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GROWTH AND DEVELOPMENT OF YOUNG TOMATO PLANTS UNDER NITROGEN DEFICIENCY

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Abstract

Reducing fertilizer supply is currently a developing trend. However, crop management with low or late N supply may lead to N deficiency. The present study is aimed at analysing the immediate consequences of a temporary N deficiency at the start of the tomato reproductive phase. Seedlings of the UC 82 processing cultivar were directly grown in 10 l sand-filled pots under greenhouse conditions. Plants were watered daily with a complete solution (N) of 6 meq N l⁻¹ until the first truss stage. Then three treatments (N), (1/3 N) and (0 N) were applied for 12 days. Nitrogen shortage resulted in reduced leaf elongation from day 4 and decreased shoot growth rate from day 6 for (0 N), and from day 6 and day 12 respectively for (1/3 N). Only (0 N) yielded a smaller rate of truss elaboration and growth. As early as day 2, the content of different nitrogen forms present in the various plant parts decreased with the N solution concentration. Nitrogen deficiency led to changes in leaf colour, a decrease in leaf chlorophyll content, an increase in leaf phenol content, and abnormal starch accumulation in the chloroplasts, whose structure was disturbed. The rapid response of tomato plants was due to their small nitrogen reserves.

1. Introduction

There currently exists a tendency to reduce crop inputs, particularly fertilizer supplies, to reduce cost and better preserve the environment (Dumas, 1990). Nitrogen alimentation is concerned and crop management using reduced or late nitrogen supply may lead to N deficiency. Various studies have focused on the behaviour of different species under nitrogen deficiency or starvation (Just et al., 1989, Chapin et al., 1988). The aim of the present study was to analyse the immediate consequences of a temporary nitrogen shortage at the beginning of the reproductive phase on growth and development of the processing tomato, as it is possible to wait for the appearance of the first trusses before supplying N to soils with good agronomic characteristics (Suniaga Quijada, 1990).

2. Materials and methods

The experiment was performed under greenhouse conditions. Seeds of the UC 82 processing cultivar were placed 1 cm deep in 10 l pots filled with siliceous sand and completely randomized using 4 repetitions. Mean maximal weekly temperatures ranged from 28 to 33°C and mean

minimal ones from 12 to 16°C. After emergence, three plants per pot were kept. Plants were watered daily until the first truss stage with a complete solution (N) containing 6 meq N l⁻¹ (ratio NO₃⁻/NH₄⁺ = 1). After several waterings with deionized water to leach residual N out of the sand, three treatments (N), (1/3 N) with 2 meq N l⁻¹ and (0 N) without N were applied for 12 days. Numerous variables were measured or observed: leaf and truss size, leaf area, shoot and root dry matter weight, organic and nitrate N contents of the different plant parts, chlorophyll and polyphenol contents of leaf ethanol extracts, leaf colour using a Minolta "Chroma Meter CR-100", and leaf cell structure through electron microscopy. Results were processed by variance analysis and means were compared by the Newman-Keuls method.

3. Results

3.1. Plant growth

The earliest effect of nitrogen starvation (0 N) on shoot growth was a decrease in the leaf lengthening rate resulting in differences in leaf area per plant from day 4 after treatment (Figure 1a). Later, on day 6, a decrease in dry matter accumulation rate was observed on the same plants (Figure 1b). For the treatment (1/3 N) significant effects on leaf area and shoot dry matter were observed only from days 6 and 12 respectively.

Until day 9 no significant difference between the treatments could be found for root dry matter weight (Figure 1c). However, as early as day 2, nitrogen starvation or deficiency generally resulted in higher values. From day 9, plants under (0 N) and (1/3 N) conditions stopped accumulating root dry matter.

3.2. Plant development

Table 1 shows the changes in the number of trusses and their total length (sum of individual truss lengths) per plant. The number of trusses per plant was influenced only on day 6, but as early as day 2, nitrogen starvation reduced the growth rate of the existing trusses. However, truss number and total length under (0 N) continued to increase. No important difference was observed between (1/3 N) and (N) throughout the experimental period.

3.3. Nitrogen content

The value of each N form content generally decreased with N availability (Table 2). This decrease was observable from day 4 and augmented over time. Organic N content showed the lowest decrease though it was reduced by about 40 % in all the organs under (0N). Leaf nitric N content did not vary appreciably between the treatments or over time and represented 10 % of total nitrate amount. However, nitrate content in stems and roots drastically decreased from day 4 under (1/3 N) and (0 N) with no further change over time.

3.4. Leaf colour and composition

After two days, N shortage resulted in a paler green leaf colour.

On day 6 it was easy to visually distinguish the (ON) treatment. Direct colour measurements were performed at the end of the experiment on the upper side of the 3rd and 4th leaf blades (Table 3). N starvation resulted in a markedly yellower tint. The quantity L representing reflected light was lower for plants well-supplied with N which had a more intense green leaf colour. In another experiment it was possible to differentiate the treatments by L as early as day 2.

Figure 2 represents the pigment absorption spectrum of leaf ethanol extracts. The two typical chlorophyll peaks for the wave lengths 434 and 664 nm demonstrate the significant influence of N availability on leaf chlorophyll content. Absorbance between 300 and 350 nm is typical of polyphenol pigments. Polyphenol content was considerably increased by N starvation.

Cell structure of palisade-tissue from the upper side of the plant's younger spread leaf was observed under electron microscopy. As early as day 2, N starvation resulted in a considerable starch accumulation in the chloroplasts. This accumulation continued to increase, which deformed the chloroplasts and dislocated the thylacoids. The leaves were rigid and tough to the touch, and stood erect as compared to the broadly spread green leaves of plants well-supplied with N.

4. Discussion

In terms of plant growth the earliest consequence of N deficiency or N starvation was a reduction in leaf elongation. Chapin et al. (1988) obtained the same result along with an increase in root growth by carbohydrate accumulation on tomato, as had Champigny et al. (1985) for wheat, before any manifestation of shoot growth reduction. Just et al. (1989) have also demonstrated that sunflower first limited leaf expansion and then used up its available N reserves while reorienting carbon flux. But in each case the increase in root dry matter production lasted only a short time and root growth stopped if the deficiency continued. Shoot growth was greatly influenced through the foliage system but elaboration of the reproductive system did not stop during the trial period even in the (0 N) treatment. Under N deficiency conditions, the distribution priority for assimilates was : first to the reproductive organs; second, to the roots and third to the shoot vegetative system.

Leaf nitrate content was low and basically constant under any condition and at any given moment. On the contrary, nitrate contents in the stems and roots rapidly decreased under N shortage conditions. Chapin et al. (1988) observed the same consequences with tomato and barley. N redistribution in the plant helped ensure continuous metabolism.

Leaf colour measurements and ethanol extract analysis have yielded a better insight into the metabolism modifications related to N shortage. N availability resulted in chlorophyll synthesis and green colour whereas N shortage resulted in polyphenol synthesis and yellow colour. Polyphenols are always present in tomato as shown in Figure 2, particularly chlorogenic acid corresponding to wave length 334 nm (Macheix, 1979), but here the content increased during N shortage.

Polyphenols are known to be able to inhibit plant growth regulators and are thus associated with slowed growth. Polyphenol synthesis could also be enhanced by the disorganization of the chloroplastic system (Siegenthales and Vaucher-Bonjour, 1971) as is found in ageing organs.

Objective leaf colour measurements appeared to be a potential non-destructive tool to directly diagnose the effects of N deficiency on tomato plants. Colour could prove to be a nutrition status indicator though further studies are necessary.

5. Conclusion

Young tomato plants responded very rapidly to nitrogen shortage as seen through various measurable parameters. Leaf colour turned to yellow depending on shortage intensity and duration. Leaf expansion and shoot growth rate were reduced. Development was only slightly influenced after 12 days. Leaf chlorophyll content decreased while leaf polyphenol content and the amount of starch in the chloroplast increased demonstrating that the entire metabolism was deeply modified. The amount of the various nitrogen forms in the different organs was quickly reduced for redistribution towards new organs. The rapidity and intensity of these modifications were due to the very small nitrogen reserves of tomato at the first truss stage. Thus, when a deficiency appears in the medium, the plant may rapidly be placed in limiting conditions which makes regulation difficult under conditions of low-fertilization.

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Table 1 - Number and total length (mm) of trusses per plant (each value is the average of data from 12 plants).

Days	Truss character- istics	Treatments		
		(N)	(1/3 N)	(0 N)
2	number	1.0	1.0	1.0
	length	4.0	4.0	2.8
6	number	1.3	1.2	1.1
	length	12.4	11.3	7.6
12	number	3.3	3.1	2.0
	length	34.4	32.3	21.6

Table 2 - Nitrogen content (g per 100 g dry matter) of the different plant parts 4 days (4 d.) and 12 days (12 d.) after beginning of treatment.

Treatment	organ	Organic N		Nitrate N	
		4 d.	12 d.	4 d.	12 d.
(N)	leaf	6.3	5.4	0.06	0.05
	stem	4.3	4.1	0.44	0.42
	root	4.9	3.9	0.36	0.14
(1/3 N)	leaf	5.0	4.3	0.03	0.04
	stem	3.3	2.7	0.06	0.09
	root	3.9	3.2	0.06	0.06
(0 N)	leaf	3.8	2.0	0.03	0.06
	stem	2.5	1.7	0.05	0.07
	root	2.7	2.0	0.02	0.05

Table 3 - Tomato leaf blade colour after 12 days of N availability differentiation. Each value is an average of 10 data.

Colour expression	Treatments		
	(N)	(1/3 N)	(0 N)
a* (green component)	-12.2 t	-13.9 u	-16.2 v
b* (yellow component)	+13.8 t	+17.7 u	+27.9 v
Luminosity or clearness L*	38.6 t	41.6 u	49.6 v

* according to Convention Internationale d'Eclairage (CIE).
The values on the same line not followed by the same letter are significantly different (Newman-Keuls, $p = 0.05$).

Figure 1. Influence of the reduction of nitrogen solution concentration on diverse tomato growth characteristics over time (days after treatment). In the figures, two distinct curves indicate significant differences ($p = 0.05$).

a : Leaf area
b : Shoot dry matter weight
c : Root dry matter weight

Figure 2. Absorption spectrum of tomato leaf-blade pigments 12 days after treatment.