MODALITY OF FERTIGATION OF PROTECTED CUCUMBER AND NITROGEN USE EFFICIENCY IN CLOSED SYSTEMS

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ABSTRACT

Cucumber and tomato are considered to be the most important protected vegetables in coastal Lebanon. Recent works established that in these intensive systems, irrigation and fertilization are still empirically based. Whereas techniques such as fertigation are used associated to traditional practices of soil application of fertilizers and animal manures. Due to the absence of recommendations based on local conditions, overirrigation and overfertilization are common. Furthermore, nutrients were added according to a discontinuous modality, that is with every other irrigation.

In this study, the effect of four frequencies of irrigation on protected cucumber were investigated in combination with two modalities of fertigation. The first is a discontinuous way as being practiced by the growers and the second is a continuous way as being recommended by scientists. Nitrogen fertilizers enriched with the heavy isotope ^{15}N allowed to study their use efficiency. The results indicated that the frequency of irrigation influenced dry matter production. In the closed systems adopted in this pot experiment, the percentages of nitrogen derived from fertilizers (%Ndff) were very high ranging from 89% to 94.6%. The nitrogen fertilizers utilizations were found to be slightly different according to the modality of fertigation. The recovery of leached nitrogen and that utilized by the above-ground parts of the plant, would add up to 50% of the N fertilizers.

Keywords: Cucumber, tomato, fertigation, nitrogen, Lebanon

INTRODUCTION

The Mediterranean basin is one of two regions well known, worldwide, for protected cultures. In Lebanon a prosperous phase was observed with 713 ha devoted to greenhouse production in 1987 (Salamé, 1989), after a first introduction in the mid-sixties. A regression linked to the local and regional situation had followed. The relief of the country had an influence on the geographical distribution of the greenhouses. Production was located below 100 m of altitude in the north and as the orange groves occupied the coastal plains in the south, it was moved to the calcareous plateau. Currently, the installation of new greenhouses on imported soils between 200m and 400m of altitude is an indicator of the expansion of this sector. Globally, there is some concern about the sustainability of these production systems associated with the high input levels and the risks of polluting the underground water with nitrates and pesticides.

In Lebanon, few studies looked at the protected crops requirements, the management practices and their consequences on the soil and water. However, an increase in soil salinity due to excessive fertilization was indicated in one study (Solh *et al*., 1987). A more recent work dealt with cultural practices and their influence on soil fertility with an emphasis on the sources of salinity, between the cities of Beirut and Tripoli. First, it confirmed that cucumber and tomato are still the main vegetables produced and grown as fall or spring crop sown in February till early July. It established too that in these intensive systems, overfertilization balanced by an overirrigation were frequent. Water and fertilizers inputs were mostly empirically based, in the absence of local results and recommendations. In addition, soil properties and nutrient contents were rarely considered, consequently the nutrient levels in the soil were very high (Ward, 1995). An illustration of the excessive inputs was given in an experiment on a representative soil that showed no response from cucumber to three nitrogen levels : 24, 36 and 52 gN/m^2. The lowest dose, provided at a concentration of 100 mg N/L in the fertigation water, was sufficient. It also gave a neutral nitrate balance in soil, demonstrating the greater liability to losses under the two higher levels of input (Abijaoude, 1996; Chlela, 1997). As for the modality of fertigation, the growers adopted the discontinuous one. They alternated between the fertigation solution and the irrigation water, estimating that in this way the salts brought in were washed to avoid damaging the crop (Ward, 1995). This practice tested on cucumber on a typical clay soil of the northern coast, gave comparable results to the continuous modality (Abijaoude, 1996; Chlela, 1997).

Based on the information so far collected, it was important to establish the crop water requirements and to test a mean of scheduling irrigation available to growers. This approach was undertaken for cucumber (Akl, 1996). Furthermore, the nitrogen requirements were studied under Lebanese conditions as well as the evolution of the soil salinity, phosphorus and potassium exportations (Abijaoude, 1996 ; Chlela, 1997). Since the effect of the modality of fertigation was not evident, it was appropriate to study it combined to four frequencies of irrigation which induced greater fluctuations in the salinity of the fertigation water. In addition to the influence on the plant response, the modality of fertigation could have an important impact on nitrogen losses. For this, an evaluation of nitrogen uptake and its use efficiency was undertaken through the application of labelled nitrogen fertilizers.

MATERIALS AND METHODS

This work was conducted in a walk-in tunnel (36m long and 8m wide), 5 km north-east of Beirut at 100 m of altitude. For the quantification of water and nitrogen losses through leaching, a pot experiment was adopted. Pots with a capacity of 12 kg, were used after filling with 10 kg of a homogeneized sandy-clay soil (57% sand, 33.5% clay and 9.5% silt). Each pot was transformed as to collect leachates. For this, it was fitted with a saucer that could be emptied by a manual pump. Overall, eight treatments were included with irrigation scheduled daily (T1), every two (T2), three (T3) or four (T4) days. For each frequency, the fertigation was either continuous (C) with every irrigation or discontinuous (D) with every other irrigation. The irrigation water was from an artesian well (EC : 0.38 dS/m and pH : 7.68).

The dose of irrigation water was based on the evaporation from a mini-pan (Nimah *et al*., 1990) placed in the middle of the greenhouse and calculated using an established coefficient (Akl, 1996). Nutrient levels corresponded to the recommended values for protected cucumber (Papadopulos, 1993) after adjustment according to previous results (Abijaoude, 1996). The concentrations in the continuous treatments were : 150 mg N/l (from ammonium sulfate), 40 mg P/l (from phosphoric acid) and 225 mg K/l (from potassium sulfate). For the discontinuous treatments, the concentrations were doubled with every other irrigation by the change in the dilution factor of the injector (Dosatron International DI 16). Each treatment was replicated four times, with six pots corresponding to the effective plants per plot. In treatments T2, T3 and T4, two of the six effective plants were the microplots receiving labelled ammonium sulfate enriched with ^{15}N (2% atom excess).

Cucumber plants (cultivar Alfares) were transplanted early May and received the first fertigation 18 days later. Leachates from individual plants were collected 24 hours after every irrigation. A subsample was frozen for mineral nitrogen analysis. Nitrate-nitrogen was evaluated using a multimeter (Orion 290A) with a selective electrode. Ammonium-nitrogen was determined by the Nessler method. By the end of the experiment, the total above-ground production of two effective plants was kept for the determination of biomass production.

From the microplots, all cucumber fruits were oven-dried, as well as the vegetative parts. Analysis for total nitrogen contents and ^{15}N atom excess were done at the International Atomic Energy Agency (AIAE) Vienna. The results allowed to find nitrogen derived from fertilizer (% Ndff) and fertilizer N utilization (Zapata, 1990). These were expressed on the basis of g/m^2 for a population density of 3 $plants/m^2$.

RESULTS

Plant response

Under the experimental conditions, there was a significant response to the different treatments, in particular to the irrigation frequency. In fact, the commercial yield, as fresh fruit production per plant, showed a clear effect with the possibility of separating the treatments to four groups. The first and best was T1C treatment, then T1D and T2C, followed by T2D with T3C and T3D. The last and worst group was T4C and T4D. By choosing one representative treatment from three of these groups (Figure 1), it becomes evident that some of them were submitted to a stress irrespective of the modality of fertigation but dependant somehow on the frequency of irrigation. Thus, T4D presented fewer peaks of fruit production. Also, when all treatments peaked as for day 53, the height was much less.

This result could be directly linked to the soil volume available to the plant and its capacity to retain water. Soil volume was reduced as compared to field conditions. According to previous observations on the same cultivar the root occupied a larger volume (by 3 times) not in depth (25 to 30 cms), but laterally expanding up to 35 cms. Consequently, the daily irrigation under field conditions seems excessive and could even lead to smaller root volumes, weakening the plant and restricting the accessible soil nutrients.

Such trend of response could also be found in the total dry matter production : vegetative parts and fruits. With the exclusion of T1 treatments, the relationship between the remaining treatments, as based on the statistical analysis, allowed for three groups. The first one formed by T2C, T2D and T3D, the second included T2D, T3D and T3C and the third the T4 treatments.

Unexpectedly, T3D performed better than T3C which was not the case for the other frequencies. On the other hand, T2D produced as much as T2C in total dry matter but not in fruits. However, a longer experimental period is necessary before allowing for final conclusions as to the impact of the salinity fluctuation on the plant performance.

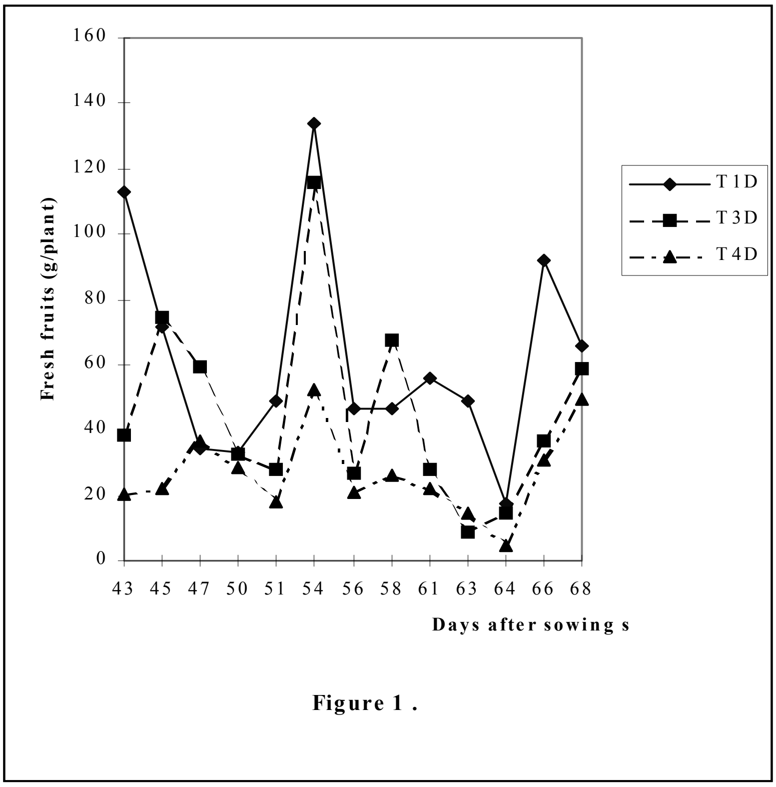

Figure 1. Yield of cucumber plants in treatments irrigated daily (T1), every three (T3) or four (T4) days.

Nitrogen losses

For the effective plants excluding the microplots, the mean volume of leachates over the experimental period was slightly different between treatments as it varied between 7.24 l/plant for T2C and 11.16 l/plant for T3D (Table 1). This was linked to the short season and to the fact that following the disturbance of the soil upon pot filling, only 3 irrigation cycles were accomplished. As a consequence, the leachates volumes were fluctuating at the beginning and started to stabilize towards the end of the second cycle (Figure 2).

In parallel, the amount of nitrogen added by fertigation was close between treatments but not quite equal. Despite this, the mineral nitrogen lost in the leachates presented large relative differences between the continuous and dis- continuous treatments (Table 1). These represented between 6.89 % for T3C and 17% for T4D of added nitrogen (Figure 3).

TABLE 1

Leachates volumes, amount of nitrogen added and leached in cucumber plants irrigated every two, three or four days continuously or discontinuously.

Treatment	Leachates volume (l/plant)	Relative difference (%)	N added (g/plant)	Relative difference (%)	Leached N (g/plant)	Relative Difference (%)
T2C	7.24	+19.6	5.44	+10.5	0.4	+63.7
T2D	8.66		6.01		0.74	
T3C	9.25	+20.6	5.46	+5.5	0.38	+118.7
T3D	11.16		5.76		0.86	
T4C	9.81	-11	5.46	-9.9	0.44	+108.4
T4D	8.73		4.92		0.82	

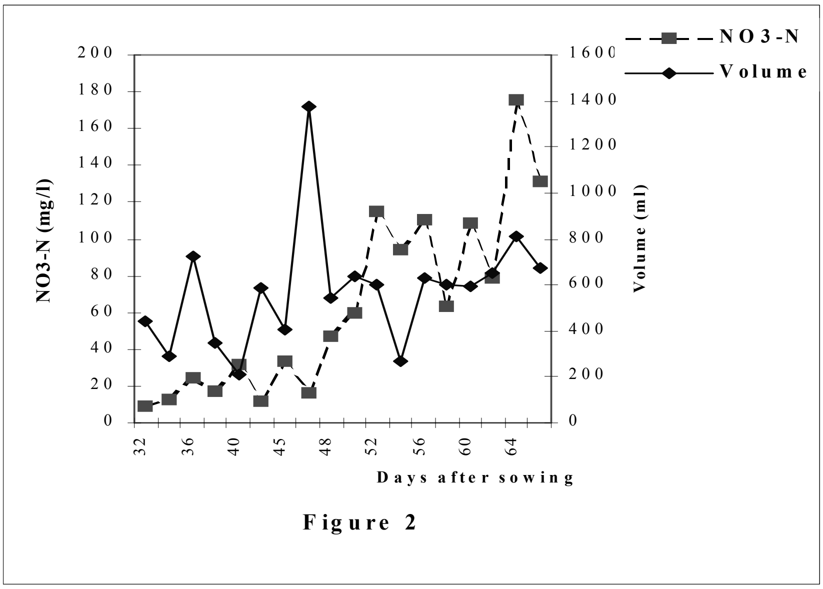

Figure 2. Volume (ml/plant) and nitrate-nitrogen concentrations (mg/l) of leachates from plants irrigated discontinuously every two days.

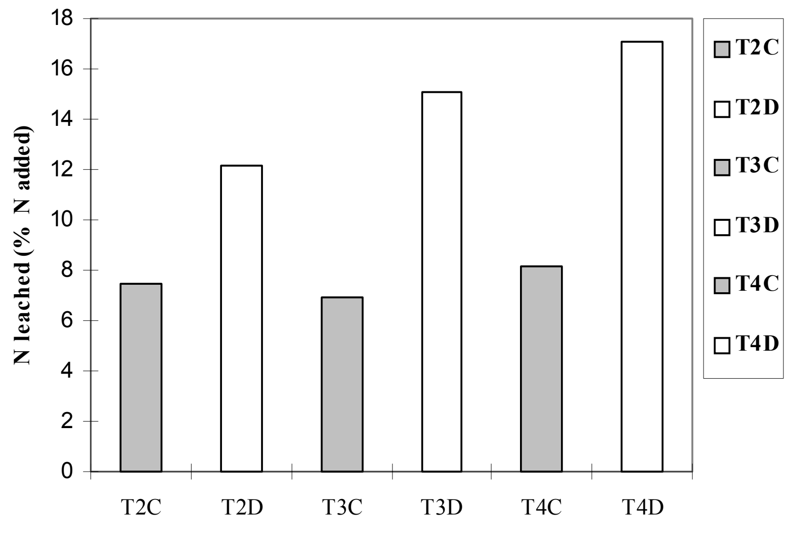

Figure 3. Nitrogen leached, as a percentage of nitrogen added per plant, from cucumber plants irrigated at three frequencies continuously © or discontinuously (D).

Nitrogen species found in the leachates were nitrate-nitrogen mainly, with the contribution of ammonium-nitrogen being less than 6.6%. Such differences were independant from the leachates volumes as shown for T2D (Figure 2) and over and above the variations in nitrogen inputs (Table 1). In fact, doubling the dose of added nitrogen, even if it is as ammonium-nitrogen in a soil having 33.5% of clay, did not allow for the same soil retention. Each addition of fertilizer helped probably to enrich the soil solution and the soil exchange sites, while the following irrigation actively washed the nitrified ammonium. For this discontinuous treatments presented higher nitrate concentrations in the leachates as illustrated for the T4 treatments (Figure 4).

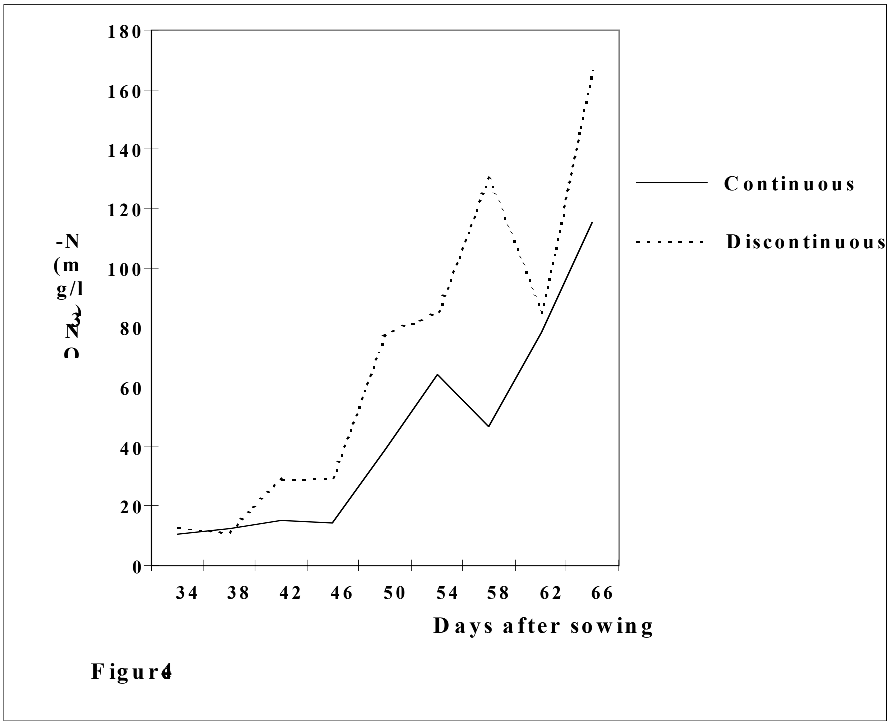

Figure 4. Nitrate-nitrogen concentrations in leachates irrigated every four days.

Fertilizer Nitrogen Utilization

The fruits of the microplots of the six treatments gave comparable total nitrogen contents, which vary between 4.89% and 5.17%. This similarity in concentrations was also the case for the vegetative parts. As for the percentages of nitrogen derived from fertilizers, the lowest value was 89 % in T4D, for the whole harvested plants (fruits and vegetative parts included) and the highest was 94.6% in T2C (Figure 5). These were an indication of the level of nutrients in the soil and of its ability to retain the added ammonium-nitrogen, despite the presence of 65% of sand. Such similar efficiency for all treatments suggests that any difference is dependant on limiting factors other than nutrients availability and the roots ability to absorb them.

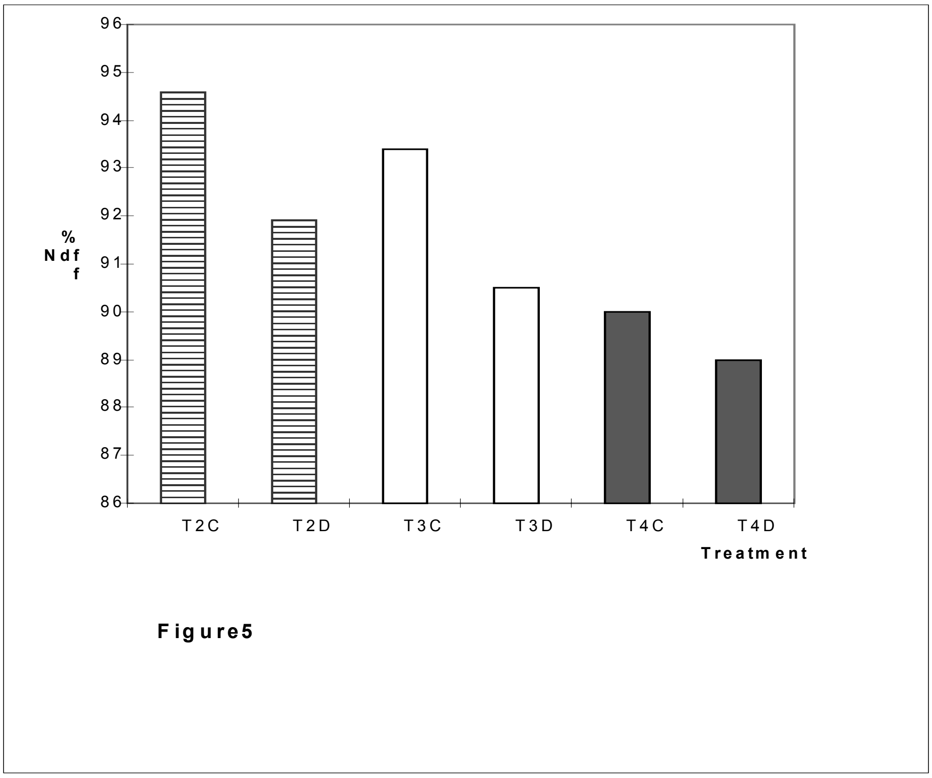

Figure 5. Nitrogen derived from fertilizers (%Ndff) in cucumber plants irrigated every two (T2), three (T3) or four days (T4) continuously © or discontinuously (D).

Concerning the nitrogen fertilizers utilization, these were found to be slightly different according to the modality of fertigation for the same irrigation frequency. Also, it was evident, due to differences in dry matter production, the more frequent the irrigation, the higher the utilization (Figure 6). For the T2 and T3 treatments, the continuous fertigation gave improved results as compared to the discontinuous modality. In fact, despites the great homogeneity in the potting procedure, the variability within the microplot position in the greenhouse could still be an important factor. Larger number of replicates might help in avoiding this aspect. These recoveries added to the nitrogen found in the leachates, would still leave some 50% of the N fertilizers to account for in the soil and roots and possibly through losses to the atmosphere.

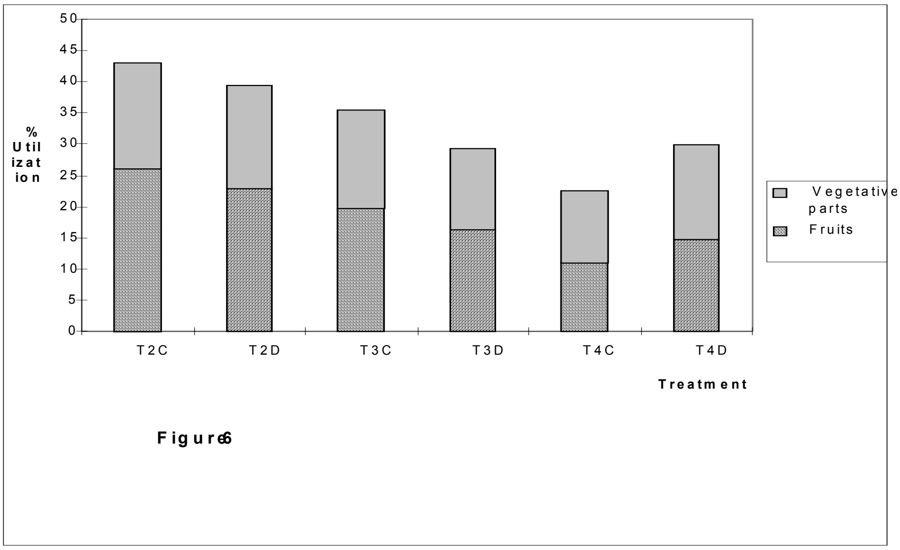

Figure 6. Nitrogen fertilizer utilization in fruits and vegetative parts of cucumber plants irrigated every two (T2), three (T3) or four (T4) days continuously © or discontinuously (D).

DISCUSSION

The ratio adopted for the major nutrients, throughout the experiment (N-P-K: 1-0.31-1.44) was close to that found in the literature : 1-0.29-1.25 (Papadopoulos, 1986). The ratio was stable which is justified for cucumber by the indeterminate growth pattern of the crop and the consequent mixing of the vegetative and fruiting stages. As for the fruits dry matter contents, these were also similar to those established in Cyprus (Papadopoulos, 1986). But, the nitrogen contents of the fruits (5.14%) were higher than those found in the previous study (3.8%), due possibly to the growing season or to the variety and fruits development and size.

For nitrates losses, the increase in the concentrations by the second cycle could be linked to the possible retention of the ammonium forms on the exchange sites (Papadopoulos, 1993) and to the time necessary to the nitrifying bacterial populations to build-up siginificantly. The values found in the leachates are within the range of the fraction (25 % of added N) estimated to be lost from N fertilizers (Hamdy, 1995).

Nitrogen found in both the leachates and the plant material represented 55% of added N in T2D and 37% in T4C. These values are slightly underestimated, as some nitrogen is exported by the roots. In fact, this nitrogen represented 3.8% of that in the above-ground parts in a treatment equivalent to T2D, but under field conditions (Awad, 1998). In this shorter growing season, due to a high root/shoot ratio, the level could be slightly larger, between 5 and 10%. The nitrogen remaining (*ca* 40%), considered to be immobilised by the biomass, held in the soil or lost by volatilization., is in agreement with other studies (Muller, 1991 ; Garabet *et al.,* 1995).

CONCLUSION

This work indicated that the frequency of irrigation strongly influenced dry matter production of younger plants disposing of relatively small volumes and highly affected yields. In addition, the modality of fertigation had an impact on the plant performance and particularly on the amounts of nitrogen lost below the root levels. Discontinuous fertigation increased nitrates leaching which confirms the objective of splitting nitrogen application whether in the soil or by fertigation to meet more closely the plant demands. Further investigation is needed over a whole growing season with greater crop nutrient demands and larger soil occupation. In addition, the fate of nitrogen fertilizers and its turnover might be different according to the soil properties, especially the clay contents. The soils cultivated to protected cucumber presenting usually higher clay contents. The nitrogen forms could also influence these responses to the modality of fertigation.

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REFERENCES

Abijaoudé, R. 1996. *Fertigation of protected spring cucumber : nitrogen requirements* (in French). Graduation Project. Faculty of Agricultural Sciences, Lebanese University.

Akl, G. 1996. *Water requirements of fertigated cucumber under different modalities of fertigation* (in French). Graduation Project. Faculty of Agricultural Sciences, Lebanese University.

Awad, S. 1998. *Fréquence et modalité de fertigation du concombre protégé et efficience de l'utilisation de l'azote dans les conditions du terrain.* Mémoire de DEA en agriculture durable en milieu méditerranéen. Aupelf-Uref, UL, USJ, USEK, 47 p.

Chléla, C. (1997). *Nitrogen inputs to protected spring cucumber and removal of nitrogen, phosphorus and potassium* (in French). Graduation project. Faculty of Agricultural Sciences, Lebanese University, 64 p.

Garabet, S., Wood, M. and Ryan, J. 1995. Field estimates of nitrogen use efficiency by irrigated and rainfed wheat in a Mediteraanean-type climate. *Accomplishments and future challenges in dryland soil fertility research in the Mediterranean area.* Proceedings of soil fertility workshop. November 19-23. ICARDA, Aleppo, Syria.

Hamdy, A. 1995. Fertilizers and their efficient use. Advanced short course on fertigation. Nov. 26-Dec 3, 1996. FAS-UL, Beirut, Lebanon : 83-138.

Muller, J.C. 1991. Quelle fertilisation demain ? Premier forum Européen de fertilisation raisonnée. Comifer. 26-27 Septembre, Strasbourg, France.

Nimah, M. N., Rubeiz, I. and Miribi, B. 1990. A simple method for scheduling and measurinevapotranspiration for vegetable crops. *Actae Hort*., 278: 721-726.

Papadopoulos, I. 1986. Nitrogen fertigation of greenhouse-grown cucumber. Plant & Soil, 93: 87-93.

Papadopoulos, I. 1993. Agricultural and environmental aspects of fertigation-chemigation in protected agriculture under mediterranean and arid climates. *Workshop on environmentally sound water management of protected agriculture under mediterranean and arid climates.* CIHEAM. Bari, Italy 16-18 July, 10 : 1-33.

Salame, G. 1989. " Recensement et rentabilité des cultures protégées au Liban ". Rapport technique-1, Liban. AG/DP/LEB/86/005. FAO, Rome. Italy.

Solh, M., Baasiri, M., Ryan, J. and Rubeiz, I. 1987. Salinity observations in greenhouses along Lebanon's coast. *Lebanese Science Bulletin*, 3(1) : 5-9.

Ward, R. 1995. *Cultural practices and soil fertility under greenhouses* (in French). Graduation Project. Faculty of Agricultural Sciences, Lebanese University.

Zapata, F. 1990. Isotope techniques in soil fertility and plant nutrition studies. In: *Use of nuclear techniques in studies of soil-plant relationships*. (Ed : Hardarson G.). Training course series no. 2. IAEA, Vienna. pp 61 - 128.