MANAGEMENT OF NITROGEN FERTIGATION OF TOMATO WITH THE USE OF ^{15}N TECHNOLOGY

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Abstract

Field studies were conducted during two seasons at the Deir Alla Research Center to compare the conventional fertilization method with fertigation on water and nitrogen use efficiency with a tomato crop (cv. Gardenia). Four N application rates (0, 50, 100 and 150 mg N/L) were applied with the irrigation water and one soil application (NS) treatment, equivalent to one of the fertigation treatments, was included. Labelled ammonium sulfate was applied to microplots within the macroplots to evaluate the N recovery and utilization efficiency. Results obtained from two seasons indicate that increasing the N rate significantly increased the total and marketable yield by both methods of application, suggesting that the crop was underfertilized. The soil application treatment gave a higher yield than the control (N0) and a lower one than the fertigated treatments. In comparison to the N0, the total number of fruits in both seasons was significantly increased at all N levels. The soil application (Ns) treatment gave the lowest number of fruits compared to the fertigation treatments in the first season and a higher number than the fertigated treatments in the second season. The parameters of fruit quality (pH of juice, titratable acidity (TA%) and total soluble solids (TSS%)) were in the acceptable range. They were not significantly affected by the rates and methods of the N application in both seasons. The rates and methods of N application did not affect the accumulation of dry matter (DM) of the fruits and shoots during the first season. But in the second season, the accumulation was higher than in the first season and it was significantly affected by the concentration and method of N application. With the soil application treatment (Ns) a higher DM content was accumulated than in the control (N0), but lower than the fertigated treatments. The total N uptake by the fruits and shoots during both seasons with the fertigated treatments was higher than with the soil application treatment (Ns) and the control (N0). The total N derived from fertilizer (Ndff) in both seasons, obtained by the shoots and fruits decreased as the N concentration increased. Therefore, the lower fertigated treatment gave a significantly higher Ndff content in comparison to the other fertigation treatments and the traditional method (Ns). The soil application treatment gave the lowest Ndff value. The same trend was observed for the shoots and fruits. The result of N utilization indicates that the fertilizer utilization by the fruits and shoots in both seasons tended to be the highest for the lowest N rate fertigation treatment and the lowest for the soil application treatment.

1. INTRODUCTION

Water and nitrogen are the main limiting factors affecting the agricultural production in arid and semi-arid regions. Improving the use efficiency of these critical factors is, therefore, the target of any new management.

Application of fertilizers with irrigation water (fertigation) has several advantages over the traditional methods. By fertigation, the time and rate of fertilizer applied can be regulated precisely. This will also ensure the application of a proper amount of nutrients to the particular growth stage optimizing the nutrient balance in the soil and minimizing the use of soil as storage reservoir for nutrients. This will improve the nutrient use efficiency, decrease leaching and volatilization losses and minimize the chances for ground water pollution. In addition applying the plant nutrients with the irrigation water is a more convenient and less expensive method as compared to the traditional methods [1]. Therefore, fertigation with different plant nutrients should be recommended for farmers in Jordan. It should be used where the plant nutrients use efficiency is low and the cost of fertilizers and wages of labors are high. Moreover, most farmers are switching currently from surface to drip irrigation as a mean to increase water use efficiency. With this in mind the traditional management of plant nutrient application must be modified and adjusted to this new trend.

The main objectives of this study were to compare the conventional fertilization method with fertigation, to evaluate the water and nitrogen use efficiency by both methods of application, and to evaluate the quantity and quality of yield as affected by methods and rates of N application.

2. METHODOLOGY

Two field experiments were conducted at the Deir Alla Regional Research and Technology Transfer Center in 1996/97 and 1997/98. The Center is located in the Jordan Valley, which is characterized by a warm winter and a very hot and long dry summer. Average monthly temperatures range from 30–45°C. The soil is calcareous with a clay loam texture. The major characteristics of the soil at the experimental site are shown in Table I.

TABLE I. MAJOR CHARACTERISTICS OF THE SOIL AT THE DEIR ALLA REGIONAL RESEARCH AND TECHNOLOGY TRANSFER CENTER

Parameters	Units	0–30 cm	30–60 cm
PH		7.7	7.5
EC	Ds /m	1.5	1.1
O.M.	%	1.0	0.52
$CaCO_3$	%	27.0	24.0
Total N	%	0.018	0.009
$NaHCO_3$ _ P	ppm	42	20
NH_4OAC — K	ppm	756	625
Ca^{++}	meq/l	12	14
Mg^{++}	meq/l	9.0	11.2
CEC	meq/100g	28.0	29.5
Bulk density	g/cm^3	1.3	1.26
Texture	Clay Loam	Clay Loam	Clay Loam

The following treatments were investigated in a randomized complete block design (RCBD) with four replications:

1–0 ppm N = N0
2–50 ppm N = N1
3–100 ppm N = N2
4–150 ppm N = N3
5- Conventional soil (Ns) application (equivalent to one of fertigation treatments).

The N fertilizer (ammonium sulfate) was applied through the irrigation water with each irrigation in order to provide the required N concentration for each treatment.

The irrigation water was filtered by sand and screen filters. The fertilizer was applied into irrigation water by an injection pump. Tomato plants were planted at 40 cm in rows with two lines and 150 cm between the rows. The plot dimension was 6m × 3.5m. Each plot contained 4 rows, each 6m long. Each row had its own irrigation line positioned between the plants. Emitters were spaced 40 cm apart in the irrigation line (Fig. 1). Irrigation was applied to replenish 80% of the Class A pan evaporation on a weekly basis.

Access tubes for the neutron probe were installed in one place. The reading was mounted in the middle of the second row of each plot. Readings were taken before and after each irrigation or rainfall at 15, 30, 45, 60 and 90 cm soil depth. The labelled ^{15}N fertilizer was applied to the microplots within each plot. The microplots were fertigated through a respirator gallon connected to special drippers that substituted the drippers of the original irrigation line. The macroplots were fertigated with a drip irrigation system.

NS	N2	N3	N0
N1	N0	N2	NS
N0	N3	N1	N3
N2	NS	N0	N1
N3	N1	NS	N2
R-IV	R-III	R-II	R-I

FIG. 1. The experiment design for fertigation of tomato using ^{15}N the Deir Alla Regional Research and Technology Transfer Center; ◂- 6 m -▸.

Tomato (cv. gardenia) was planted on December 28, 1996, in the first season and on December 5, 1997, in the second season. Red ripe fruits were harvested from the middle two rows for each treatment at weekly intervals. Data of yield and fruit numbers were recorded throughout the harvest season.

Representative harvested fruit samples were collected from each harvest to be analysed for the chemical properties, pH, titratable acidity (TA%), total soluble solids (TSS%), dry matter and the N content. The dry mater content of fruits and shoots was determined by oven drying at 65–70°C. The total N was analysed according to the Kjeldahl method.

For the ^{15}N measurements, representative fruit samples were taken at each harvest, oven dried at 65–70 °C and ground to pass a 2 mm sieve. Two plants from each microplot were collected at the end of the season, dried at 65–70°C and prepared for ^{15}N analysis.

3. RESULTS AND DISCUSSION

3.1. The First Season 1996/97

The amounts of N applied through the irrigation water were 0, 84, 168 and 252 kg N/ha and 168 kg N/ha for the soil application treatment (Table II). The amount of fertigation water applied, including the dissolved fertilizer, was 168.5 mm. 54.2 mm irrigation water without fertilizer was added before the treatments started, in addition to 304.6 mm of rainfall during the growing season (Table II).

There was no significant difference in total and marketable yield between the N fertigation treatments (N1, N2, N3) and the soil application (Ns). However, all these treatments were higher in total and marketable yield with significant differences than the control treatment (N0) (Fig. 2).

The highest yield was obtained with the N3 treatment (70.3 t/ha). The soil application treatment gave a higher yield (67.5 t/ha) than the control treatment (58.4 t/ha) but a lower one than the N2 treatment (69.8 t/ha), which received the equivalent amount of N. It was higher than the N1 treatment (66.4 t/ha), which received the lowest amount of N.

The highest marketable yield was obtained with the N3 treatment (63.8 t/ha). The soil application treatment gave a higher marketable yield (61.1 t/ha) than the control treatment (46.2 t/ha), the N2 treatment (58.9 t/ha) and the N1 treatment (57.6 t/ha). The total number (x 10000) of fruits increased with the increasing N rates: 98.1, 101.8, 127.1, 71.1 , 92.4 for N1, N2, N3, N0 and the soil application (Ns) treatments, respectively (Fig. 3).

Monthly water applied was 43.05, 0.0, 33.48, 47.62, and 98.61 mm, and rainfall was 111.7, 106.0, 75.03, 4.3, 7.3 mm for January, February, March, April and May, respectively (Table III).

TABLE II. TREATMENTS, N APPLICATION, IRRIGATION WATER ADDED AND RAINFALL 1996/1997

Treatments	Amount
N0	0 kg N/ha
N1–50 ppm	84 kg N/ha
N2–100 ppm	168 kg N/ha
N3–150 ppm	252 kg N/ha
NS-soil application	168 kg N/ha
Irrigation water added and rainfall	
Fertilizer water (mm)	168.5
Irrigation water (mm)	54.2
Rainfall (mm)	304.6

TABLE III. IRRIGATION WATER APPLIED AND RAINFALL (mm) DURING THE SEASON 1996/1997

Month	Irrigation water (mm)	Rainfall (mm)
January	43.05	111.7
February	0.0	106.0
March	33.48	75.03
April	47.62	4.3
May	98.61	7.3
Total	**222.76**	**304.6**

The soil application (Ns) treatment gave a lower number of fruits compared to the fertigation treatments, but it was higher than the N0 treatment. The increase in yield was more affected by the increased number of fruits than by the weight per fruit [2].

The chemical properties of the fruits are shown in Fig. 4. The pH of the fruit juice was not significantly affected by the rates and methods of N application, but there was a trend of increasing pH with increasing N concentration. The values were 4.36, 4.37, 4.38, 4.42, and 4.44 for the N1, N2, N3, N0 and soil application (Ns) treatments, respectively.

For the titratable acidity (TA%) all treatments N1, N2, N3 and N0 gave the same value (0.49) while the soil application treatment gave 0.48. This result indicates a decrease in total soluble solids (TSS%) with the increase of N. The N0 treatment gave the highest value, significantly different from the N3 treatment. The values were 4.33, 4.25, 3.95, 4.5 and 4.05 for the N1, N2 , N3, N0, and soil application (Ns) treatments, respectively.

The dry matter of the fruits was increased with the increasing N rates: 2.83, 3.08, 3.32, 2.85 and 1.98 kg/ha for N1, N2, N3, Ns and control (N0) treatments, respectively (Fig. 5). There were no significant differences between the N fertigation treatments and the soil application (Ns) treatments. But all these treatments were significantly higher than the control treatment (N0).

The vegetative (shoots) dry matter was not affected by the N treatments. There was no significant difference between the treatments: 3.57, 3.32, 3.98, 3.35, and 3.47 kg/ha for the N1, N2, N3, N0 and soil application (Ns) treatments, respectively (Fig. 5). This is due to the climatic conditions during the growing season. At the beginning, especially in January after transplanting, the temperature was high and suitable for plant growth. Afterwards, when the plants started to flower the temperature dropped down and reached -0.6°C. The average temperature during February was still less than 15°C (Fig. .6), which means that the fruit failed to set at 13°C or below. It depressed stem elongation, auxiliary shoot and root growth, and leaf initiation.

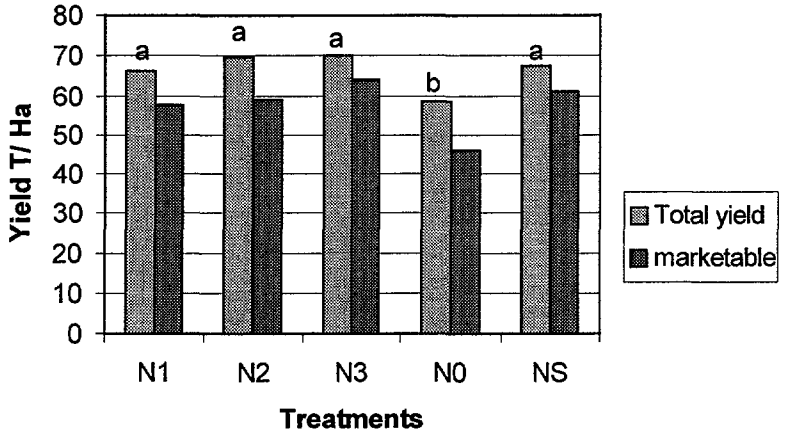

Figure (2): The effect of N rates and methods of application on total and marketable yield of tomato- Jordan Valley-Deir Alla Center 1996/1997.

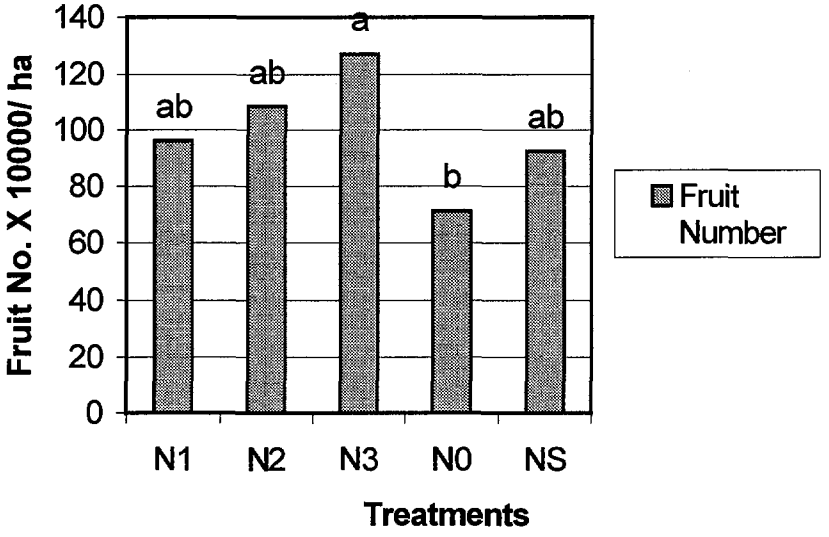

Figure (3): The effect of N rates and methods of application on the fruit number of tomato-Jordan Valley-Deir Alla Center 1996/1997.

Nitrogen Utilization

The N percentage in the total dry matter (fruits and shoots) was not affected by the rates and methods of N applications. However, the fruits contained a higher percentage of N than the shoots (Table IV). The N percentages for dry matter of fruits were significantly different for all N application treatments compared to the control treatment (N0). For the shoots there were no significant differences for all N application treatments compared to the control.

The total N uptake by the fruits and shoots was the highest for the N3 treatment (149 kg N/ha). It differed significantly in comparison to the other fertigation treatments and the soil application (Ns) treatment. All fertigation treatments and the (Ns) were significantly higher than the control treatment (96.7 kg/ha).

The N uptake by the fruits was highest for the N3 treatment (90 kg N/ha). There was no significant difference with the other fertigation and Ns treatments. However, there was a significant difference between all fertigation and Ns treatments compared to the N0 treatment (46 kg N/ha). For the shoots no significant difference was found between the N uptake among all treatments. The

quantity of N uptake by the shoots ranged from 47.8 to 59.4 kg N/ha (Table IV). The increase in N uptake was probably caused by a N diffusion gradient, because of the dense root system.

The total nitrogen derived from the fertilizer (Ndff) for the shoots and fruits decreased with the increasing N concentration. The N1 treatment showed (39.2 kg N/ha) a significantly higher content in comparison to the other fertigation treatments and the traditional method (Ns). The soil application treatment showed a lower content than the fertigation treatments (12.8 kg N/ha) (Table IV).

TABLE IV. NITROGEN UTILIZATION BY TOMATO FRUITS AND SHOOTS 1996/1997

Treatments	% N	N Uptake kg/ha	% Ndff	Ndff kg/ha	% fertilizer utilization
		Fruits			
N1 — (N50 ppm)	2.69a	76.2a	26.60	21.75a	25.89a
N2 — (N100 ppm)	2.57a	79.2a	24.90	19.72a	11.73b
N3 — (N150 ppm)	2.71a	90.2a	13.32	12.01b	4.76c
Ns = N2	2.72a	77.6a	13.97	10.84b	6.45c
N0	2.32a	46.0b	-	-	-
		Shoots			
N1 — (N50 ppm)	1.64a	58.8a	26.03	17.46a	20.80a
N2 — (N100 ppm)	1.67a	55.6a	21.72	9.28b	5.50b
N3 — (N150 ppm)	1.49a	59.4a	14.07	4.88c	1.90c
Ns = N2	1.37a	47.8a	8.53	1.99d	1.20c
N0	1.51a	50.7a	-	-	-
		Fruits and shoots			
N1 — (N50 ppm)	2.10a	135.0b	29.0	39.21a	46.6a
N2 — (N100 ppm)	2.09a	134.8b	21.5	29.00a	17.2b
N3 — (N150 ppm)	2.04a	149.6a	11.2	16.89b	6.7c
Ns = N2	2.35a	125.4b	10.2	12.83b	5.1c
N0	1.52b	96.7c		-	-

* Means for fruits, shoots and total followed by the same letter within a column are not significantly different at 5% level according to DMR analysis.

	Treatments
N0 ppm	0 kg N\ha
N1 — 50 ppm	84 kg N\ha
N2 — 100 ppm	168 kg N\ha
N3 — 150 ppm	252 kg N\ha
NS — Soil application	168 kg N\ha

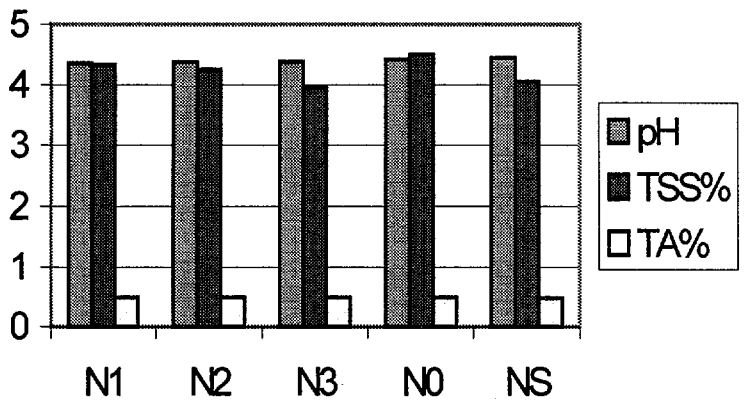

Figure (4): The effect of N rates and methods of application on the chemical properties of tomato fruits — Jordan Valley-Deir Alla Center 1996/1997.

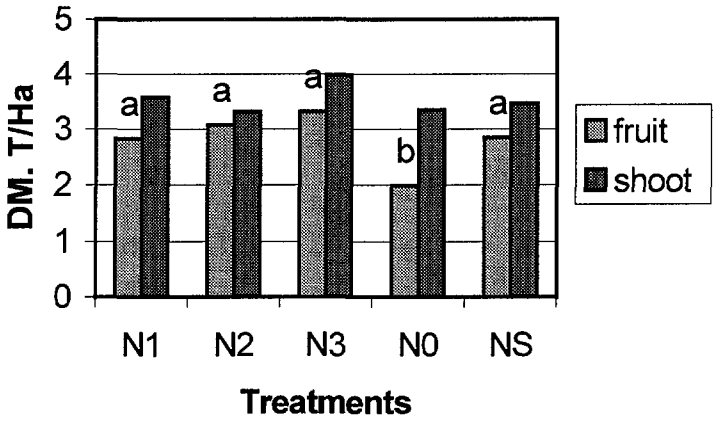

Figure (5): The effect of N rates and methods of application on the dry matter of tomato fruits & shoots — Jordan Valley-Deir Alla Center 1996/1997.

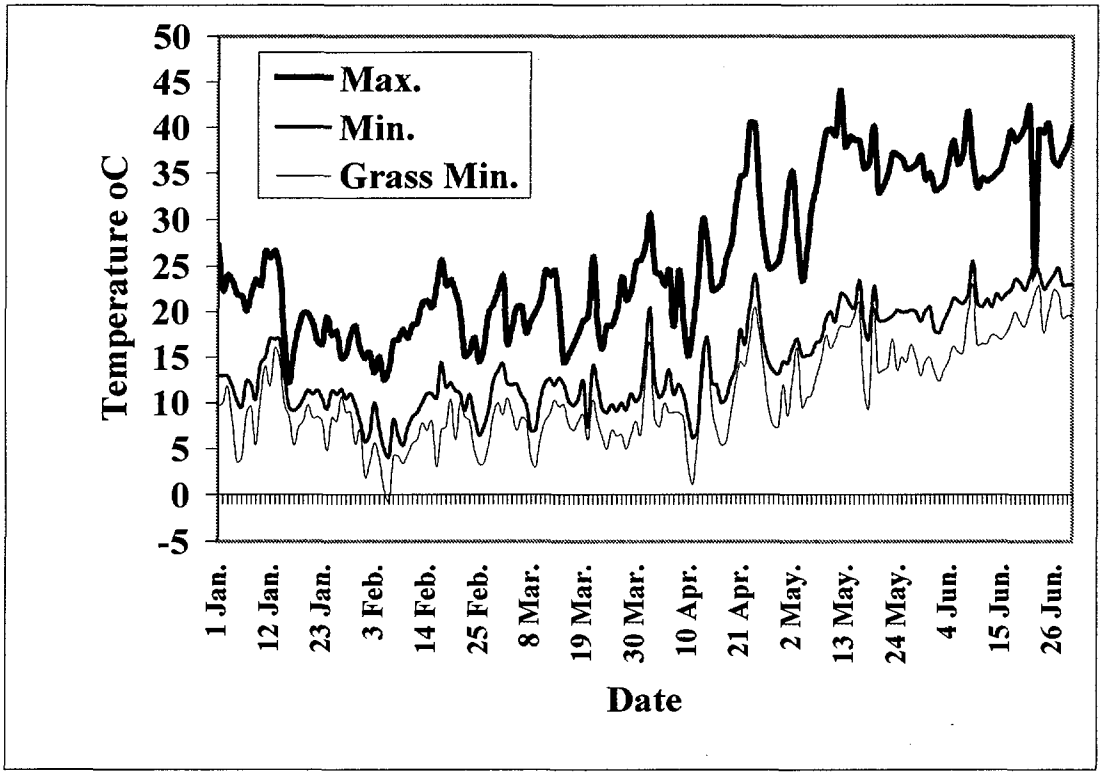

Figure (6): The maximum, minimum, and grass minimum temperature — Jordan Valley. Deir Alla Center 1996/1997.

The Ndff for the fruits was significantly higher for N1 (21.75 kg/ha) and N2 (19.72 kg/ha) than for N3 (12.01 kg/ha) and Ns (10.8 kg/ha). The Ndff for the shoots was the highest for N1 (17.4 kg/ha) and significantly different from the fertigation and Ns treatments. The Ndff for the soil application (Ns) treatment was the lowest (1.99 kg/ha) and significantly different from the fertigation treatments.

The fertilizer N utilization by the fruits and shoots was decreased with increasing N concentration. The fertilizer N utilization by the total tomato crop (fruits and shoots) was the highest for the N1 treatment. It reached 46.6%, significantly different from the other fertigation and soil application treatments. The fertigation treatments had a higher fertilizer N utilization (17.2% and 6.7% for N2 and N3, respectively) as compared to the soil application treatment, which was 5.1%

(Table IV). The same trend was observed for the fruits and shoots. This could be the result from the N fertilizer being leached from the root zone during irrigation as well as from volatilization losses [2].

3.2. The second season 1997/98

The amounts of N applied through the irrigation water were 0, 64, 128 and 192 kg N/ha and 175 kg N/ha for the soil application treatment (Table V). The amount of fertigation water (including the dissolved fertilizer) applied was 128.7 mm. And 56 mm irrigation water without fertilizer was added before the treatments started, in addition to 333.1 mm of rainfall during the growing season (Table V).

TABLE V. TREATMENTS, N APPLICATION, IRRIGATION WATER ADDED AND RAINFALL, 1997/1998

Treatments	Amount
N0 — ppm	0 kg N/ha
N1 — 50 ppm	64 kg N/ha
N2 — 100 ppm	128 kg N/ha
N3 — 150 ppm	192 kg N/ha
NS — Soil application	175 kg N/ha
Irrigation water added and rainfall.	
Fertilizer water (mm)	128.7
Irrigation water (mm)	101
Rain (mm)	337.3

It should be noted that the amount of N added by the soil application treatment in the first season was equivalent to amount of N in the fertigated treatment N2 (168 kg N/ha), while in the second season the amount was 175 kg N/ha, which was closer to the highest amount of N in the fertigated treatment N3 (192 kg/ha).This was due to the differences in the quantity of fertigation water in both seasons.

The amounts of monthly water applied were 11, 0.0, 32, 61, 89 and 36.7 mm, and rainfall was 72, 122, 89, 35, 15.7 and 3.6 mm for December, January, February, March, April and May, respectively (Table VI).

The results indicate that the total and marketable yield responded positively to the fertigation. The total and marketable yield from the fertigation treatments significantly differed from the soil application treatment (Ns). All these treatments produced a higher total and marketable yield, significantly different from the control treatment (N0) (Fig. 7).

TABLE VI. IRRIGATION WATER APPLIED AND RAINFALL (mm) DURING THE SEASON, 1997/1998

Month	Irrigation water (mm)	Rainfall (mm)
December	11	72
January	0.0	122
February	32	89
March	61	35
April	89	15.7
May	36.7	3.6
Total	229.7	337.3

The highest yield was obtained with the N3 treatment (80.4 t/ha). The soil application treatment gave a higher yield (68.2 t/ha) than the control treatment (58.4 t/ha) but a lower one than the N2 (79.7 t/ha) and N1 treatments (75.16 t/ha) which received the lowest amount of N. There were significant differences in yield between the fertigation treatments and the soil application treatment (Ns) and N0. Significant differences in yield were also noted between Ns and N0.

The highest marketable yield was obtained with the N3 treatment (64.4 t/ha). The soil application treatment gave a higher marketable yield (50.21 t/ha) than the control treatment (44.9 t/ha), but a lower one than the N2 (61.1 t/ha) and N1 (56.7 t/ha) treatments.

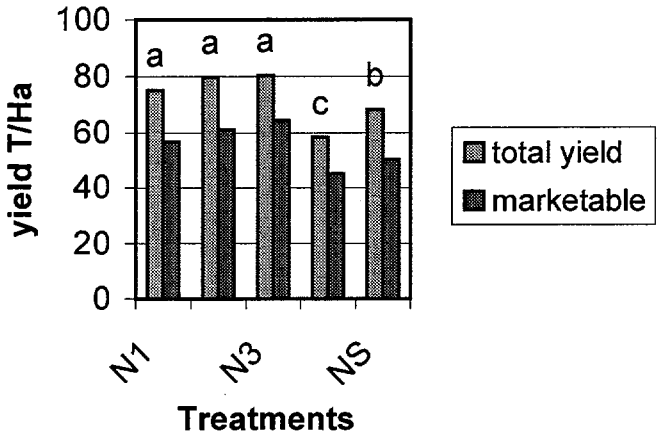

Figure (7): The effect of N rates and methods of application on total an marketable yield of tomato — Jordan Valley-Deir Alla Center 1997/1998.

The number of fruits was increased by increasing nitrogen rates: 88.1, 91.5, 92.2, 95.5 and 70.5 (to be multiplied by 10000) for the N1, N2, N3, Ns and N0 treatments, respectively (Fig. 8). The only significant difference was found between all treatments and the control (N0).

The soil application (Ns) treatment gave the highest fruits number, higher than the fertigation treatments and the N0 treatment.

The chemical properties of the fruits are shown in Fig. 9. The pH of fruit juice was not significantly affected by the rates and methods of N application, but there was a trend of increasing pH with increasing N concentration. The values were 4.53, 4.71, 4.80, 4.33, and 4.91 for the N1, N2, N3, N0 and soil application (Ns) treatments, respectively.

All treatments N1, N2 ,N3 and Ns gave a value ranging from 0.30 to 0.37 for the titratable acidity (TA%) while the N0 gave 0.52. There were no significant differences between all treatments.

The results indicated an increase in total soluble solids (TSS%) with increasing N concentration. The N3 treatment gave the highest value of TSS% with no significant differences between all treatments. The values of TSS% were 3.76, 3.89, 4.20, 3.78 and 3.86% for the N1, N2, N3, N0, and soil application (Ns) treatments, respectively.

The dry matter content of the fruits and shoots was affected by the concentration and method of N application. There were significant differences between the fertigation treatments and the Ns treatment as well as significant differences between Ns and N0 (Fig. 10).

The dry matter accumulated in the fruits was 4.69, 4.79,4.83,4.10 and 3.50 t/ha for the N1, N2, N3, Ns and control (N0) treatments, respectively (Fig. 5).

The shoots accumulated more dry matter than the fruits .The N3 treatment gave the highest quantity of dry matter (5.85 t/ha) with no significant differences as compared to the other fertigation treatments, but with significant differences as compared to the Ns and N0 treatments. The N2 treatment gave the second highest quantity of dry matter (5.65 t/ha), while the N1 treatment was higher than the Ns and N0 (5.50 ton/ha) with significant differences among them. The Ns treatment gave a higher quantity than the N0 treatment (4.75 t/ha) with significant differences as compared to N0 (3.98 t/ha). To understand these results, it is useful to look at the climatic conditions during the growing season 97/98, shown in Fig. 11. The conditions for plant growth were normal. This is indicated by the fact that the accumulated dry matter during the second season was higher than during the first season.

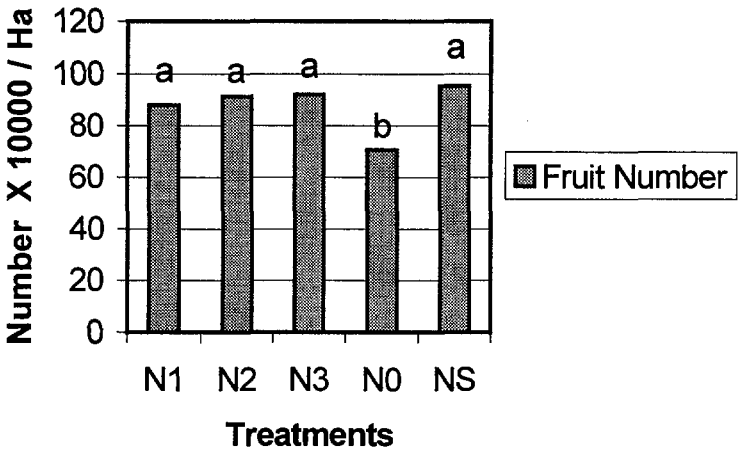

Figure (8): The effect of N rates and methods of application on the fruit number of tomato-Jordan Valley-Deir Alla Center 1997/1998.

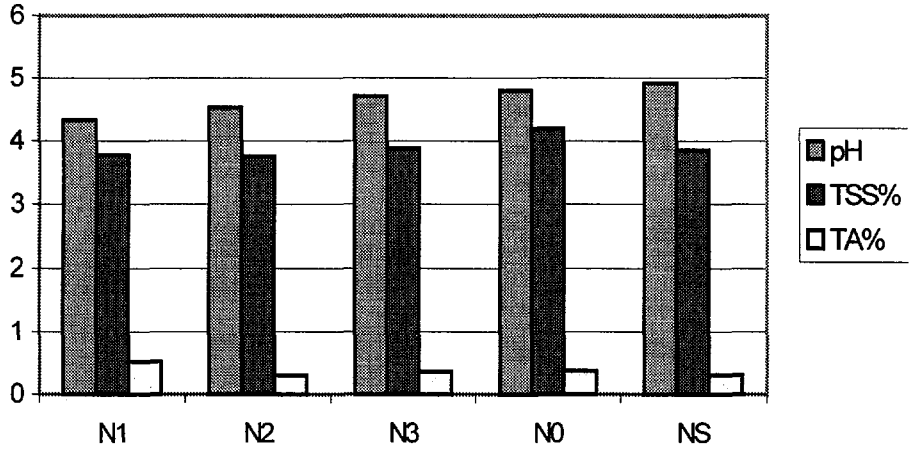

Figure (9): The effect of N rates and methods of application on the chemical properties of tomato fruits — Jordan Valley-Deir Alla Center 1997/1998.

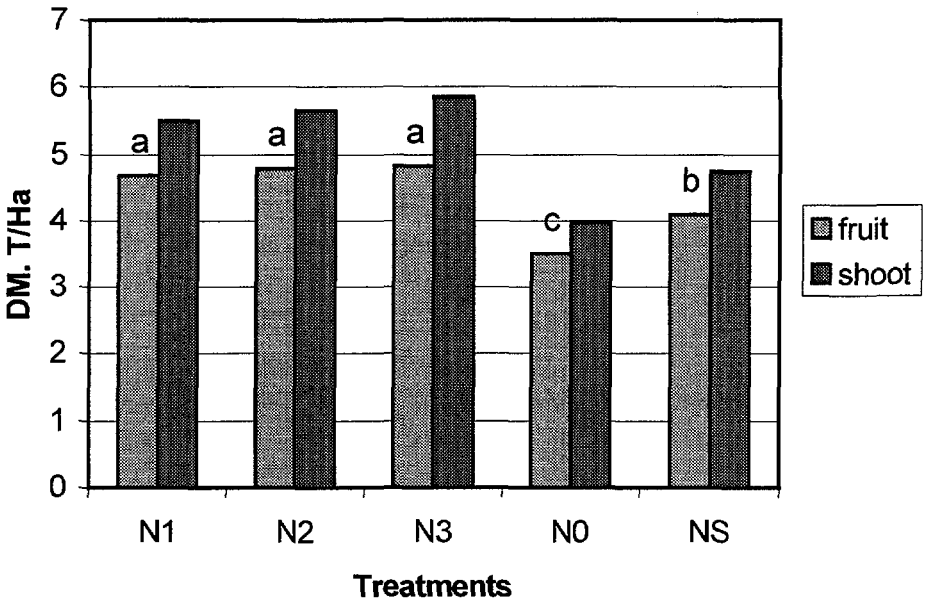

Figure (10): The effect of N rates and methods of application on the dry matter of tomato fruits & shoots — Jordan Valley-Deir Alla Center 1997/1998.

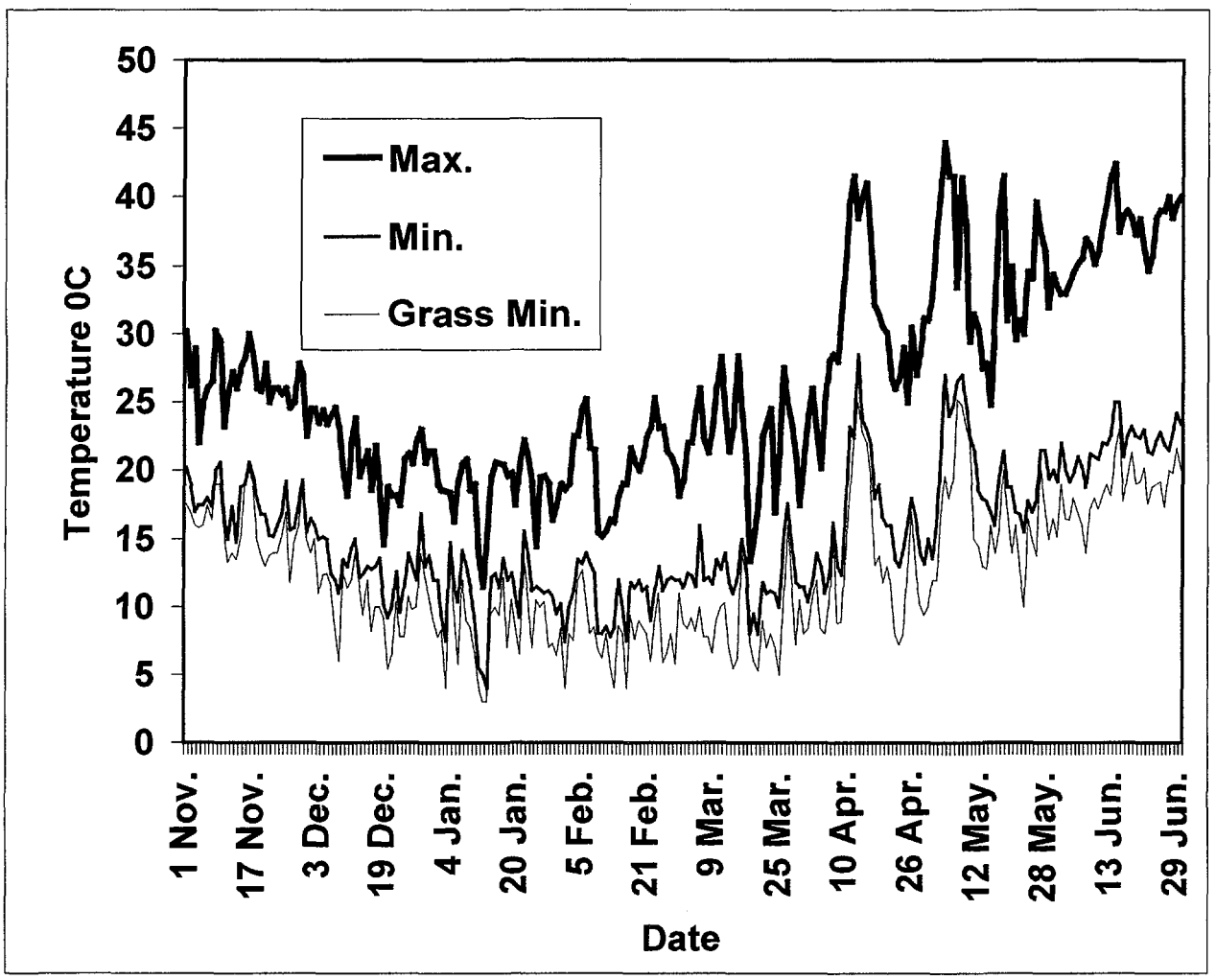

Figure (11): The maximum, minimum, grass minimum temperature — Jordan Valley. Deir Alla Center 1997/1998.

Nitrogen Utilization

Rates and methods of N application affected the N content in the dry matter (shoots and fruits) with a significant difference between all N application treatments and the N0 and Ns treatments. The fruits contained a higher N percentage than the shoots, with no significant difference between all treatments (Table V).

The total N uptake by the fruits and shoots was higher with the fertigation treatments and ranged from 200 to 221 kg N/ha. It differed significantly from the soil (166 kg N/ha) and control (140.3 kg N/ha) treatments.

The N uptake by the fruits was highest at the N3 treatment (90 kg N/ha) with no significant difference with the other fertigation treatments and Ns. But there was a significant difference between all fertigation and Ns treatments and the N0 treatment (88.2 kg N/ha). The N uptake by the shoots was the highest for the fertigation treatments and ranged from 74.5–82.1 kg/ha with a significant difference from the Ns and N0 treatments, ranging from 52–56 kg/ha.

The total N derived from the fertilizer (Ndff) obtained by the tomato crop (shoots and fruits) decreased as the N concentration increased. The N1 treatment gave (30.9 kg N/ha) a significantly higher value than the other fertigation treatments and the traditional method (Ns). The soil application treatment gave a lower Ndff value than the fertigation treatments (10.35 kg N /ha) (Table 4).

The Ndff values for the fruits were significantly higher at N1 (16.87 kg/ha)) than at N2 (12.92 kg /ha), N3 (13.27 kg /ha) and Ns (5.4 kg/ha). All fertigation treatments were significantly different from Ns

The same trend was seen in the Ndff by the fruits and shoots. The Ndff values for fruits were 16.87, 12.92, 13.27 and 5.4 kg/ha at N1, N2, N3 and Ns, respectively. The Ndff values for the shoots were 13.9, 8.78, 8.08 and 4.95 kg/ha at N1, N2, N3 and Ns, respectively .

The % fertilizer N utilization by the fruits and shoots was decreased with the increasing N concentration. It was the highest for the N1 treatment, and reached 48.3% with significant differences as compared to the other fertigation and soil application treatments. The % of N utilization for N2 (16.9%) was significantly higher than for N3 and Ns. The N3 had 11.1% as N utilization with a significant difference as compared to the soil application treatment (Ns), which was 5.1%. (Table V). The same trend was observed for the fruits and shoots. This could be due to the N fertilizer being leached from the root zone during irrigation as well as due to volatilization losses [2].

4. SUMMARY AND CONCLUSION

Increasing the N rate significantly increased the total and marketable yield by both methods of application during both seasons. This suggests that the crop was underfertilized. The soil application treatment gave a higher yield than the control (N0) and a lower one than the fertigated treatments

The total number of fruits in both seasons was significantly increased with all N treatments above the N0 treatment. The soil application (Ns) treatment gave a lower fruit number as compared to the fertigation treatments in the first season and a higher one than the fertigated treatments in the second seasons.

The parameters of fruit quality, pH of the juice, the titratable acidity (TA%) and total soluble solids (TSS%) were not affected by the rates and methods of N in both seasons.

The accumulation of dry matter of the fruits and shoots during the first season was not affected by the rates and methods of N application. But, in the second season the accumulation was higher than in the first season and it was significantly affected by the concentration and method of N application. The dry matter accumulated with the soil application treatment (Ns) was higher than the control (N0) and lower than the fertigated treatments.

TABLE VII. NITROGEN UTILIZATION BY TOMATO FRUITS AND SHOOTS, 1997/1998

Treatments	% N	N Uptake kg/ha	% Ndff	Ndff kg/ha	% Fertilizer Utilization
			Fruits		
N1 — (N50 ppm)	2.76a	129.84a	13.0	16.87a	26.37a
N2 — (N100	2.58a	125.51a	10.3	12.92b	10.1b
ppm)	2.88a	139.09a	9.55	13.27b	6.91c
N3 — (N150	2.67a	110.07ab	4.91	5.40c	3.09d
ppm)	2.52a	88.20b	-	-	-
Ns (175 kg N/ha)					
N0					
			Shoots		
N1 — (N50 ppm)	1.35a	74.5a	18.66	13.90a	21.71a
N2 — (N100	1.33a	75.1a	11.70	8.78b	6.35b
ppm)	1.40a	82.1a	9.84	8.07b	4.20c
N3 — (N150	1.18a	56.0b	8.84	4.95c	2.82d
ppm)	1.31a	52.1b	-	-	-
Ns (175 kg N/ha)					
N0					
			Total: fruits and shoots		
N1 — (N50 ppm)	2.17a	204.3a	15.1	30.90a	48.3a
N2 — (N100	1.93a	200.6a	10.8	21.70b	16.9b
ppm)	1.95a	221.1a	12.8	21.34b	11.1c
N3 — (N150	1.55b	166.0b	6.2	10.35c	5.9d
ppm)	1.66b	140.3b	-	-	-
Ns (175 kg N/ha)					
N0					

* Means for fruits, shoots and total followed by the same letter within a column are not significantly different at 5% level according to DMR analysis.

Treatments	
N0 — ppm	0 kg N/ha
N1 — 50 ppm	64 kg N/ha
N2 — 100 ppm	128 kg N/ha
N3 — 150 ppm	192 kg N/ha
NS — soil application	175 kg N/ha

Ndff (%)= (% plant 15N/% fertilizer 15N) × 100

Ndff (kg/h) =[Ndff (%) × total N uptake]/100

% Fertilizer N utilization = [Ndff (kg/h)/rate of N applied] × 100

Total Ndff (%) = [total Ndff (kg/ha)/total N uptake (kg /ha)] × 100.

The % N in the fruits and shoots during the first season was not affected by the rates and methods of N application. The % N in the shoots plus fruits was significantly affected by the N application rates. During the second season the % N in the fruits plus shoots was significantly affected only by the fertigation treatments. In both seasons, the fruits contained a higher N % than the shoots, with no significant difference between the treatments. The total N uptake by the fruits and shoots of the fertigated treatments during both seasons was higher than the total N uptake of the soil application treatment (Ns) and the control (N0).

The total nitrogen derived from the fertilizer (Ndff) in both seasons, calculated for the shoots and fruits decreased as the N concentration increased. Therefore, the lower fertigated treatment gave a significantly higher content in comparison to the other fertigation treatments and the traditional method (Ns). The soil application treatment gave the lowest value of Ndff. The same trend was observed for the shoots and fruits.

The results of the N utilization indicated that the fertilizer utilization by the fruits and shoots during both seasons tended to be highest for the fertigated treatment rate (N1) and the lowest for the soil application treatment.

The results show that under the experimental conditions, the crop responded positively to the low N rates applied by fertigation to obtain an acceptable yield with a high efficiency of fertilizer use. Moreover, the higher N fertigated rates guide to a non significant increase in yield, with a high reduction in the fertilizer use efficiency. It could have a negative impact on the environment resulting in soil and water pollution. Generally, to reach an acceptable yield with high fertilizers use efficiency we suggest to apply relatively low rates of N fertigation, keeping in mind regional site conditions such as soil, irrigation water, climate, etc.

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