Effect of N-deficiency on photoassimilate partitioning and rhythmic changes in fruit and stem diameter of tomato (*Lycopersicon esculentum*) during fruit growth.

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Abstract

Tomato (*Lycopersicon esculentum*) plants were grown hydroponically inside the green house of Hiroshima university, Japan. At the first fruiting stage, N was withdrawn from the rooting medium for a period of 19 days and its effect on photosynthesis, partitioning of both ^{13}C and ^{15}N, N contents of various organs and changes in stem and fruit diameter of the plant was studied in order to identify the mechanism of resource management on the parts of the plant at low N. Compared to the control, N-deficiency treatment decreased biomass growth of all organs. The treatment depressed leaf photosynthesis within a few days and the decrease in stem diameter was detected after a lag period of about 11 days, however there was no clear impairment of fruit diameter. The circadian rhythm in fluctuations of diameter was less manifested in the fruits compared to the stem. N-deficiency induced daytime shrinkage and reduced night expansion of fruit. It is concluded that nitrogen deficiency reduces source activity more severely than sink activity, and results in limiting fruit production without restriction of fruit expansion.

Key words

fruit diameter, micro-morphometry, nitrogen, partitioning, tomato, stem diameter,

Introduction

Nitrogen is a major essential element for plants and deficiency of this nutrient primarily reduces photosynthesis in source leaf (Makino 2001). The reduction in biomass production in the source leaves affects growth of the plant and its organs, roots and shoot .Additionally, some other workers believe that the effects of P-deficiency on sink are direct and not mediated through the source activity (Pieters *et al.*, 2001). However, such data for N deficiency is not available. For finding factors limiting plant biomass production based on the source-sink relationship, a precise methodology is necessary to measure the effects of N-deficiency on both source and sink organs of the plant. A micromorphometric and non destructive technique can be utilized to measure the changes in the diameters of the stem (Genard *et al.*, 2001) and fruit (Link *et al.*, 1998) which fluctuated diurnally to coincide with the changes in the water status of the plant. The objectives of the present study are to examine the limiting factor of tomato fruit production by monitoring the effect of N-deficiency on stem and fruit diameter of tomato plant during fruit growth, while simultaneously recording the effect of stress on primary production, photosynthesis and assimilate partitioning.

Methods

Plant culture

Tomato (*Lycopersicon esculentum* L.cv. Momotarou) plants were grown hydroponically inside the glass house as described by Fujita et al. (2003). At the first fruiting stage (65 days old), N was withdrawn from the nutrient medium in three pots and this treatment was continued for 19 days. Plants from both control and N-deficiency treatment were harvested at 1, 9 and 19 days after treatment in three replicates, separated into individual plant parts, dried, weighed, and ground to powder with a vibrating sample mill

(Model T1-100, Heiko Co Ltd., Fukushima, Japan) and aliquots were taken for analysis of nitrogen by Kjeldahl method described elsewhere.

Measurement of photosynthesis, transpiration and stomatal conductance

Photosynthetic rate of the 1st and 2nd leaves below the fruiting truss were measured at 11.00 am on each day in both control and N-deficiency treatment plants during the 19 d period of treatment. with a portable infra red gas analyser (Model L1 6400, Licor Co. Ltd., Lincoln, Nebraska, USA). The photosynthetically active radiation during measurement was above 1000 ?mol $m^{-2}.s^{-1}$.

Measurement of stem and fruit diameter

Changes in stem and fruit diameters were continuously recorded in both control and N-deficient plants with a shrinkage type micro-displacement detector (Imai *et al.*, 1990). The sensors were connected to a computerized data acquisition system (NEC, Sanei Kogyo Co. Ltd., Tokyo). The sensors were fastened to the stem or a growing fruit and connected to the power system and data logger. The sensitivity in measurement was within a limit of 2 ?m. All measurements were recorded three times.

$^{13}CO_2$ feeding and determination

$^{13}CO_2$ and ^{15}N-NO_3 feedings were conducted as previously described by Fujita et al. (2003). The ^{13}C or ^{15}N abundance in the powdered sample was determined with a mass spectrometer (model Delta plus, Finnigan Co., San Jose, CA, USA) .

Conclusion

Dry mass accumulation

The dry mass accumulation was decreased in the N-deficient plants compared to the control during the 19 d period of treatment and the decrease was more significant in leaf and stem than fruit and roots.

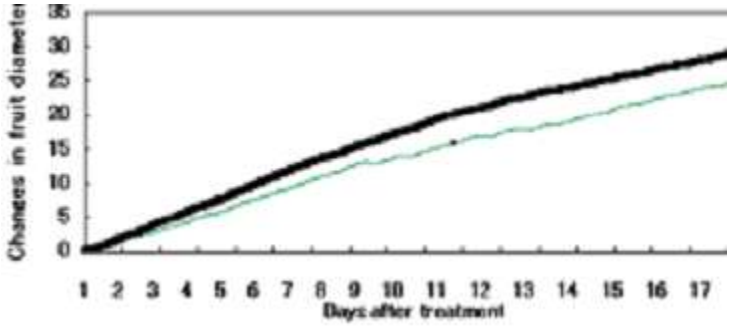

Fig. 1. Effect of N deficiency on changes in fruit diameter in tomato.

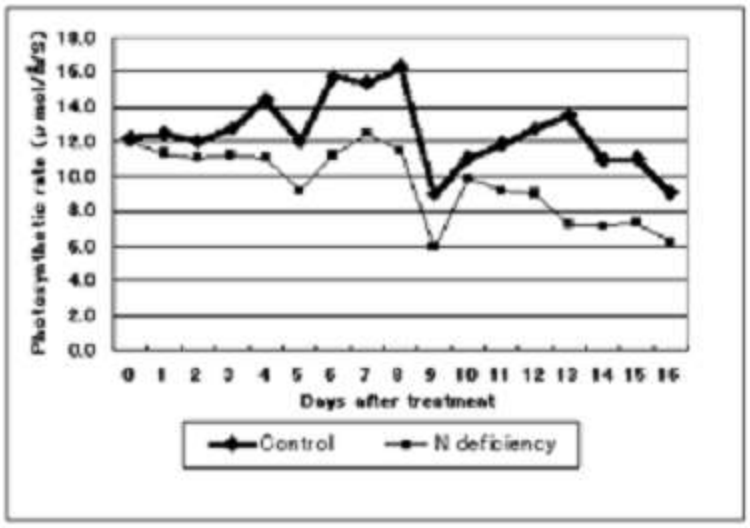

Fig. 2. Effect of N deficiency on photosynthetic rate in leaves of tomato.

Stem and fruit diameter

During the period of treatment, the diameter of the stem in the control plants exhibited daytime shrinkage and nighttime expansion and increased temporally up to 19 days after treatment (data not shown). There was similar rhythmic shrinkage and expansion in stem of the plants subjected to N-deficiency. However, during 7-11days after the treatment, the diameter of the N-deficient plants was larger than the control, but after 11days, no increase in stem diameter in the N-deficient plant was observed. During the initial period, N-deficiency alleviated daytime shrinkage in comparison to the control. The diameter of the fruit increased with passage of time in both of the control and N-deficient plants during the period of treatment (Fig.1). N-deficiency had no significant reduction in fruit expansion during the period. The circadian rhythm in contraction and expansion of the fruit diameter was not as distinct as that of the stem and expansion occurred all throughout the treatment period in both control and N-deficient plants. (Fig.1)

Apparent photosynthetic rate/ stomatal conductance

The apparent photosynthetic rate (Fig.2) mostly remained similar in both control and N-deficient plants during the first few days of treatment. However, there was a reduction of the rate in the N-deficient plant compared to control. (Fig.2).

^{13}C partitioning

Among the plant organs studied, ^{13}C atom % was very high in the fed leaf and it was followed by the fruits. N-deficiency reduced ^{13}C atom % of the fruits but it improved that of the peduncle on day 19. The export rate of ^{13}C into other plant parts from the fed leaf was not changed by N-deficiency at day 9 after treatment, however it tremendously decreased at day 19. N-deficiency had no significant effect on partitioning of ^{13}C to fruits (major sink) on day 9 after treatment, but at day 19, it depressed significantly.

^{15}N partitioning

In contrast to ^{13}C, less ^{15}N was partitioned into the fruits. In the control, partitioning was maximum in favour of the leaves and fruits. N-deficiency slightly increased partitioning in favour of the fruits.

The effect of low P on expansion and contraction of stem and fruit diameter provided new insight for distinguishing the influence of P-deficiency on the sink from that of the source (Fujita et al. 2003). Namely, at low P increase of fruit diameter terminated a few days earlier than depression of

photosynthetic rate, suggesting that sink activity is affected more severely than source activity by P deficiency (Fujita et al. 2003). However, the data in the present study indicates the opposite trend under suboptimal N supply conditions. Withdrawal of N from culture media depressed photosynthetic rate within a few days after the treatment but it had no reduction of the fruit diameter during the experimental period (Figs. 1 and 2). This seems to be caused by significant reduction of nitrogen from leaves at low N while maintaining relatively high concentration of nitrogen in fruits at the expense of leaves and stem. A micromorphometric and non destructive technique can be utilized to measure the changes in the diameters of the stem (Genard *et al.*, 2001). P deficiency depressed stem diameter about 5d after treatment (Fujita et al. 2003), however in the present study, N deficiency did about 11d. Since the diameters of the stem (Genard *et al.*, 2001) coincide with the changes in the water status of the plant, it seems that these differential response may be partially associated with function of the water channel proteins aquaporins (Clarkson *et al*., 2000).

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