635.64: 631.671: 581.14
581.11: 635.64: 631.84

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THE EFFECT OF NITROGEN APPLICATION AND WATER SUPPLY ON GROWTH AND WATER REQUIREMENT OF TOMATO UNDER CONTROLLED CONDITIONS

by

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1. INTRODUCTION

In a previous experiment (1) the effect of temperature and irrigation regime on transpiration, water requirement and various growth aspects of tomato plants has been described. A decrease in yield was observed when the water supply was inadequate. This decrease was more pronounced at higher temperatures than at lower ones. The water requirement, expressed as g water transpired per g dry matter produced, decreases also, due to a relatively stronger reduction in transpiration. It may be expected that the effect of water supply is influenced not only by temperature but also by mineral nutrient supply. Especially the application of nitrogen is known to have a large effect on the growth of plants. HAWTHORN and POLLARD (4), stated that in lettuce "the full utilization of nitrogen is assured by adequate moisture and also the full benefits of additional soil moisture can be obtained only if the supply of nitrogen is adequate". Comparable conclusions with nitrogen were obtained with other species also (3, 6).

Our aim was to investigate the effect of nitrogen and water supply on the growth of tomato, and to verify, whether the above statement applies, and leads to a more economic water use or lower water requirement of the plant.

2. MATERIAL AND METHODS

In the experiments with young tomato plants small metal containers, 20 cm high and 10 cm in diameter were used, each of which was filled with 2 kgms of loamy soil. They were put into a growth chamber for 28 days. The average temperature and relative humidity during the experimental period were 25.3 °C

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and 57%, respectively. The light period was 12 hours per day and the intensity 7.1×10^4 erg. sec.$^{-1}$ cm^{-2} ⌀ sphere. For further details concerning the cultivation and methods used, see (1).

The experiment covered 5 nitrogen levels, 3 levels of moisture supply, and 5 replicates. In the nitrogen treatments, various amounts of ammonium nitrate (0; 0,05; 0.1; 0.2 and 0.3 g per kg air dry soil) were added. A soil analysis revealed that the nitrogen content of the control approximately was 0.06 g/kg soil. In the various irrigation treatments A, B and C, water was added when either 20, 50 or 90% of the available moisture range between field capacity and wilting point were used.

The total water loss of the pots was measured by weighing. Once a week the soil in the pots was covered with plastic sheets for 24 hours for separate determination of the rates of transpiration and evaporation. At the end of the experiment, various growth aspects were measured. Moreover, the gain in fresh weight and the dry matter production were determined.

3. Experimental results

A. Growth aspects

Various growth aspects of the tomato were measured; the results are presented in table I. It is evident from this table that the height of the shoot is affected by the irrigation regime, confirming the results obtained in a previous experiment (1), but not significantly so by the nitrogen level. It was found that the stem diameter, and the number of leaves and internodes did not show a regular response to the various treatments in the course of the experiment. The average leaf number per plant was 9.7, and the average stem diameter 5.2 mm. Though no change in leaf number was observed, the length and the width of the leaves however, varied considerably, thus changing the total leaf area (Table I, plate 1).

Leaf area has been presented in figure 1a versus the nitrogen content at various levels of irrigation (A, B and C). It is evident that the leaf area increases with nitrogen content. This increase is more pronounced at a higher level of water supply. At the highest nitrogen level and the lowest irrigation regime (C), however, a small decrease occurs in leaf area and also in fresh and dry weight (vide table I). It may be that at such supra optimal nitrogen applications under dry soil conditions, the osmotic pressure of the soil solution increases, reducing the availability of water. Mitscherlich's equation can be applied to the data in fig. 1a, supposing that the increase in yield is proportional to the difference between maximum and actual yield or:

$$\frac{dy}{dx} = m \quad (A_{max}-y)$$

Hence:

$$y = A_{max}\ [1-10^{-m(x-q)}]$$

in which A_{max} represents the maximum leaf area to be expected, y; the actual leaf area at a certain level of nitrogen and water supply, while m and q are constants. In figure 1b, $\log \frac{A_{max}-y}{A_{max}}$ is plotted versus the nitrogen level (x) for the various irrigation treatments A, B and C. It is evident that straight lines, approximately parallel to each other are obtained in this way. Only the treatment with the highest nutrient level and the lowest irrigation regime (C) shows a large

TABLE I. The effect of nitrogen and water regime on growth, transpiration, and water requirement of tomato plants under controlled conditions.

Treatmen		Height of shoot (cm)	Total leaf area (cm^2)	Fresh weight shoot (g)	Dry weight shoot (g)	Water content (g/g dry wt)	Chlorophyll content (10^{-3} mg/cm^2)	Dry weight root (g)	Ratio root to shoot	Transpiration rate (g/h 100 cm^2)	Water requirement (shoot + root)
1	A	29.3 ±0.5	345 ±34	13.41 ±1.09	1.419 ±0.123	8.5 ±0.2	9.2 ±0.3	0.155 ±0.008	0.112 ±0.008	0.52 ±0.02	730 ±22
	B	26.3 ±0.2	315 ±29	11.20 ±0.77	1.277 ±0.108	7.9 ±0.3		0.166 ±0.012	0.131 ±0.005	0.38 ±0.01	610 ±17
	C	22.5 ±0.3	275 ±15	9.18 ±0.24	1.110 ±0.039	7.4 ±0.2		0.152 ±0.012	0.136 ±0.006	0.12 ±0.01	375 ±18
2	A	29.7 ±0.8	412 ±20	15.42 ±0.80	1.782 ±0.126	7.7 ±0.2	11.8 ±0.1	0.191 ±0.013	0.108 ±0.007	0.44 ±0.00	645 ±18
	B	28.0 ±1.0	392 ±36	13.60 ±1.10	1.510 ±0.132	8.0 ±0.3		0.171 ±0.015	0.114 ±0.008	0.23 ±0.02	550 ±16
	C	22.9 ±0.3	315 ±18	10.58 ±0.53	1.159 ±0.050	8.1 ±0.2		0.142 ±0.008	0.123 ±0.007	0.11 ±0.01	315 ±38
3	A	30.0 ±0.6	531 ±26	19.16 ±0.93	1.978 ±0.137	8.8 ±0.3	13.7 ±0.2	0.183 ±0.013	0.093 ±0.008	0.45 ±0.03	690 ±33
	B	27.4 ±0.6	461 ±10	15.96 ±0.46	1.733 ±0.063	8.2 ±0.2		0.163 ±0.008	0.094 ±0.007	0.31 ±0.02	575 ±31
	C	23.6 ±0.7	337 ± 8	11.63 ±0.25	1.156 ±0.056	9.2 ±0.5		0.109 ±0.008	0.094 ±0.004	0.10 ±0.00	470 ±12
4	A	29.5 ±0.7	613 ±20	21.55 ±0.89	1.972 ±0.096	10.0 ±0.3	14.9 ±0.6	0.142 ±0.010	0.072 ±0.004	0.49 ±0.02	645 ±23
	B	27.7 ±0.5	528 ±21	17.55 ±0.30	1.633 ±0.130	9.9 ±0.5		0.123 ±0.011	0.075 ±0.002	0.18 ±0.02	530 ±20
	C	25.7 ±0.3	366 ±15	13.08 ±0.29	1.235 ±0.038	9.6 ±0.3		0.096 ±0.007	0.078 ±0.004	0.09 ±0.00	265 ± 7
5	A	30.6 ±0.5	666 ±15	22.95 ±0.58	2.131 ±0.026	10.0 ±0.1	15.1 ±0.9	0.135 ±0.007	0.066 ±0.003	0.47 ±0.02	590 ±13
	B	28.0 ±0.5	559 ±20	18.76 ±0.72	1.725 ±0.139	10.0 ±0.5		0.108 ±0.011	0.063 ±0.003	0.14 ±0.01	495 ±27
	C	25.7 ±0.4	357 ±13	12.79 ±0.36	1.197 ±0.058	9.7 ±0.4		0.092 ±0.007	0.077 ±0.002	0.10 ±0.01	410 ± 9
initial weight				0.77				0.008			

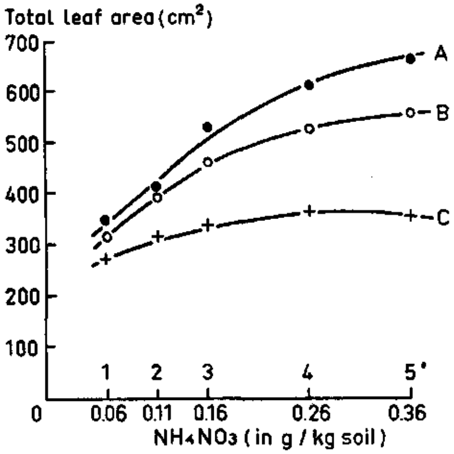


FIG. 1a.
The effect of nitrogen on leaf area at various levels of water supply (A: 100 – 80%, B: 100 – 50%, C: 100 – 10% of the available moisture range).

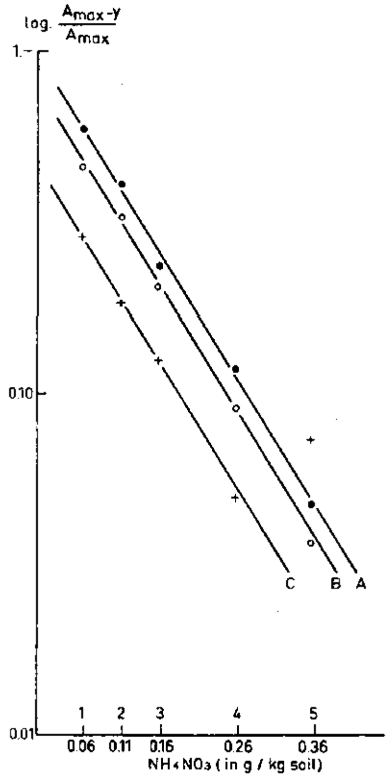


FIG. 1b.
As fig. 1a, the ordinate represented as $\log\frac{A_{max} - y}{A_{max}}$.

deviation from the resulting line. This deviation, as explained before, is referred to an osmotic effect and thus to a decrease in availability of water. The values, found for A_{max}, m, and q for the various irrigation treatments are:

Irrigation treatment	A_{max}	m	mq
A	695	3.81	+0.04
B	580	3.81	–0.09
C	385	3.81	–0.31

Some chlorophyll determinations of plants at the various nitrogen treatments at irrigation level A were made, by extracting leaf discs with 90% ethanol. The extraction was repeated several times in a waterbath between 50 and 60°C in order to assure complete extraction. The chlorophyll concentration was measured with a BLEEKER colorimeter at wavelength 6650 Å, and expressed as mg per cm² leaf area (Table I). It is obvious that the chlorophyll content versus nitrogen supply increases rapidly at first, whereas this increase is smaller at high concentrations of nitrogen. The trend is comparable with that of leaf area (fig. 1a, treatment A).

The fresh weight of the shoot is largely affected by nitrogen and water regime, and varies between 9.18 and 22.95 g per plant. The effect of one factor

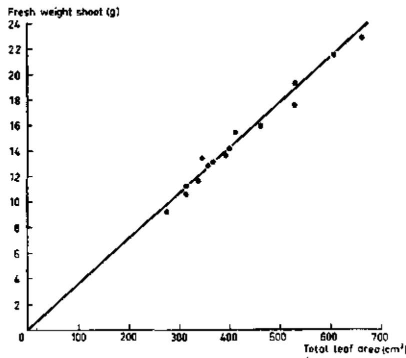


FIG. 2. The relation between total leaf area (in cm^2) and fresh weight (in g).

is more pronounced when the other reaches the optimum condition. For instance, the yield increases from 9.18 to 12.79 g in the range of nitrogen supply at the moisture level C, whereas the increase is more pronounced at higher levels of water supply *e.g.* from 13.41 to 22.95 g. at the moisture level A (table I). The same holds true when the conditions are reversed. Our results confirm those by other authors (3, 4, 6) that full benifit only can be obtained if both factors are adequate. The fresh weight yield of the shoot shows practically the same trend as the total leaf area, since the leaves contribute for the largest part to this yield and the thickness of the leaves did not show significant variation. In figure 2, the leaf area has been plotted versus the increase in fresh weight. It is evident that no deviation from this line was obvious.

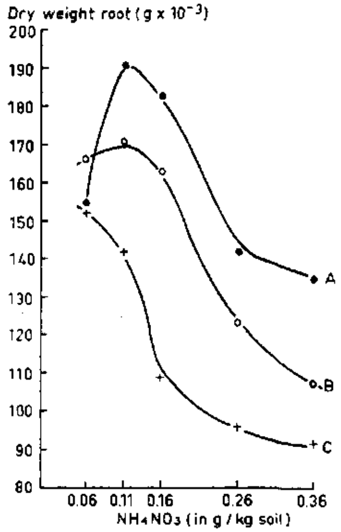
From this a formula was derived $y = 0.035\ x$, in which y represents fresh weight in g per plant and x the leaf area in cm^2.

B. Dry weight of shoot and root

The dry weight of the shoot increases with an increase in nitrogen, *e.g.* from 1.11 to 1.20 g at the lowest applied water regime (C) while the increase is more pronounced at a higher water regime: it ranges from 1.42 to 2.13 g at the moisture level A (table I). Though roughly the same trend occurs in dry weight as compared with fresh weight and leaf area, no definite relation exists between them, because the water content is not equal in all treatments. Though differences in the water content are not very significant, an increase in the water content with an increase in nitrogen application is suggested. No effect of the water regime on the water content was observed, contrary to the results obtained in a previous experiment. This result may be attributed to the fact that the water content is highly variable and depends among other things on the prevailing moisture and climatic conditions at harvest.

The effect of water regime and nitrogen on the dry weight yield of the root is presented in fig. 3a. Generally, a higher yield occurs with an increase in water supply, whereas nitrogen application decreases the yield of the roots. Treatments A and B seem to show an optimum at 0.11 mg NH_4NO_3. The difference with the yield at 0.06 g NH_4NO_3, however, is not significant (table I).

The ratio of root to shoot behaves in a way similar to the dry weight as regards its relation to nitrogen content of soil. It decreases with increase in nitrogen content of the soil (fig. 3b). Contrary to the dry weight of the root, the ratio of root to shoot generally increases with decrease in water supply, but the differences are not very large.



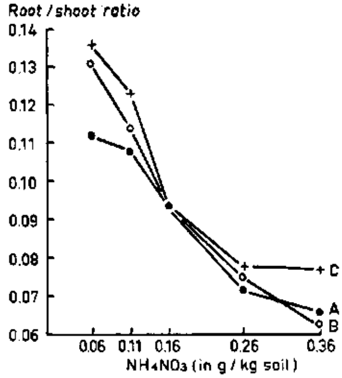


FIG. 3b. The effect of nitrogen content of soil on the ratio of root to shoot at varous levels of water regime (A, B and C).

FIG. 3a. The effect of nitrogen on dry weight of root, at various levels of water supply (A: 100 – 80%, B: 100 – 50%, C: 100 – 10% of the available moisture range).

C. Transpiration

The transpiration increased both with an increase in nitrogen application and in water supply. This increase was due at least partly to the increase in the evaporating leaf surface. In order to investigate whether the transpiration rate per unit leaf area also changes under the various conditions, the transpiration measured in the last week of the experimental period was considered in relation to the total leaf surface. It is evident from table I that transpiration expressed in g 100 $cm^{-2}.h^{-1}$ was not significantly affected by nitrogen whereas a large decrease occurred with decreased water supply (from A to B and C respectively). The results of treatment B varied, owing to the fact that it was more difficult to measure the transpiration under comparable soil moisture conditions than it was for the treatments A and C. In some treatments, *e.g.*, the transpiration measurement took place sooner after irrigation than in others.

In order to obtain more details on the effect of water regime on transpiration per unit area, the transpiration of each pot during the last week per unit leaf area was plotted versus the moisture content present during the measurement (fig. 4).

The items of treatment A roughly ranged between 20 and 18% soil moisture content, those of treatment B between 18 and 13% and those of treatment C between 13 and 10% soil moisture. It is again evident that nitrogen did not change the transpiration per unit leaf area. The effect of soil moisture is large and the results are comparable with transpiration measurements performed in short time experiments under controlled conditions (2,5). The relatively low transpiration maximum obtained in our experiments (0.5 g. h^{-1}.100 cm^{-2}) is due to mutual shading of leaves, whereas in the other investigation (5) separate leaves were used.

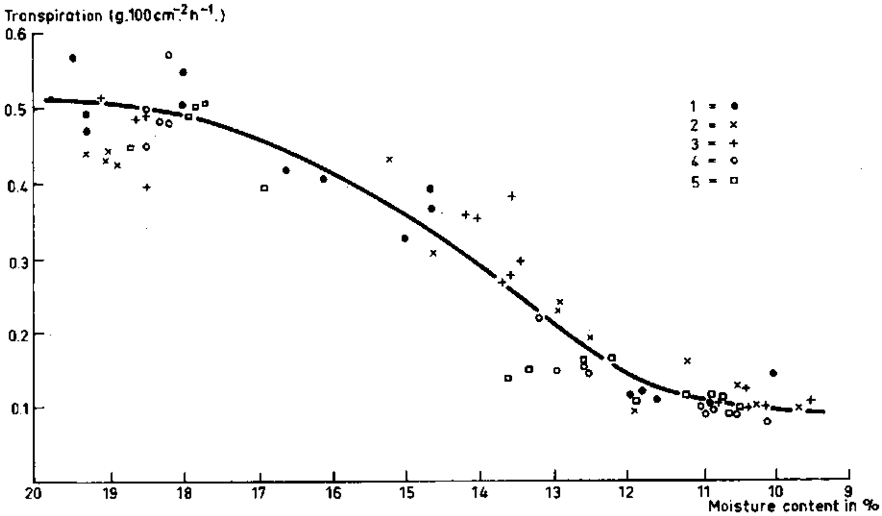


FIG. 4. The effect of soil moisture on the transpiration rate per 100 cm^{-2}. hr^{-1} at various levels of nitrogen.
•: control or 0.06 g NH_4NO_3 initially, ×: 0.05 g added/kg soil,
+: 0.1 g added/kg soil, o: 0.2 g added/kg soil, □: 0.3 g added/kg soil.

D. Water requirement

The water requirement expressed as g water transpired per g dry matter produced varied between approximately 700 and 300 under the different conditions (table I). Examination of the effect of nitrogen supply reveals no regular decrease nor increase at any level of water regime. This result might be explained by the fact that the total amount of water transpired depends on the leaf area and on the transpiration per unit leaf area. Since the latter did not show a change at various nitrogen applications, and the former was affected by nitrogen in a similar way as dry weight, no change in the water requirement could be expected. The effect of the water regime on the transpiration rate per unit area, however, was large, resulting in a large decrease in the water requirement. This decrease was roughly the same at the different nitrogen levels because of the same trend between leaf and dry weight.

4. CONCLUSIONS AND SUMMARY

The effect of nitrogen and water regime on growth and water requirement of tomato was studied. Experiments were run for 28 days in a growth chamber at 25°C and 57% relative humidity and a light intensity of 7.1×10^4 erg sec^{-1} cm^{-2} ⌀ sphere. Five different nitrogen levels were applied, *viz.*, 0, 0.05, 0.1, 0.2 and 0.3 g NH_4NO_3 per kg of soil and 3 levels of moisture A, B and C were maintained while 5 replicates were present.

The number of leaves and internodes and the diameter of the stem were not significantly affected by any treatment. On the other hand the total leaf surface increased largely with increase in nitrogen and water supply owing to increase in length and width of all individual leaves. The effect of one factor was more pronounced under optimal conditions of the other. A formula for the effect of nitrogen and water regime was derived, treating the results according to the MITSCHERLICH equation.

Since leaf area contributes largely to the fresh and dry weight of the plant, approximately the same trend was observed in yield. The relation between fresh weight (y) in g per plant and leaf area (x) in cm^2 could be expressed as $y = 0.035\ x$. The relation with dry weight was not so evident owing to the fact that the greater part of the dry weight occurs in the stem of the tomato plant.

The water content increased with an increase in nitrogen, whereas no significant effect of water regime was observed, contrary to results obtained previously (1). The chlorophyll content (treatment A) increased with increase in nitrogen, approximately in the same way as leaf area and fresh weight. The dry weight of the root was higher with a higher water supply (A> B>C) and was lower at higher nitrogen levels. The decrease in root weight combined with the increase in dry weight of the shoot leads to a considerable decrease in the ratio of root to shoot with higher levels of nitrogen. The effect of the water regime on the root/shoot ratio was small.

Total transpiration is mainly determined by leaf area and transpiration rate per unit leaf area. It was found that the latter was unaffected by nitrogen, but largely dependent on the moisture content of the soil (fig. 5). Since dry weight and leaf area approximately changed in the same way under the various conditions, a variation in the water requirement only occurs if the transpiration rate per unit area changes. Water requirement and transpiration rate per unit area decreased in a similar way with a decrease in the irrigation regime, whereas no significant effect of nitrogen was observed.

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A

B

C

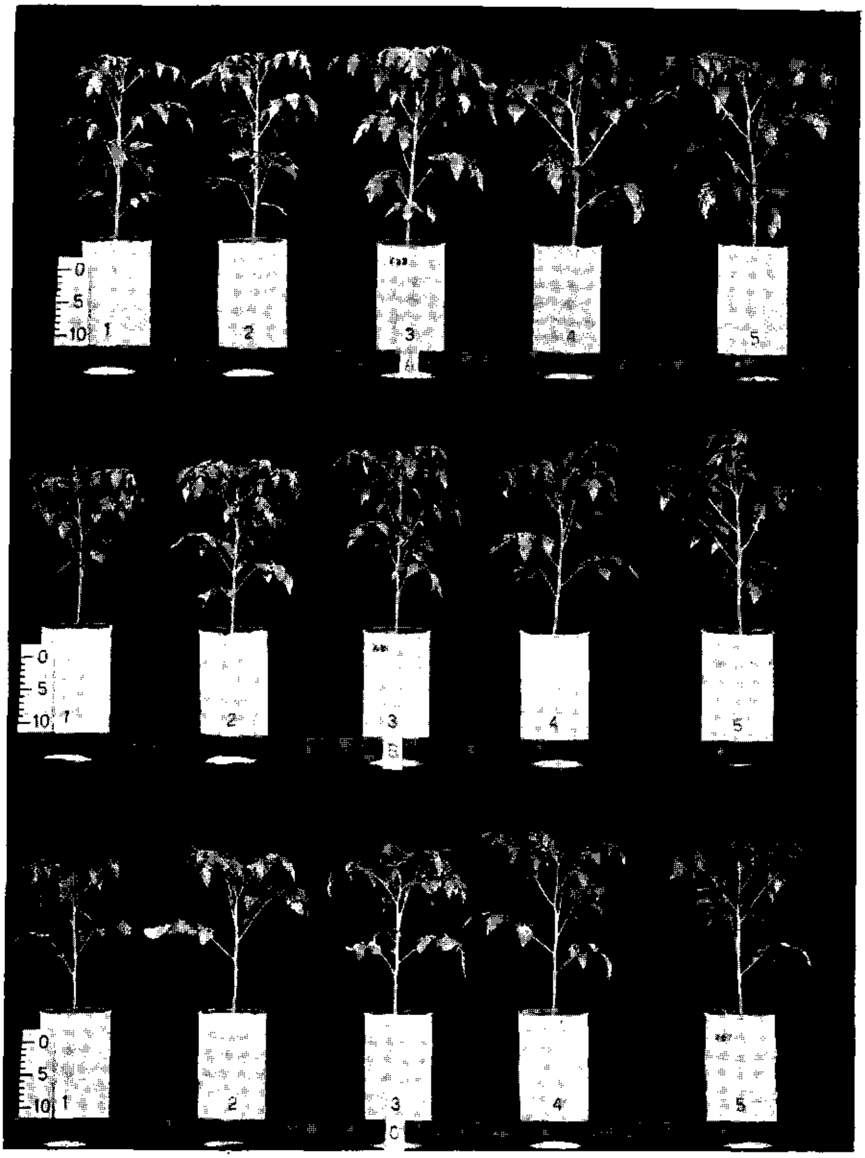

PLATE 1. Growth of tomato plants at various water supply A, B, and C and different applications of nitrogen (numbers 1, 2, 3, 4 and 5 representing 0, 0.05, 0.1, 0.2 and 0.3 g NH_4NO_3 added to the pot respectively). The vigour of the plants is shown by the diameter of shoot and lateral spread and not by the height.