabe et al., 2014).

One of the significant issues in tomato production is determining the crop's water requirement and applying the correct irrigation technique. Nepali farmers have a lower production rate due to inefficient water use. An imbalance in water supply collaborates with other problems or diseases, decreasing fruiting characteristics and yield. Proper maintenance of the water level reduces the yield gap and ensures the reduction of other problems as well. Hence, this study was conducted to determine the effect of different soil moisture levels on tomato flowering, fruiting, and yield.

Materials and Methods:

Experimental setup

The field experiment was carried out in a horticulture farm of the Institute of Agriculture and Animal Science (IAAS), Lamjung Campus (latitude 28°12'N and longitude 84°22'E, and altitude 700 masl), during June-September 2019 inside a plastic rain shelter. The experiment was laid out in a completely randomized design with four treatments (Table 1) replicated 10 times. Individual plants were considered as replicates. The treatments were different irrigation levels, i.e., 25%, 50%, 75%, and 100% field capacity (FC). Moisture was maintained by drip irrigation, having holes at 30 cm. After measuring the FC of each bed, a soil moisture sensor was used to determine whether they were adequate as designated by their treatments. Moisture sensors were calibrated after each observation to ensure reliable FC observation.

Plant material

The tomato seedlings of the Srijana variety used in this research were collected from Suryabinayak Agro Farm, Bhaktapur, Nepal. The seedlings were transplanted in the Horticulture farm, Lamjung, inside a rain shelter in six plots of size 18.4 m × 1 m in two rows maintained at 50 cm while 25 cm maintained between plots. Ten-day old seedlings were transplanted into each plot in June. Each plot was 1m wide, with two rows positioned 25 cm from each outer edge, maintaining a 50cm gap between them. Seedlings within each row were spaced 60cm apart.

Vermicompost was applied at 250g per plot before seedling transplantation. Ten plants were randomly selected from each plot and tagged. Staking was done with bamboo and wire inside the rain shelter. Then, plants were trained and pruned to remove lower leaves and secondary branches. Harvesting started 35 days after transplanting, and there were five harvests altogether at 5-7 day intervals over one month.

Measurement of growth parameters

The effects of different moisture regimes on flowering, fruiting, and yield of tomatoes were assessed through the number of flower clusters, flowers per cluster, number of fruits/clusters, number of fruits/plant /plots, and total fruit weight. The number of flowers and fruits were counted manually and recorded while the weight of the fruit was measured in a weighing machine. The fruit set percentage was determined based on the total number of fruit sets and flower counts (Equation 1).

$$\text{Fruit set percentage (\%)} = \frac{\text{(Total number of fruit set)}}{\text{(Total number of flower count)}} \times 100\% \text{................ Equation 1}$$

Statistical analysis

The data obtained were entered and recorded in Microsoft Excel. SPSS 16.0 was used for the analysis of variance, and means were separated by LSD at a 5% level of significance. This analysis was done using SPSS and R Studio version 3.6.1. The post hoc test was performed using Tukey's method, and the data are expressed as mean ± standard error.

Table 1: Treatment and description of treatment in the experiment.

Treatment	Description of moisture regime
T_1	25% soil moisture of FC
T_2	50% soil moisture of FC
T_3	75% soil moisture of FC
T_4	100% soil moisture of FC

Results:

Flower clusters per plant and flowers per cluster

The number of flower clusters per plant demonstrated significant variation ($p = 0.004$) across different moisture regimes. The total count of flower clusters per plant ranged from 2.8 to 4.7. Specifically, plants subjected to 75% FC moisture regimes exhibited significantly higher numbers of flower clusters per plant (4.7), which was statistically at par with 100% FC. Conversely, those exposed to 25% FC displayed the significantly lowest ($p<0.05$) count of flower clusters per plant. (Table 2). There was no significant effect ($p>0.05$) of different moisture regimes in terms of flowers per cluster (Table 2).

Fruit set percentage

The varying moisture regimes significantly influenced the percentage of fruit set ($p = 0.013$). A notably higher fruit set percentage of 72.83% was observed in plants under the 100% field capacity (FC) moisture regime, statistically comparable to the 75% FC moisture regime at 58.95% (Table 2). In contrast, plants subjected to the 25% FC moisture regime exhibited a significantly lower fruit set percentage of 39.81%. Additionally, plants under the 50% FC moisture regime displayed an intermediate fruit set percentage of 45.59%, significantly differing from the higher and lower percentages observed under the 25%, 75%, and 100% FC moisture regimes (Table 2).

Fruits per cluster

The number of fruits per cluster exhibited significant variation ($p < 0.05$) across different moisture regimes, ranging from 3.93 to 5.54 fruits per cluster. Specifically, plants exposed to the 100% field capacity (FC) moisture regime recorded a significantly higher number of fruits per cluster (5.54) compared to those subjected to the other moisture regimes (25%, 50%, and 75% FC), which displayed comparable numbers of fruits per cluster (Table 2).

Fruits per plant

Similarly, varying moisture regimes significantly influenced the number of fruits per plant ($p = 0.004$). Plants exposed to the 100% field capacity (FC) moisture regime produced a significantly higher number of fruits per plant (19.6), which was statistically comparable to the 75% FC moisture regime (16.80). In contrast, plants subjected to the 25% FC moisture level yielded a significantly lower number of fruits per plant (6.7). Additionally, plants under the 50% FC moisture regime displayed a statistically different number of fruits per plant (10.0) than those under the 25%, 75%, and 100% FC moisture levels (Table 2).

Fruit yield per plant

Different moisture regimes significantly affected fruit weight and yield ($p < 0.05$). The yield per plant varied from 140.07 g to 426.26 g, with the highest yield (426.26 g) recorded in the 100% field capacity (FC) moisture regime and the lowest yield (140.07 g) recorded in the 25% FC moisture regime (Figure 1).

Table 2: The effect of moisture regime on average flower per cluster of tomato plants.

Treatments	Flower cluster/ plant (Number)	Flowers/cluster (Number)	Fruit set (%)	Fruits/cluster (Number)	Fruits/plant (number)
25% FC	2.80^{b}	6.18	39.81^{b}	3.93^{b}	6.70^{b}
50% FC	3.90^{ab}	5.83	43.59^{b}	3.64^{b}	10.00^{ab}
75% FC	4.70^{a}	5.60	58.95^{ab}	3.44^{b}	16.80^{a}
100% FC	4.60^{a}	5.58	72.83^{a}	5.54^{a}	19.60^{a}
p- value	0.004^{*}	$(0.75)^{NS}$	0.013^{*}	0.002^{*}	0.004^{*}

Mean separations were performed using the Tukey posthoc test at *p*-value <0.05. Means sharing same letters are not significantly different at p <0.05.

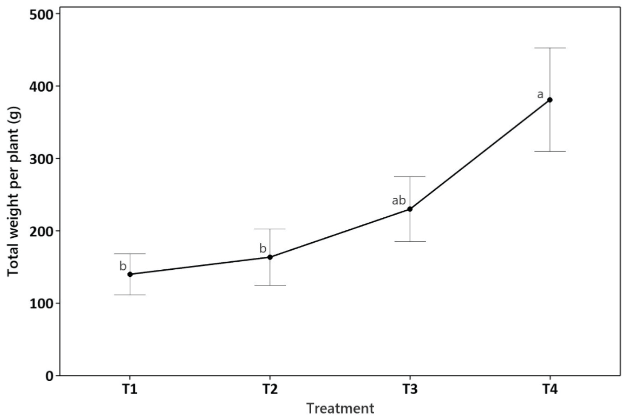

Figure 1. Effect of moisture regime on total weight per plant.

Discussion:

The results demonstrated that varying moisture regimes significantly (p <0.05) influenced the number of flower clusters per plant. Similar findings were reported by Abdulmalik et al. (2012) and Farooq et al. (2009), who observed that moisture stress significantly affected the number of flower buds per plant in field experiments. Enhanced moisture stress reduced the number of flower buds, as it increased ethylene production and caused flower abscission (Ramalan and Nwokeocha, 2000; Ganeva et al., 2019; Fawzy et al., 2019). Conversely, Astija and Musdalifah (2018) found that higher soil moisture regimes resulted in increased flower clusters per plant due to more rapid branch formation. Increased irrigation resulted in a greater number of flowers and fruits and a higher conversion rate of flowers into fruits (Subramanian et al., 2006). Conversely, water stress led to higher rates of floret abortion and the premature death of entire flower heads (Oliver and Francois, 2018). Under water deficit conditions, the abortion of flowers is a significant limitation, resulting in reduced fruit sets (Oliver and Francois, 2018).

In this study, the fruit set percentage was high at 75% and 100% FC moisture content, indicating an absence of moisture stress, which adversely affects the fruit set (Sharma, 2015). Water stress reduces the likelihood of viable pollen reaching the stigma by altering the relative positions of the anther and stigma (Fábián et al., 2019; Bhandari et al., 2023). Additionally, the concentration of abscisic acid (ABA) increases in plants, leading to a decrease in fruit set (Subramanian et al., 2006; Abdulamalik et al., 2012; Sibomana et al., 2013; Bhandari et al., 2023; Burlakoti et al., 2024).

The highest number of fruits per plant was achieved with higher soil moisture levels. A reduction from 100% to 75% FC led to a non-significant decrease in total fruits per plant, consistent with Mahomoud et al. (2012). Lower soil moisture reduces the number of ovules per floret due to insufficient water absorption, resulting in high flower abortion rates and fewer fruits per plant (Nuruddin et al., 2003). Sibomana et al. (2013) also found that moisture deficit reduces the number of flowers and fruits. Several studies (Colla et al., 1999; Zotarelli et al., 2009; Birhanu and Tilahun, 2010; Kahlaoui et al., 2011; Fawzy et al., 2019) reported that tomato plants under moisture stress had smaller and fewer fruits. Conversely, Nahar and Ullah (2011) observed an increase in fruit numbers at 70% FC compared to 100% FC, which was attributed to better-assimilated partitioning towards fruit development. Similarly, Banjaw et al. (2017) reported fewer tomato fruits with increased water stress, while Marouelli and Silva (2007) found that fruit number per plant was unaffected by soil water tensions.

Plants in the driest soil conditions show significantly lower yields than those in well-irrigated conditions (Dishani and Silva, 2016; Celebi, 2014), mainly due to reduced nutrient uptake, limited photosynthesis, and less favorable growing conditions at low FC. Earl and Davis (2003) suggested that soil water deficits primarily reduce crop yields by decreasing canopy absorption of photosynthetically active radiation, leading to lower radiation use efficiency. Aldesuquy et al. (2012) also reported that reduced irrigation decreases carbohydrate accumulation, photosynthetic pigments, and nitrogenous compounds, reducing yield. Increased soil water stress lowers water absorption rates by roots relative to the plant's transpiration rate, causing internal water deficits that affect photosynthesis, reduce leaf area, and lead to smaller cells and intercellular volumes, thereby decreasing fruit moisture accumulation (Ghosh et al., 2010; Evita, 2012; Banjaw et al., 2017; Romero et al., 2017; Astija and Musdalifah, 2018). Similarly, Sibomana et al. (2013) found that increased water stress decreases tomato yields due to higher floret abortion and fewer flower buds forming fruits. In contrast, plants at 100% FC show increased vegetative growth, more flowers and fruits, higher fruit set percentages, and increased fruit weight and volume (Sharma, 2015; Harmanto et al., 2005). The individual fruit size and weight significantly influence total tomato yield, mainly due to increased fruit dimensions (Romero et al., 2017; Mangena, 2018; Fawzy et al., 2019; Candido et al., 2000).

Reduced water supply increases soil moisture tension, which can lead to growth cessation, loss of turgidity, yield reduction, and plant death (Ramalan and Nwokeocha, 2000). Conversely, increased yield can result from better irrigation availability throughout the crop growth, as confirmed by Bahadur et al. (2006) and Marouelli and Silva (2007).

Conclusion:

This study investigated the impact of varying moisture regimes on several vital parameters influencing tomato yield. The results underscored the significant effects of moisture levels on flower clusters per plant, fruit set percentage, fruits per cluster, fruits per plant, and overall fruit yield. Notably, plants subjected to higher moisture regimes, particularly at 100% FC, consistently exhibited superior performance across these metrics. They displayed greater numbers of flower clusters per plant, higher fruit set percentages, and increased numbers of fruits per cluster and per plant compared to plants grown under lower moisture conditions. Conversely, lower moisture levels, such as 25% FC, significantly reduced these yield attributes. The findings corroborate earlier studies highlighting the sensitivity of tomato yield to moisture stress. In conclusion, this research highlights the importance of managing soil moisture levels to optimize tomato yield. Understanding soil moisture levels and their effect on plant yield attributes helps growers implement better irrigation strategies that lead to higher crop productivity.

Declaration of the conflict of interest:

The authors declare that there are no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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