Effect of Different Soil Moisture Regimes on Growth, Water Use, and Nitrogen Nutrition of Potted Tomato Seedlings

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Abstract In a pot experiment under controlled conditions, 25 day old seedlings of the tomato (Lycopersicon esculentum Mill.) cultivar, House Momotaro were grown for 25 days under three different soil moisture regimes (SMRs), viz, irrigated up to container capacity (CC) level allowing 75, 50, 25% depletion of CC moisture (DCCM) (Hereafter referred to as at 75, 50, 25% DCCM). The plants showed a higher periodic average evapotranspiration (ET) rate, and a higher cumulative ET 25 days after transplanting (DAT) when more water was made available in their root zone through irrigation. Growth of different plant parts and water use efficiency increased significantly with frequent irrigation with minimum soil drying from CC level. The sensitivity of tomato seedlings to soil moisture stress was reflected by a significant reduction in fresh and dry matter under severe water stress conditions. Nitrogen dilution effects in different plant parts were observed for the wetter SMRs. However, total N uptake was remarkably enhanced with increased availability of soil moisture. Significant and positive correlations of fresh and dry matter production with water use and N uptake were noted. A soil moisture regime up to 25% DCCM for irrigation was optimal in terms of growth and nitrogen uptake as well as efficiency in utilization of water and nitrogen. It was eventually suggested that the allowable extent of soil moisture depletion for irrigation in potted tomato seedlings should be less than 25% DCCM under abundant water conditions, and within 25 to 50% DCCM under limited water conditions. The findings are significant in relation to irrigation scheduling and water management not only for maximizing the early growth of tomato in pot culture, but also for avoiding the risk of any drastic reduction in growth and final yield of tomato.

Key words Growth, Container capacity, Nitrogen uptake, Soil moisture regimes, Tomato, Water use efficiency

Introduction

The rapid development of ground water supply and the development of water conveyance systems have enhanced the interest in irrigated agriculture over the traditional rainfed one all over the world. Except some humid areas like Japan, natural soil water levels are seldom high enough to supply the optimum plant water potential required for maximum yield of most crops. Especially in tropical regions such as Bangladesh, India, Pakistan, Thailand, and so on, there is a severe dry season which may last from several months to about half a year. During the dry season, rainfall is minimal, solar radiation is very strong and therefore the soil becomes so dry that no crops can grow unless appropriate irrigation is applied because of the deficiency in soil moisture. For instance, in Bangladesh, winter vegetable crops like tomato, cauliflower, cabbage grown in the dry season need optimal watering for raising and establishment of seedlings. Since shortage of water is very severe during this period, the smallest amount of water must be used for getting good seedlings and successful crop production. As irrigation is a costly agricultural input, its judicious application is necessary. TEARE et al. reported that water-use efficiency is closely related to solar radiation, which

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provides energy for growth and transpiration for green plants. Kramer suggested that the most promising way to increase the efficiency of water-use in crops is to increase the production of dry matter rather than to minimize water-use.

An important problem related to commercial irrigation concerns the effect of varying soil moisture deficit on crop growth. Stanhill published an excellent review on the effect of soil moisture regimes on crop growth. As defined by Stanhill, a soil moisture regime is an irrigation treatment in which the soil is allowed to dry up to a definite measured point within the available water range before sufficient water is applied to restore the entire root zone to field capacity. Although a large amount of literature is available, only a few studies deal with tomato despite its highly appreciable commercial and nutritional values and sensitivity to moisture stress. Salter observed that maximum growth and yield of tomato could be obtained when the soil moisture content was maintained in the region of field capacity which progressively decreased in the drier treatments. Ware and McCullum reported that seedlings of tomato can be planted in less moist soils, but the field must be irrigated of shorter intervals so that the soil water potential does not fall much below the field capacity level since the water use rate by the crop increases continuously with time until fruit development. Khan et al. observed that tomato plants might be irrigated up to 0.40 bar soil moisture tension.

Araki and Goto, however, examined the effect of temporary soil drying up to wilting after re-rooting of the transplanted seedlings in plastic pots under greenhouse conditions on the growth and nitrogen nutrition of tomato plants. They observed that stem elongation, leaf area enlargement, and increase of dry matter production were reduced after interruption of watering. But such reduction was rapidly alleviated after re-watering and the plants grew at the same rate as those both well watered conditions (control). The content of N increased in both vegetative parts and fruits of different cultivars after interruption of watering, while the contents of other mineral nutrients remained unaffected. The N content increased in stem, petioles, and fruits but decreased in laminae after interruption of watering. In another study, Araki observed that vegetative growth of greenhouse tomato was considerably reduced when the plants were irrigated based on leaf water potential \( \psi_L \) than on soil moisture potential \( \psi_S \) of pH 2.0. However, marketable yield, and the content of total soluble solids in fruits were significantly higher when \( \psi_L \) rather than \( \psi_S \) was used as a criterion for the timing the irrigation. Leaf water potentials \( \psi_L \) of -1.0 MPa at the early growth stage (from planting to flowering on the third cluster) and -0.5 MPa thereafter were recommended as indicators for irrigation. Cultivation of tomato in pots under controlled conditions is practiced in Japan because of adverse low temperature. Irrigation criteria suitable for potted tomato plants under greenhouse conditions have not been established.

Since nitrogen is the most important growth and yield determining plant nutrient, special management is referred. One of the major factors related to its expected uptake by the plants is the available water supplies in the root zone. A dry soil usually leads to reduced root growth and consequently limits the ability of the plants to utilize plant nutrients in the amounts required for optimum growth and yields. Excessive irrigation could also promote a substantial leaching of N beyond the root zone and ultimately to ground water, thus reducing nitrogen use efficiency as well as posing a potential threat of NO₃ pollution to ground water.

Irrigation and nitrogen fertilization are two essential but costly inputs in irrigated agriculture. Their economical use required that maximum growth should be achieved per unit application of these inputs. Prijhar emphasized the need for synchronizing the nutrient-rich zone and the moisture-rich zone with the active root zone for satisfactory nutrient uptake.

Khan et al. reported that in Bangladesh, an optimum early vegetative growth is essential for a higher fruit yield of tomato, where irrigation and nitrogen fertilization play the key role. Khan et al. in another experiment also conducted in Bangladesh, further observed that irrigation at an early stage which appeared to be essential for optimum early vegetative growth is one of the major determinants for a higher final yield of tomato. Plants suffering from water stress at the early stage of growth failed to
produce an optimum fruit yield even after irrigation with a large amount of water of the later stages of growth[12]. In Bangladesh and some other tropical Asian countries, the season for tomato production coincides with scanty and erratic rainfall. Moreover, under these conditions, water for irrigation is not only a costly but also a hardly available agricultural production input. As a result, ensuring optimum utilization of limited irrigation water is the prime of objective of water management in agricultural production.

As far as tomato is concerned, it appears from the cited literature[11, 12] that water management in tomato cultivation requires special attention during the early stages of growth as compared with the later stages. Therefore, a preliminary study on water management for tomato should be directed towards the optimum irrigation requirement to ensure proper vegetative growth at the early stage. In order to clarify the appropriate irrigation schedule for an optimum early vegetative growth of tomato, we evaluated growth and nitrogen nutrition of tomato seedlings in relation to different soil moisture regimes under the assumption that optimum early vegetative growth is conducive to a higher tomato yield. The specific objective of this study was to clarify the extent of soil moisture depletion that can be allowed to irrigate tomato seedlings in pot culture with a view to maximizing vegetative growth as well as ensuring higher efficiencies of water and nitrogen utilization.

**Materials and Methods**

A pot experiment was carried out under controlled conditions. The container capacity moisture which can be compared well with the field capacity moisture under field conditions was considered to be the uppermost limit of plant available water held by a soil in pot culture experiment. The soil moisture regimes tested in the present study were designed based on irrigation of the pots by allowing different levels of soil moisture depletion from the container capacity level as follows: I₁-irrigation allowing 75% depletion of container capacity moisture (DCCM), I₂-irrigation allowing 50% DCCM, I₃-irrigation allowing 25% DCCM. The pots used to grow tomato plants were 20 cm high and 16 cm in diameter. Although ARAKI[11] recommended a soil depth of 40 cm in forcing cultivation of tomato in the greenhouse, shallower pots were used in our experiment because we planned to limit our study within the vegetative growth period of the plants. The aforesaid 3 different soil moisture regimes were tested in a completely randomized design with each of them being replicated 6 times. Eighteen pots were filled near the top (soil depth in the pot was around 15 cm) with an equal amount (1084.23 g oven dry weight) of soil commercially available for pot culture (trade name, “Soil Friend”, Mitsui Toatsu Hiryo Co.). The moisture content of the soil at container capacity level was determined following the method described by CASSEL and NIELSEN[5]. Cessation of drainage from a saturated soil core with consequent attainment of an equilibrium moisture content (container capacity level) was implemented based on a moisture content versus time curve as suggested by BURROWS and KIRKHUM[3] for the detection of field capacity level. The average container capacity moisture content obtained for 5 replicated determinations was 1058.5 g kg⁻¹. We determined the moisture characteristic curve for “Soil Friend” using hanging water column[9] and centrifugal[6] methods and found that the aforementioned 4 soil moisture conditions such as CCM, and 25, 50 and 75% DCCM corresponded to the ψₛ values of -9.35 × 10⁴, -4.12 × 10⁴, -2.11 × 10⁶, and -1.90 × 10⁷ Pa, respectively. The initial levels of total nitrogen, available P₂O₅, and K₂O in the soil indicated by the supplier were 180, 240, and 150 mg/l, respectively. Seeds of the tomato (*Lycopersicon esculentum* Mill.) cultivar House Momotaro were germinated on moist blotting paper kept in an incubator. The germination of more than 95% of the sown seeds, required about 4 days. Subsequently, the seedlings were reared for 25 days on a tray containing the same soil with proper aftercare in the ambient environment of the laboratory room. On May 17, 1997, healthy and uniform seedlings were transplanted in the aforementioned soil-filled pots to a depth of around 4 cm. After transplantation, all the pots were irrigated with the required amount of water to increase soil moisture content up to the container capacity level. The pots with transplanted seedlings were kept for 25 days in a temperature-controlled glasshouse. Throughout the 25-day growing period, day and night time temperatures were...
maintained at 25 and 15 °C, respectively. The daily relative humidity and solar radiation during the experimental period are given in Figure 1. The relative humidity varied within a narrow range of 53 to 70% throughout the growing period. The values of solar radiation during 0 ~ 5, 5 ~ 10, 10 ~ 15, 15 ~ 20, and 20 ~ 25 DAT were 12.2, 9.5, 18.8, 12.9, and 13.4 MJ/(m² day), respectively. Complete randomization among the pots was maintained through random rearrangement of the pots everyday throughout the study period. After the aforementioned first common irrigation up to CC level on the day of transplanting, the plants were irrigated when required to maintain the aforementioned 3 different soil moisture regimes. For this purpose, the weight of the pots was recorded several times a day to determine their soil moisture contents and soil moisture loss at different times. These data were used to calculate the cumulative soil moisture loss and hence for determining the time and quantity of irrigation water required. Using the container capacity moisture content and the allowable extents of depletion of soil moisture from CC level for 25, 50 and 75% DCCM treatments, 3 different levels of critical soil moisture loss (CSML) at which irrigation should be applied to different pots were calculated. Time of irrigation for a particular treatment was determined by comparing the cumulative weight loss with the corresponding level of CSML. As the pots were weighed several times a day and the weight loss at each time was calculated using the preceding weight only, possible error due to plant weight increase was indeed very minimum. The time of irrigation for a particular treatment was determined when the cumulative soil moisture loss of the concerned pot reached or just crossed the corresponding CSML. Thereafter, irrigation was applied to raise the soil moisture status up to the container capacity level by just replenishing the total amount of lost water within each irrigation cycle. Soil water depletion (SWD) in the pots was computed on a daily basis for each irrigation cycle using soil moisture data as described by Michael15). The periodic SWD values obtained were integrated to calculate the cumulative evapotranspiration (CET) or total water use (TWU) for any particular pot during the 25 day growing period. Plant height and the number of leaflets per plant were monitored at 3-day intervals. On June 11, 1997, the plants were harvested. The roots in each pot were collected through careful washing out of the soils with root-mass on a sieve and were gently blotted. Fresh matter in each pot was recorded separately for roots, stem, and leaves. The amount of dry matter production in the pots was recorded after the harvested plant parts were dried in an oven at 60°C for 72 h. Water use efficiency was calculated according to the method of Cassel et al.9 in order to evaluate the contribution of unit quantity of water to fresh and dry matter production. The samples of roots, stems and leaves were analyzed for total nitrogen content by the micro-Kjeldahl17 method. The uptake of N was calculated according to the formula given below

$$N \text{ uptake (mg)} = N \text{ content (mg/g DW)} \times DW (g)$$

Agronomic efficiency of N uptake for fresh and
dry matter production was computed as the ratio of total fresh and dry matter production to total N uptake. Results obtained for all the parameters examined were expressed as the average of 6 replications.

Results

Soil moisture dynamics

Figure 2 shows the changes in the soil moisture status with time in relation to different treatments. Similar moisture status in all the pots was maintained for a few days after transplanting since on the day of transplanting, all the pots were irrigated by raising the soil moisture status up to the container capacity level. Later on, variable soil moisture status was observed in different pots due to differential irrigation and evapotranspiration. In the pots receiving irrigation of 75, 50 and 25% DCCM the soil moisture content was always close to 264.6, 529.3, 739.9 g/kg, respectively since these three moisture levels were considered to be critical.

Water use

The cumulative evapotranspiration (CET) or consumptive use of water and 5-day average evapotranspiration (ET) rates of tomato plants during 25 days growing period under different soil moisture regimes (SMR) are shown in Figure 3. The CET increased with the progression of growth irrespective of SMR (Figure 3a). However, it is remarkable that from 7 DAT, in case of the driest treatment (75% DCCM), the increase in CET was not appreciable. On the contrary, in the two other treatments (50 and 25% DCCM), CET continued to increase distinctly up to 25 DAT regardless to the levels of SMR at which they were grown. Among these plants, those which received more frequent irrigation under wetter SMR, registered a markedly higher CET from 11 DAT up to 25 DAT.

The mean ET rate per day varied remarkably for the plants grown under different SMRs.
(Figure 3b). For the plants grown at 75% DCCM, the ET rate started with the maximum of 53.01 g/(plant·day) during 0–5 DAT, and afterwards, it continuously declined to a minimum of 15 g/(plant·day) during 10–15 DAT since during this period, irrigation was not applied. After the first irrigation on 18 DAT, the ET rate increased to some extent. Conversely, the plants irrigated at 50 and 25% DCCM registered progressively higher rates of ET with the progression of growth up to 25 DAT. The plants irrigated under a wetter SMR had a higher ET rate, and this was clearly observed from 5–10 DAT. The maximum ET rates of 291 and 529 g/(plant·day) for the pots irrigated at 50 and 25% DCCM respectively, were observed during the period of 20–25 DAT.

**Plant height and leaf number**

The height of the tomato plants grown with irrigation at different levels of soil moisture from the CC level showed gradual increase with the progression of growth period up to 25 DAT (Figure 4a). However, the rate of increase in plant height in case of the driest treatment (75% DCCM) was not as conspicuous as that found in the other two cases (50 and 25% DCCM). At 24 DAT, the tallest plants were observed for the pots irrigated at 25% DCCM followed by those irrigated at 50% DCCM.

Likewise, plants grown under wetter SMR always showed a remarkably higher number of leaflets than the drier ones following 6 DAT (Figure 4b). Production of new leaves almost ceased during 6–21 DAT for the plants irrigated at 75% DCCM. Afterwards, a slight new flush was observed in response to one irrigation on 18 DAT. But the plants irrigated at 50 and 25% DCCM continued to grow and produced new leaves until 24 DAT. Among these two, number of leaflets per plant decreased with the increase of the DCCM before irrigation.

**Fresh and dry matter production and distribution**

The effects of different SMRs were significant (P<0.05) on both fresh and dry matter production and their distribution in the roots, stems, and leaves of tomato plant (Table 1). Total fresh matter production was as low as 19.69 g/plant in the pots irrigated at 75% DCCM compared to 90.38 and 138.92 g/plant in the pots irrigated at 50 and 25% DCCM, respec-

<table>
<thead>
<tr>
<th>Treatment (DCCM, %)</th>
<th>Fresh matter (g/plant)*</th>
<th>Dry matter (g/plant)*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Leaf</td>
<td>Stem</td>
</tr>
<tr>
<td>75</td>
<td>10.79</td>
<td>4.85</td>
</tr>
<tr>
<td></td>
<td>(54.80)</td>
<td>(24.63)</td>
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<tr>
<td>50</td>
<td>52.47</td>
<td>25.52</td>
</tr>
<tr>
<td></td>
<td>(58.05)</td>
<td>(28.24)</td>
</tr>
<tr>
<td>25</td>
<td>81.11</td>
<td>40.91</td>
</tr>
<tr>
<td></td>
<td>(58.39)</td>
<td>(29.45)</td>
</tr>
<tr>
<td>LSD&lt;sub&gt;0.05&lt;/sub&gt;</td>
<td>5.78</td>
<td>3.22</td>
</tr>
<tr>
<td>CV (%)</td>
<td>9.76</td>
<td>11.02</td>
</tr>
</tbody>
</table>

* Figures in the parentheses indicate percentage of the total.
tively, indicating the striking benefit of frequent irrigation. Although the pots irrigated at 50% DCCM produced a remarkably higher amount of fresh matter per plant than those irrigated at 75% DCCM, the value was significantly lower than the maximum. A similar trend in total dry matter production was observed in response to different SMRs. Similarly, fresh and dry matter production in the roots, stems, and leaves was significantly different for various SMRs.

In the pots irrigated at 75% DCCM, a greater proportion of total fresh (21%) and dry (17%) matter was distributed in roots (Table 1). But in the pots irrigated at 50 and 25% DCCM, the proportion of total fresh and dry matter distributed in the roots ranged from 14 to 12, and 11%, respectively. Consequently, a greater proportion of total fresh and dry matter was found in stems and leaves in the pots irrigated at 50 and 25% DCCM in comparison to those irrigated at 75% DCCM.

**Nitrogen content and uptake**

Nitrogen contents in the roots, stems, and leaves did not vary appreciably with the SMRs (Figure 5a). However, the plants grown at 75% DCCM appeared to show the highest concentration of N in the roots, stems, and leaves in comparison to the plants irrigated with 50 and 25% DCCM.

The uptake of N in the roots, stems, and leaves varied significantly in response to different SMRs (Table 2). Wetter SMRs with more frequent irrigation resulted in a significantly higher N uptake in different plant parts. Thus, there was a significant difference in total N uptake ranging from a minimum of 70.32 mg/plant for the pots irrigated at 75% DCCM to a maximum of 503.49 mg/plant for the pots irrigated at 25% DCCM.

![Fig. 5. Nitrogen content and distribution of total N uptake in plant parts of tomato grown under different soil moisture regimes. Vertical bars indicate standard error.](image)

**Table 2. Nitrogen uptake in different parts of tomato plants grown under different soil moisture regimes.**

<table>
<thead>
<tr>
<th>Treatment (DCCM, %)</th>
<th>Leaf (mg/plant)</th>
<th>Stem (mg/plant)</th>
<th>Root (mg/plant)</th>
<th>Total (mg/plant)</th>
</tr>
</thead>
<tbody>
<tr>
<td>75</td>
<td>53.19</td>
<td>9.88</td>
<td>7.25</td>
<td>70.32</td>
</tr>
<tr>
<td>50</td>
<td>280.09</td>
<td>47.10</td>
<td>19.38</td>
<td>346.57</td>
</tr>
<tr>
<td>25</td>
<td>410.65</td>
<td>58.98</td>
<td>33.86</td>
<td>503.49</td>
</tr>
<tr>
<td>LSD&lt;sub&gt;0.05&lt;/sub&gt;</td>
<td>31.88</td>
<td>4.64</td>
<td>3.48</td>
<td>52.20</td>
</tr>
<tr>
<td>CV (%)</td>
<td>10.45</td>
<td>9.75</td>
<td>14.03</td>
<td>13.83</td>
</tr>
</tbody>
</table>
The proportion of total N uptake in the stems remained constant (11−13%) irrespective of SMRs, while the proportion of total N uptake in the roots and leaves varied to some extent in response to the SMRs (Figure 5b). In the pots irrigated at 75% DCCM, around 10 and 76% of the total N uptake was found in the roots and leaves, respectively. On the contrary, in the pots irrigated at 50 and 25% DCCM, the proportion of total N found in the roots was 5 and 6% and that found in the leaves was 82 and 80%, respectively.

Total N uptake by the plants was found to be positively and significantly related to their total water use. The 2nd order polynomial regression line used to express this relation (Figure 6) showed a highly significant coefficient of determination ($R^2=0.970$).

**Fresh and dry matter production in relation to water use and N uptake**

The increased total water use was associated with the increase in both fresh and dry matter production with a simple linear positive relationship and the relationship could be described by the simple regression lines shown in Figure 7a. The highly significant $R^2$ values (0.986 and 0.973) obtained for both lines indicate their good fit to the relationship between the fresh and dry matter yield and total water use.

Likewise, a strong dependence of both fresh and dry matter production on N uptake by the plants was observed. This relationship could also be well represented by the simple linear regression lines shown in Figure 7b. The $R^2$ values (0.946 and 0.982) for the lines were also highly significant.

**Apparent efficiency of water and nitrogen use**

The apparent efficiency of water used by tomato plants expressed in terms of the amount of dry matter production per unit quantity of water use affected by SMRs is shown in Figure 8a. Frequent irrigation brought about a substantial improvement in the water use efficiency of tomato plants, which was maximized when the plants were irrigated at 50% DCCM. Under wetter conditions, a slight decrease in this parameter was observed.

The irrigation treatment at 25% DCCM appeared to be more efficient in nitrogen utilization than the other two (Figure 8b). However, the apparent differences in this parameter between the plants irrigated at 75 and
Fig. 8. Apparent water and nitrogen use efficiency (WUE and NUE) of tomato plants grown under different soil moisture regimes.

50% DCCM and also between those irrigated at 50 and 25% DCCM were not significant.

Discussion

The cumulative evapotranspiration of tomato plants during 25 days growing period increased when the plants were grown under wetter SMR. Under the conditions of the present experiment, since the atmospheric evaporative demand for water was the same for the plants grown under different SMRs, soil water supply and water extraction ability of the plants, which in turn may largely be related to their root growth could provide a satisfactory explanation for the observed differences. A drier soil condition may be unfavorable for plant evapotranspiration at a required optimum rate for two reasons. Water supply capability of a drier soil might be insufficient to meet the evapotranspiration demand of a growing plant especially during the peak period of water use, resulting in stomatal closure. Higher mechanical impedance under dry soil conditions may hamper root growth and could result in reduced water uptake. Plant leaves can not transpire at their full potential once their stomata begin to close which could readily occur when the transpiration rate exceeds the rate of water supply to the leaves. These effects on the trend of water use in the present study are very evident in the case of the plants irrigated at 75% DCCM (maximum extent of soil drying). For this treatment, along with the progression of growth, as the soil continuously dried out (Figure 2), roots grew only to a limited extent (Table 1), and the evapotranspiration rate (which is expected to increase with the progression of growth as observed in the case of the other two treatments) abruptly fell and reached a minimum value of only 15 g/plant·day during 10 to 15 DAT (Figure 3b) since during this period, no irrigation was applied. Subsequently, although the first irrigation was applied on 18 DAT, the ET rate did not increase above 49 g/plant·day since plant growth was already seriously retarded. Reduced rates of evapotranspiration under drier SMR in potato were observed by KHAN et al.9,10 In the other two cases, there was an increase in the ET rate along with the progression of growth and higher rates were observed in the pots irrigated at a lower soil moisture depletion from the CC level (Figure 3b).

The plants grew vigorously, producing higher amounts of fresh and dry matter in the roots, stems, and leaves as more water was made available in the soil (Table 1) and water stress brought about a significant reduction in plant growth and hence a significant reduction in fresh and dry matter production. In the present study, a significant reduction in both fresh and dry matter production occurred when irrigation was applied at more than 25% DCCM. These results reflect the considerable sensitivity of tomato seedlings to water stress conditions. However, the reduction in fresh and dry matter production was more drastic for the increase of pre-irrigation soil drying (PISD) from 50 to 75% DCCM compared to that for the increase of PISD from 25 to 50% DCCM (Table 1). Thus, the results show that the maximum allowable soil moisture depletion (MASMD) should not exceed 25% DCCM when abundant water is
available. However, under limited water MASMD should be within the range of 25 to 50% DCCM in order to avoid the risk of a drastic reduction in plant growth and presumably final yield. Distribution of fresh and dry matter in different plant parts may also be a useful indicator of the potential of a plant to produce the final yield. Plants with a larger proportion of total fresh and dry matter partitioned in the green photosynthetic organs, especially in the leaves, are able to produce higher final yield. In this sense, the plants irrigated at a lower of DCCM appeared to be more efficient in fresh and dry matter partitioning (Table 1).

Reduction in N concentration was observed in different parts of more frequently irrigated plants in comparison to the less frequently irrigated ones (Figure 5), which may be associated with the stimulation of growth and subsequent N dilution effects. Such a N dilution effect related to stimulated growth has been reported for wheat and also for small grains. The plants under a wetter SMR grew vigorously, and consequently could absorb more N from soil as clearly indicated by the strong dependence of total N uptake on total water use (Figure 6). Consequently, despite the N dilution effect, the total N uptake in the tomato plants increased as they assimilated a large amount of dry matter under wetter SMRs (Table 2). The strong positive correlation of fresh and dry matter production with water use and N uptake (Figure 7) indicates that increased availability of water is important for satisfactory N uptake. And satisfactory uptake of both water and N is essential for optimum plant growth and hence a higher fresh and dry matter production. PRIHAR considered that when adequate N fertility is ensured, satisfactory N uptake and crop yield are largely determined by the availability of water in the crop root-zone. For satisfactory N uptake it is essential to synchronize the N-rich zone and moisture-rich zone with the active crop-root zone. Significant positive interactions between soil water supply and N level have also been reported by other researchers for tomato, other vegetables, and also for grain crops.

An optimum early vegetative growth has been reported to be essential for a higher fruit yield of tomato, which requires an optimum supply of irrigation water. It has also been reported that irrigation at the early stage which appeared to be essential for enhancing early vegetative growth was a prerequisite for a higher final yield of tomato. The results obtained in the present study indicate that the allowable extent of soil moisture depletion for irrigation to maximize the growth of potted tomato seedlings should be less than 25% DCCM under abundant water conditions, and 25 to 50% DCCM under limited water conditions.

The present study showed how water can be used most efficiently for obtaining suitable seedlings of tomato under a limited supply of water. The findings of this study can be utilized for water management in the cultivation of tomato seedlings especially in pot culture under deficient water situations. In conclusion, this study may be applied for the cultivation of other crops in the greenhouse and under field conditions in the dry season in Bangladesh and in other tropical regions.

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