Morphological and physiological responses of tomato cv. NCL 1 subjected to excess water stress

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Abstract

A pot experiment was undertaken to determine the effect of flooding duration on morphological and physiological growth parameters of tomato cv NCL 1 in nethouse, Horticulture Farm, IAAS, Rampur during August to October 2002. There was four different flooding duration with 3 replication. Each pot contained single plant in polyethylene bag of size 30 X 20 cm. Plant height, numbers of leaves per plant, canopy diameter, leaf area, root length and total dry weight were reduced significantly (P<0.05) in each treatment over control. Among the plant characters, leaf area was maximum sensitive parameter affected by duration of flooding (84% reduction over control) followed by leaf dry weight and root dry weight. There was increase in the stem diameter (16%), senescence score (200%), number of adventitious roots (402%) and specific leaf weight (74%) over control at 9th day after flooding stress.

Key words: Tomato, anoxia, waterlogging stress, change per day

Introduction

Tomato (Lycopersicon esculentum Mill) is one of the main vegetables grown throughout the country. It is a warm season crop grown in Terai, river basin, foothills and mid hills of Nepal. Terai has major acreage in winter; whereas spring and rainy seasons are the main seasons in hills. Tomato production is extremely difficult in hot and humid lowland areas of tropics during monsoon months (Kuo et al., 1982). Planting of tomato in the rainy season in low-lying areas of terai/inner terai often coincides with the periods of heavy rainfall and high temperature (AVRDC, 1997). In the tropical lowland, heavy rainfall brings about multitudes of problems. The temperature goes above permissible level and most of the areas remain flooded during rainy season. These may be manifested in overall reduction in plant growth, reduced yield, wilt infestation and in severe cases even death of the plant. So rainy season tomato cannot be grown in terai. Planting of tomato for rainy season production in the low-lying areas of the tropics often with periods of heavy rainfall and high temperature manifested in overall reduction of plant growth, reduced yield, and quality and in severe condition, even death of the plants, because of bacterial and or fungal wilt infestation (Bose, 1993).

Farmers trying to grow tomato in hot and humid conditions often face the problems of excess water throughout rain. Plants show different kinds of morphological, anatomical, biochemical and physiological adaptation in response to excess water (Adhikari, 1992). These adaptations manifested by tolerant/ resistant plants could further serve as indices for the efficient screening or selection of tomato suited for wet season in the terai and inner terai region of the country. Selection of appropriate adoptive plant characters that are useful on breeding program can be achieved. So this experiment
was conducted to assess the effect of flooding duration on morphological and physiological parameters of tomato cv NCL 1 under net house condition.

**Materials and Methods**

The experiment was conducted in net house, IAAS, Rampur, Chitwan during August to October 2002. The seed of tomato cv. NCL 1 was sown in pots containing 1:1:1 FYM: sand: soil at August 18th 2002. The 30 days old seedlings were uprooted and transplanted in polybags of 30 X 20 cm size containing 1:1:1 sand: FYM: soil. Polybags were placed in clay pot and soil was placed to give support. After 12 days of seedling establishment, the treatments were imposed. Hole of the pot was plugged to avoid water loss during the experimental period. The experiment was conducted in CRD design with 3 replication. There were 4 treatments; T1 = control (plant grown at field capacity); T2 = 3 days flooding; T3 = 6 days flooding and T4 = 9 days flooding. In each flooding duration, water was maintained at 1 cm above soil level. Each polybag contented a plant and so there were 12 plants in the experiment. Water level was maintained by applying water constantly whenever water level was decreased. Observations were recorded as follows,

1. **Non destructive observations**

   **Plant height, numbers of leaves and canopy diameter**
   Plant height, number of leaves per plant and plant canopy were measured before the treatment application and every 3 days interval to 9 days. Leaves measuring greater than ½ cm in length were included in the count.

   **Non destructive measurement of total chlorophyll**
   Minolta chlorophyll meter (Model SPAD 502) was used to make quick and easy measurement of the leaf greenness (MINOLTA, 1999), which is positively correlated to leaf chlorophyll content (Murdock et al., 1997). The SPAD value determined by chlorophyll meter provides an indication of relative amount of total chlorophyll content of plant leaves. Third, fourth and fifth leaves from the top of the plant were fixed and average measurement was recorded from every 3rd and 4th leaflets of the rachila.

   **Senescence and abscission of leaves**
   This was determined at 9th day after treatment imposed by visual scoring the degree of senescence of the plants (Adhikari, 1992) as follows,
   - 1 = No senescence
   - 3 = Less senescence (1/4th of the leaves per plant senescence)
   - 5 = High senescence (1/2nd of the leaves per plant senescence)

   **Plant vigor**
   This was determined at 9th day after treatment imposed by visual scoring each plant based on the total sum of the plant condition (Adhikari, 1992).
   - 1 = less healthy (About half of the leaves in each plant were drooping)
   - 3 = healthy (Lower leaves less green and dull)
   - 5 = Very healthy (all the leaves green and healthy)

   **Stem diameter.**
   Stem diameter was measured by using verniar caliper
2. Destructive observations:

**Leaf Area**
Leaf area was measured by using leaf area meter at 9th day after treatment imposed.

\[
\text{Specific leaf weight} = \frac{\text{Leaf wt (dry)}}{\text{Leaf area (m}^2\text{)}}
\]

\[
\text{Specific leaf area} = \frac{\text{Leaf area (m}^2\text{)}}{\text{Leaf wt (dry)}}
\]

**Dry weight**
Dry weight of the root, leaves and stem was separately determined from the same plant used for leaf area. The drying was done in an oven for 48 h at 65±2°C.

**Root shoot ratio**
The dry weight of the root was divided by the dry weight of the shoot in a plant to get the parameter.

**Adventitious root formation**
Adventitious root formation was counted on the basis of roots above soil and water surface at 9th day after treatment application.

**Root length**
Root length was determined at 9th day after treatment application. Plants were watered heavily, polybag was cut into 2 half and soil was removed leaving roots almost intact in the plant.

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**Results and Discussion**

**Effect of flooding duration on non-destructive parameters**
There were significant (P<0.05) differences observed among plant height, canopy diameter, numbers of leaves, stem diameter and adventitious roots (Table 1). There were reduction on plant height, canopy diameter and leaf numbers in each flooding treatment over control. At three and six days of flooding duration, plant height and numbers of leaves were not significantly different but adventitious root formation was significant differed. At nine day after flooding, plant height was reduced by 54.7%, numbers of leaves by 60% and chlorophyll reading by 19%. Plant height was maximum sensitive character to flooding stress. Stem elongation was inhibited due to gibberellic acid (GA) deficiency or ethanol transport to shoot from anaerobic roots (Kuo, 1993). Stem diameter was increased by 5.37% and 16.12% at 6th and 9th day after flooding respectively but it was reduced by 3.25% at 3rd day after flooding over control. The hypertrophy of stem was presumably caused by auxin or ethylene entrapped in hypocotyl of plant (Kawase, 1981)
Table 1. Non destructive parameters as affected by duration of flooding on tomato cv. NCL1 in Net house, IAAS, Rampur, 2002.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Plant height (cm)</th>
<th>Plant canopy (cm)</th>
<th>No of leaves</th>
<th>Chlorophyll reading (SPAD value)</th>
<th>Stem Dia. (cm)</th>
<th>No of Adv. roots</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>30.73a (100)</td>
<td>19.50a (100)</td>
<td>15.0a (100)</td>
<td>39.9 (100)</td>
<td>0.93 (100)</td>
<td>4.3a (100)</td>
</tr>
<tr>
<td>3 DF</td>
<td>22.73b (-26.03)</td>
<td>15.90ab (-18.46)</td>
<td>10.33b (-31.13)</td>
<td>35.33 (-11.45)</td>
<td>0.90 (-3.25)</td>
<td>7.2a (67.44)</td>
</tr>
<tr>
<td>6 DF</td>
<td>20.37b (-33.7)</td>
<td>13.37b (-31.43)</td>
<td>9.20b (-38.6)</td>
<td>33.56 (-15.88)</td>
<td>0.98 (5.37)</td>
<td>18.4b (327.9)</td>
</tr>
<tr>
<td>9 DAF</td>
<td>13.89c (-54.7)</td>
<td>11.37b (-41.7)</td>
<td>6.0c (-60.0)</td>
<td>32.30 (-19.04)</td>
<td>1.08 (16.12)</td>
<td>21.6b (402.32)</td>
</tr>
</tbody>
</table>

LSD=0.05 4.628 4.896 2.8  ns  ns 4.46

Means followed by same letters within each column are not significantly different at 5% by DMRT
Figures in parenthesis indicates percent decreased or increased over control
+ = Indicates increased over control
- = Indicates decreased over control
DAF = Days after flooding

Development of adventitious roots were maximum which increased by 67%, 327.9% and 402.32% at 3rd, 6th and 9th day after flooding respectively. The hypertrophy of stem enhanced adventitious root formation on the shoot.

This induces partial recovery of air diffusion from leaves to roots (Kawase, 1981), thus inducing excess water tolerance to the plants. Kawase (1981) reported that adventitious roots in waterlogged plants were caused by accumulation of auxin and food materials in the stem near the water line where O₂ deficiency stops downward translocation. Formation of adventitious root primodia in the hypocotyl of waterlogged sunflower was primarily controlled by auxin, translocation of which is blocked by the transient rise of ethylene occurring with in 12 h of stress (Wample and Reid, 1979).

Leaf greenness (SPAD value) was not significantly affected by the duration of flooding. Reduction in plant canopy was because of increased in ethylene production, which leads leaf wilting and senescence. ACC (1-Amino-Cyclop propane-1-Carboxylase) in tomato travels via xylem sap to the shoot, where in contact with O₂, it converted to ethylene. The upper (adaxial) surface of the leaf petiole of tomato has ethylene responsive cells that expand more rapidly when ethylene concentration is high. This expansion results in epinasty in which the leaves grow downward and appear drooping (Tai and Zeiger, 1991). Root zone flooding is followed by rapid depletion of soil oxygen, which in turn changes plant growth as a result of altered water, carbohydrate, mineral nutrient, hormonal relations and accumulation of toxic substances (Adhikari and Paje, 1993).

Effect on destructive parameters

Leaf dry weight, root dry weight and total dry weight, and root length were significantly (P<0.05) reduced over control (Table 2). Maximum effect of flooding was at 9 day after flooding on leaf area, which was reduced by 84% over control. Leaf area was the maximum sensitive character to flooding stress followed by plant height. Restricted nitrogen supply and increased ethylene production is
attributed to cause leaf growth reduction (Adhikari, 1992). Root to shoot ratio was not significantly affected by flooding duration but it was reduced with increasing duration of flooding. Decrease in root shoot ratio indicates that the effect of flooding was more on root than shoot growth. In cauliflower, flooding duration increased root shoot ratio (Adhikari, 1992). Redox potential falls rapidly and reaches to negative values after flooding and affects the availability of ions to root zone (Crane and Davies, 1988). Similarly effect of excessive moisture on the roots include slower root elongation, suppressed root hair formation and rotting and drying of roots and eventually death of the plant (Adhikari, 1992).

### Table 2. Plant destructive growth parameters as affected by duration of flooding on tomato cv. NCL1 in Net house, IAAS, Rampur, 2002.

<table>
<thead>
<tr>
<th>Flooding duration</th>
<th>Leaf area (cm²)</th>
<th>Leaf dry wt (g/plant)</th>
<th>Root dry wt (g/plant)</th>
<th>Total dry wt (g/plant)</th>
<th>Root: Shoot ratio</th>
<th>Root length (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>357.6a (100)</td>
<td>0.922a (100)</td>
<td>0.094a (100)</td>
<td>7.869a (100)</td>
<td>0.012 (100)</td>
<td>19.03a (100)</td>
</tr>
<tr>
<td>3 DAF</td>
<td>83.90b (-76.53)</td>
<td>0.360b (-60.9)</td>
<td>0.045b (-52.12)</td>
<td>3.895b (-50.5)</td>
<td>0.011 (-8.33)</td>
<td>3.66ab (28.21)</td>
</tr>
<tr>
<td>6 DAF</td>
<td>82.90b (-76.86)</td>
<td>0.354b (-61.6)</td>
<td>0.033b (-64.8)</td>
<td>3.883b (-50.6)</td>
<td>0.010 (-16.67)</td>
<td>8.23b (-56.75)</td>
</tr>
<tr>
<td>9 DAF</td>
<td>56.81b (-84.11)</td>
<td>0.240c (-73.9)</td>
<td>0.028b (-70.2)</td>
<td>2.711b (-65.54)</td>
<td>0.0096 (-20.0)</td>
<td>7.94b (-58.27)</td>
</tr>
<tr>
<td>LSD(0.05)</td>
<td>66.68</td>
<td>0.1330</td>
<td>0.018</td>
<td>2.63</td>
<td>rs</td>
<td>5.87</td>
</tr>
</tbody>
</table>

Means followed by same letters within each column are not significantly different at 5% by DMRT.
Figures in parenthesis indicates percent decreased or increased over control.

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Under flooding there is degeneration of root tissues particularly the apical meristem existing roots cease extending and dry matter accumulation is arrested.

**Effect on specific leaf area (SLA), specific leaf weight (SLW), plant vigor and senescence**

There was increased in the specific leaf weight as the duration of flooding increased. It was 67% in 3 days, 73% at 6th day and 74% increased at 9th day of flooding respectively (Table 3). This was because of reduced numbers of leaves and leaf area. There was less number of leaf and leaf area for sink and higher dry matter accumulations because of less competition for photosynthesis partitioning. Leaf area and SLA were reduced and maximum reduction was observed on 9 days of flooding which was 43% and 73% respectively.
Table 3. Plant parameters as affected by duration of flooding on tomato cv. NCL1 in Net house, IAAS, Rampur, 2002.

<table>
<thead>
<tr>
<th>Flooding duration</th>
<th>SLA</th>
<th>SLW</th>
<th>Senescence score</th>
<th>Plant vigor score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>386.345</td>
<td>0.00258</td>
<td>1.00</td>
<td>4.33</td>
</tr>
<tr>
<td>(100)</td>
<td>(100)</td>
<td>(100)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 DAF</td>
<td>233.050</td>
<td>0.00432</td>
<td>2.33</td>
<td>2.33</td>
</tr>
<tr>
<td>(-39.67)</td>
<td>(67.4)</td>
<td>(133)</td>
<td></td>
<td>(-46.81)</td>
</tr>
<tr>
<td>6 DAF</td>
<td>233.72</td>
<td>0.00447</td>
<td>2.33</td>
<td>1.667</td>
</tr>
<tr>
<td>(-39.50)</td>
<td>(73.25)</td>
<td>(133)</td>
<td></td>
<td>(-61.50)</td>
</tr>
<tr>
<td>9 DAF</td>
<td>218.5</td>
<td>0.00448</td>
<td>3.0</td>
<td>1.00</td>
</tr>
<tr>
<td>(-43.57)</td>
<td>(73.64)</td>
<td>(200)</td>
<td></td>
<td>(-76.9)</td>
</tr>
</tbody>
</table>

Figures in parenthesis indicates percent decreased or increased over control
+ = Indicates increased over control
- = Indicates decreased over control
DAF= Days after flooding
Higher SLW indicates that thicker leaves and more photosynthetic rate. SLW is measure of photosynthesis. There was enough dry matter accumulation to support the corresponding plant growth

References


