MODALITY OF FERTIGATION OF PROTECTED CUCUMBER AND NITROGEN USE EFFICIENCY UNDER FIELD CONDITIONS

T. ATALLAH
Faculty of Agricultural Sciences, Lebanese University, Beirut

T. DARWISH
Lebanese National Council for Scientific Research, Beirut

M. EL MOUJABBER
Faculty of Agriculture, USEK, Kaslik

Lebanon

XA0201524

Abstract

Cucumber and tomato are the most important protected vegetables in coastal Lebanon. Recent research established that in these intensive systems, irrigation and fertilization are still empirically applied. Techniques such as fertigation are used but associated to traditional practices of soil application of fertilizers and animal manure addition. In 1997, a pot experiment was conducted in order to find the optimal irrigation frequency and modality of fertigation. For this, four frequencies of irrigation were combined with two modalities: discontinuous irrigation as practiced by the growers and continuous irrigation, as recommended by the scientists. In these closed-system conditions, the frequency of irrigation influenced the dry matter production. In addition, the percentages of nitrogen derived from fertilizers were very high, from 89 to 95%. The discontinuous modality allowed for greater nitrate leaching. The evaluation of the main findings for plants grown in the soil, was conducted in 1998, in a greenhouse, 35 km north of Beirut. The treatments were reduced to two frequencies of irrigation combined with the two modalities of fertigation. The objectives were to assess, with the use of ^{15}N labelled fertilizers, the most efficient treatment as far as plant performance and losses from the plant-soil system are concerned.

1. INTRODUCTION

In Lebanon, protected cultures are, once more, in expansion with indications of new greenhouses installed every year, particularly at altitudes between 400 and 500 m. In these intensive systems, few studies looked at the crop requirements, the management practices and their consequences on the soil and water. A survey conducted on these aspects showed that an overfertilization balanced by an overirrigation was frequent. Input of water and fertilizers was mostly empirically based [1], in the absence of local results and recommendations. Not only the soil status was not taken into consideration, but the nutrients were added according to a discontinuous modality: with every other irrigation.

Based on these findings, it was important to establish the water and nutrients requirements of the predominant crops. This was undertaken for cucumber, as it occupies with tomato, the largest area. For this, the effect of different irrigation frequencies combined with two modalities of fertigation, continuous and discontinuous, on the water and nitrogen balances was studied. In 1997, an experiment including four irrigation frequencies: every one, two, three and four days combined with the two modalities, was conducted in pots [2]. This research indicated that the frequency of irrigation strongly influenced the dry matter production, particularly in the case of plants disposing of relatively small volumes. On the other hand, the modality of fertigation had an impact on the amounts of N lost below the root zone. Discontinuous fertigation increased the leaching of nitrate.

In this paper, a confirmation of some of these results was looked for, under field conditions for a typical spring growing season. Treatments consisted of irrigating every two or three days, continuously or discontinuously, the amount of water and nutrients being otherwise equal. One of the objectives was to study the water balance, which will be discussed in another paper. In this paper, the effect of the frequencies and modalities of fertigation on the plant performance, nitrogen use efficiency and some aspects of N losses in the soil will be presented.

2. EXPERIMENTAL SET-UP

The experiment was conducted under field conditions in Jbeil (35 km north of Beirut) at 100 m of altitude. The unheated greenhouse used for this purpose was oriented north-south and was 8 m large and 39 m long. The soil depth varied between 40 cm (at the east) and 60 cm (at the west near the terrace edge). Because of its stoniness, the soil presented a high permeability. In addition, it had a clay texture, a pH of 7.78, 8.8% of total calcium carbonate, and 2.9% of organic matter.

The treatments consisted of two irrigation frequencies: every two and three days, combined with two modalities of fertigation: continuous and discontinuous, with every other irrigation. This gave all together 4 treatments replicated five times in 5 blocks. The dose of irrigation was based on the evaporation from a mini-pan placed at the west side of the greenhouse [3]. Nutrient levels were based on recommendations for cucumber [4], adjusted in acccordance to previous works in the region [5,6]. This meant in the case of the continuous treatments: 135 mg/L of N (as ammonium sulfate) and 40 mg/L of P (as phosphoric acid) and 200 mg/L of K (as potassium sulfate). The microplots (2 effective plants per plot) received ammonium sulfate enriched with ^{15}N (1.5% a.e.).

To follow eventual nitrate movement in the soil, two sets of tensionics were placed: one set at 25 cm of depth and the other one at 50 cm. Each set was represented in three blocks for the four treatments. Tensionics were emptied every 8 to 10 days and the nitrate concentration analysed on a RQflex2. In addition, soil samples were collected from the wet bulb (15 cm away from the drip) at the beginning and at the end of the experiment and analysed for their salinity and nitrate content.

3. RESULTS

3.1. Plant performance

Over the duration of the experiment (71 days), corresponding to an average spring season in coastal Lebanon, the overall N input for the macroplots was 25.75 g N/m^2 for a population density of 3 plants/m^2.

With regard to the yield, covering a period of 57 days, a significantly higher fruit production per unit area was found for the T2C treatment (Fig. 1). This result indicates the advantage of this modality of input under the experimental conditions, as this could be associated with the fluctuations in salinity. In fact, the irrigation water had an EC of 1.13 dS/m, which is considered as presenting an increasing risk of salinity according to the FAO [7]. Thus, the discontinuous treatments (T2D and T3D) received solutions with a salinity ranging from 1.13 dS/m to 4.56 dS/m, whereas the continuous treatments had a stable salinity of 2. 79 dS/m.

This optimum was not only important for the fresh fruits production but it was also obvious in the number of fruits produced per unit area and particularly in the number of non-commercial fruits (Fig. 2). Therefore, not only more fruits were produced in T2C but also healthier fruits, not submitted to stress as in the other treatments.

Similar results were obtained for the above-ground dry matter production as for the fruits. In order to verify the impact of the salinity on the plant, the plant height was followed across the season. The T2C plants were significantly higher starting from day 78 after sowing, which was 23 days after the beginning of the differential fertigation. This lasted until the day 95. On the other hand, an influence of salinity was found in the microplots of T2C and T2D when the roots were digged, washed and dried. The treatment T2D presented a higher root mass than T2C, all located near the soil surface as there was no difference in rooting depth. Such a strategy is an indication of a stressful environment, and the large root mass is an avoidance of the soil conditions in depth.

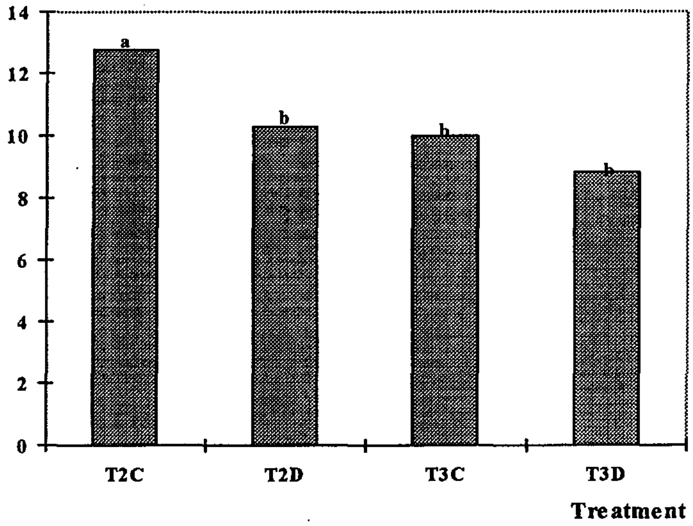

FIG. 1. Fresh fruits production (kg/m2 of cucumber plants from the macroplots, irrigated every 2 T2) or 3 (T3) days continuously © or discontinuously (D).

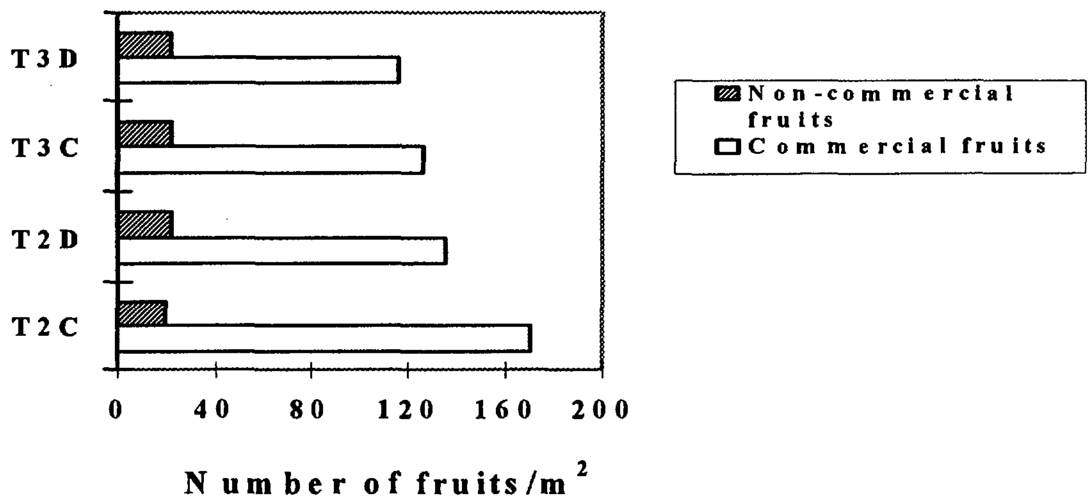

FIG. 2. Number of commercial and non-commercial fruits produced per unit area by cucumber plants irrigated every 2 (T2) or 3 (T3) days continuously © or discontinuously (D).

3.2. Nitrogen in the plants

When considering the macroplots, the nitrogen use efficiency by the fresh fruits per unit of applied N fertilizers was highest for the T2C treatment, with 495 g/g of N. Whereas, it was 398 g for T2D, 388 g for T3C and 341 g of fresh fruit for T3D. Furthermore, the ratio fruits dry matter/shoots dry matter was the highest in the T2C (2.86) and the lowest in the T3C treatment (2).

In the microplots, the use of labelled N fertilizers allowed to study the proportion of nitrogen derived from fertilizers (% Ndff). In fruits and shoots together, the Ndff (%) varied between 54.76% and 69.86%. This proportion was lower in the shoots and fruits of T3C than of the 3 other treatments (Fig. 3). This result could eventually have a link with the lower water consumption in this treatment and a potential capillary rise during the growing season. These values are smaller than in 1997, being between 89% and 94.6% [2], In that case, a closed system (pot experiment) was adopted.

Concerning the fertilizer N utilization (%) by the fruits, the T2 treatments gave higher results than the T3 treatments. This could be due to the significantly higher fertilizer N yield. No statistically significant difference was found in the shoots (Fig. 4). This means that the frequency of irrigation (2 days) was better in ensuring fertilizer N utilization. But, the difference between T2C and T2D remains to be explained. They both used similarly the N from the fertilizers, but T2C performed better in transforming this to fruit production. Fertilizer N utilization, in fruits and shoots added together, was the highest in T2C with 69% and the lowest in T3C with 46.15%. These values are much higher than in 1997, which were lower than 45%, due to the shorter growing season then [2]. The inclusion of roots in the T2 treatments slightly increased the values (70.59% for T2C), indicating the small contribution of roots to the overall N uptake and utilization.

3.2. Nitrogen in the soil

Nitrogen movement was studied with the installation of tensionics in the soil at 2 depths: 25 cm within the root zone and at 50 cm underneath the active root zone. For both, the first sampling was done before any fertilizer addition and the second one after the uniform application of nutrients to all treatments. This means that six of the samplings were conducted after the differential fertigation was started (Fig. 5). The mean concentrations for these six samples at 25 cm were as follows: T2C: 31.5 mg N/L, T2D: 56.3 mg N/L, T3C: 53 mg N/L and T3D: 143 mg N/L. The latter treatment showed the smallest decrease in concentration: 8 mg/L only. T2D and T3C presented similar decreases and final concentrations. T2C with the most important activity and uptake had the lowest mean concentration and a small amount of N loss as nitrate across the season (16 mg/L).

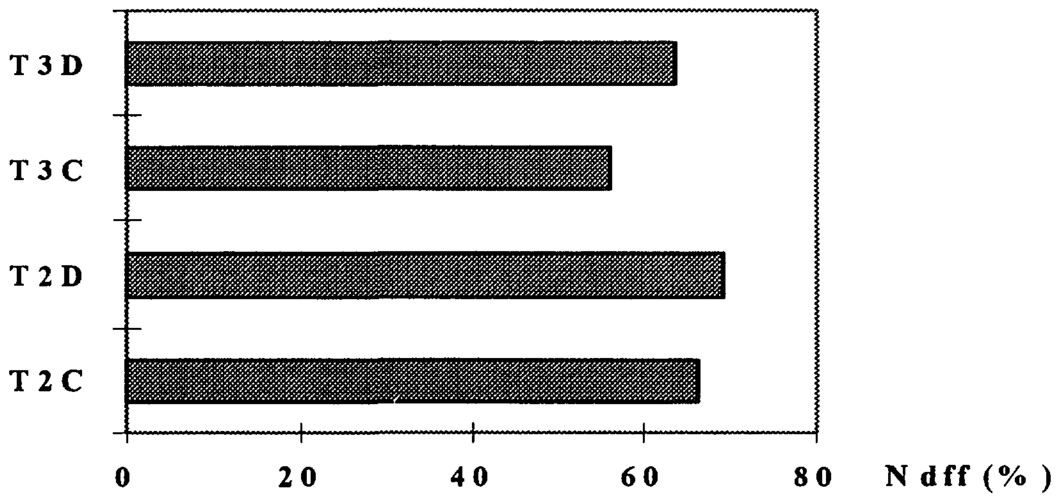

FIG. 3. Average values of nitrogen derived from fertilizers (%) by fruits and shoots of cucumber.

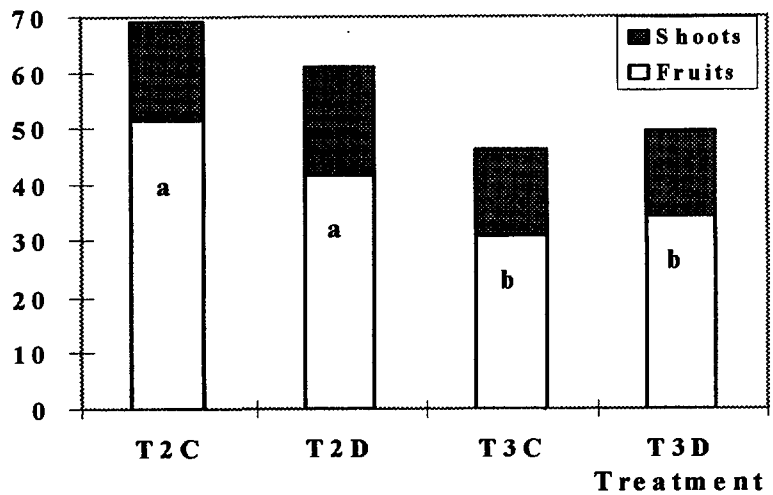

FIG. 4. Fertilizer nitrogen utilization (%) by fruits and shoots of cucumber plants irrigated every 2 (T2) or 3 (T3) days continuously © or discontinuously (D). Fruit values presented statistical differences.

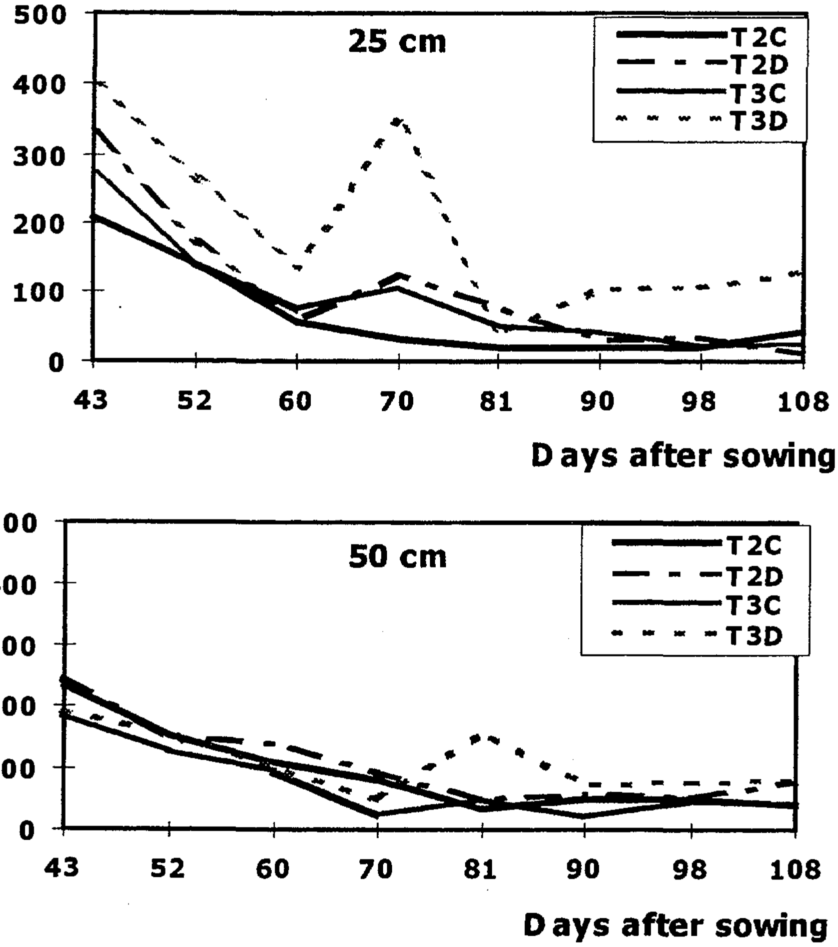

FIG. 5. Variations of nitrate–nitrogen (mg/L) concentrations in soil solutions extracted from tensionics placed at 25 cm and 50 cm in treratments irrigated every 2 (T2) or 3 (T3) days continuously (c) or discontinuously (D).

It was clear that T3D had the lowest activity, but the most favorable nitrifying conditions. This is shown by the small loss of nitrate at 50 cm (-22 mg/L) and the highest nitrate-N concentration (91.5 mg/L). At 50 cm, the concentrations were as follows: T2C: 61.2 mg/L, T2D: 79.5 mg/L and T3C: 47.8 mg/L. Each of these values could be considered as the mean concentration for the growing season. For each frequency, the values for the discontinuous treatments were higher than for the continuous modality.

Comparison between the two depths shows that the T2 treatments had higher concentrations at 50 cm, unlike the T3 treatments. This could be due, on one side, to the higher uptake in the T2 treatments, within the root zone, but also to a possible higher nitrifying activity, on the other side.

Another aspect of N was related to the determination of nitrate-N at three soil depths, at the beginning and at the end of the growing season (Table I). In comparison to the results from soils in the region, these concentrations were relatively low and were half of those found at 0–20 and 20–40 cm depths [6]. Such a moderate content of N was also demonstrated elsewhere. This is related to the proportion of N derived from the fertilizer (Ndff %).

At the end of the experiment, the nitrate content of the treatments T2D, T3C and T3D was significantly increased as compared to the beginning of the experiment (Table I). Within a depth of 0–40 cm, being the main zone of root activity, the soil volume occupied by the 3 plants/m^2, was close to

216 cm^3, or the equivalent of 54% of the total soil volume. Based on this observation, the nitrate-N accumulation was as follows: -0.36 g N/m^2 in T2C, + 1.82 g N/m^2 in T2D, +8.03 g N/m^2 in T3C and + 8.13 g N/m^2 in T3D. Once more, T3C showed a smaller N uptake as expressed by a higher accumulation in the root zone. Consequently, N losses following the growing season would be 4 times higher for the T3D treatment than for the T2D treatment. This higher N fertilizer utilization is in agreement with the dry matter production. On the other hand, the finding with the tensiometers also suggested a more active nitrification with the 3-day irrigation frequency. As for the balance, a very close correspondance was obtained between the difference between input and uptake and the nitrate-N accumulation in the soil (Table II). This allows to decide that the N losses were minimal for all treatments. This could be largely explained by the amount of nitrate accumulated in the soil.

These overall results are remarkable, considering the narrow separation between the treatments. The key to such significant differences within this narrow range could be the electrical conductivity of the fertigation solutions and of the soil. The electrical conductivity of the soil at the end of the experiment showed, as for the nitrate-N, significant differences in the 0–20 cm soil layer (Table III).

TABLE I. NITRATE-N CONCENTRATION (mg/kg dry soil) IN THE SOIL AT THE BEGINNING AND AT THE END OF THE EXPERIMENT, AT 3 DEPTHS. WITHIN EACH LINE, VALUES FOLLOWED BY THE SAME LETTER ARE STATISTICALLY NOT DIFFERENT

Soil depth (cm)	NO_3-N^- (mg/kg)				
	Beginning	End			
		T2C	T2D	T3C	T3D
0 –20	60.7 a	61.5 a	81.5 b	125.5 b	110.5 b
20–40	54.5 a	51 a	51 a	62 b	68 b
40–60	33.5	18	23	19	18

TABLE II. NITROGEN BALANCE IN TREATMENTS IRRIGATED EVERY TWO (T2) OR THREE (T3) DAYS ON A CONTINUOUS (C) OR DISCONTINUOUS (D) BASIS

Treatment	Nitrogen (g/m^2)			
	Input	Removal by plants	Input-Removal	NO_3^--N build-up (0–40 cm)
T2C	25.75	24.17	1.58	-0.36
T2D	25.75	20.39	5.36	+1.82
T3C	25.75	19.01	6.74	+8.03
T3D	25.75	17.92	7.83	+8.13

TABLE III. ELECTRICAL CONDUCTIVITY (dS/m) OF THE SOIL AT THE BEGINNING AND AT THE END OF THE EXPERIMENT, AT THREE DEPTHS. WITHIN THE LINE 0–20 cm, VALUES FOLLOWED BY THE SAME LETTER ARE STATISTICALLY NOT DIFFERENT

Soil depth (cm)	EC (dS/m)				
	Beginning	End			
		T2C	T2D	T3C	T3D
0 -20	2.19 a	2.40 a	3.87 b	3.77 b	3.75 b
20–40	1.92	1.80	2.25	2.70	2.50
40–60	2.07	1.07	1.30	1.44	1.62

The proportion of N derived from the fertilizers (%) varied between 54.76% and 69.86%. These values were relatively high under field conditions, confirming the moderate input of nutrients and suggesting a medium N status in the soil. With regard to the fertilizer N utilization, the treatments irrigated every two days gave higher results for the fruits, due to the dry matter production. However, the fate of some 30% of N fertilizers at best, and 46% at worst, remained unknown.

In general, the nitrate-N build-up in the soil was lower for the T2 treatments than for the T3 treatments, because of the higher fertilizer utilization and possibly better oxidizing conditions in the latter.

4. CONCLUSION

For this experiment, the length of the growing season was closer to that of the growers in springtime. The N input was based on previous results and could be considered as moderate but sufficient. Despite the narrow range that separated the irrigation frequencies (every 2 or 3 days) significant results were obtained as far as the plant performance is concerned. This included fresh fruit production, the number of fruits, the number of non-commercial fruits and shoots dry matter production. The best treatment was the continuous irrigation every two days (T2C). This could possibly be linked to the irrigation water having a relatively high electrical conductivity, with an increasing risk of salinity. Such background lead to an important fluctuation in salinity for all treatments, except the T2C receiving the most stable and frequent input.

REFERENCES

[1] WARD, R. (1995) Cultural practices and soil fertility in greenhouses. (in French). Graduation project. Faculty of Agricultural Sciences, Lebanese University, (1995).

[2] ATALLAH, T., DARWISH, T., EL MOUJABBER, M. Modality of fertigation of protected cucumber and nitrogen use efficiency. Report in Coordination meeting of RAW/5/002 "Water balance and fertigation for crop improvement". 3–6 novembre 1997, Beirut, Lebanon (1997).

[3] AKL, G. (1996) Water requirements of fertigated cucumber under different modalities of fertigation (in French). Graduation project. Faculty of Agricultural Sciences, Lebanese University, (1996).

[4] PAPADOPOULOS, I. Micro-irrigation systems and fertigation. Advanced short course on fertigation, Beirut 26 Novembre-2 decembre 1995, Lebanon. 52–82 (1995).

[5] ABIJAOUDE, R. Fertigation of protected spring cucumber: nitrogen requirements (in French). Graduation project. Faculty of Agricultural Sciences, Lebanese University (1996).

[6] CHLELA, C. Nitrogen inputs to protected spring cucumber and removal of nitrogen, phosphorus and potassium. (in French). Graduation project. Faculty of Agricultural Sciences, Lebanese University (1997).

[7] AYERS, R.S., WESTCOT, D.W. Water quality for agriculture. Irrigation and drainage paper. n° 29. FAO. Rome, Italy. 174 pages (1985).