Effects of Crop Up Metalosate® Multimineral™ Foliar Applications under Greenhouse Planted Tomatoes Compared to Standard Micronutrient mixes used by the Farmers in Southern of Morocco

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INTRODUCTION

Unheated, plastic greenhouses are of great importance in Morocco's agricultural economy and bring in a considerable amount of foreign currency. Most of the protected cultivation is concentrated along a narrow, relatively frost-free area of the Atlantic coast between Laarache and Agadir and as far as Dakhla which receives abundant light during the period October - March (from 1150 to 1400 hrs).The estimated protected cultivation in Morocco is about 8,540 ha including vegetables, cut flowers and fruit tree crops. The area dedicated to vegetable crops is dominated by tomato crops: 3,650 ha (56%); strawberry: 2,370 ha (17.7%) and melon: 1,290 ha (11.5%). Pepper, cucumber and green beans cover the remaining.

Eighty five percent of protected vegetable crops are located in the south of Morocco (Souss-Massa valley) with a total area of 3,162 ha and a production of over 500,000 Tons in 2012.
Given that the water resources available in the area where early vegetables are grown are lower than the potential requirement, it is necessary to economize water use. Thus, almost all Moroccan farms use localized irrigation. The irrigation water used comes either from wells or from dams and quality varies from region to region (0.4 to 7 dS/m) with a pH higher than 7.8. Along with micro-irrigation, fertigation is being widely used in order to rationalize the addition of fertilizers and improve the production and quality. However, fertigation management remains to be improved, particularly for micro-nutrients. In fact, most soils are rich in calcium bicarbonate which leads to Fe, Zn, Mn, Cu and Mo deficiencies. Therefore foliar application of micronutrients could help mitigate these deficiencies and could help in increasing productivity of the vegetable production and ameliorate their qualities

It is well known that micronutrients (Cu Mn, Zn and B) are involved in the reproductive phase of plant growth and hence in determining the yield and quality of the harvested crop.
Since micronutrients are involved in many physiological processes, their deficiencies may lead to impairment and/or reduction in synthesis of some important compounds such as amino acids. It follows that supplying growing plants with readily available amino acids may compensate for such deficiencies and increase the productivity of the crop.

In addition to this nutritional effect, solutions of trace elements also have a role in bio-activation while improving certain processes in the plant (photosynthesis, response to stress, response to diseases). This phenomenon could be explained by the presence of mixtures of amino acids in solutions of trace elements. These are used for their ability to form chelates with trace elements (Albion, 2010). Indeed Chelated minerals are easily absorbed by plants. (Ashmead, H.D., et al., 1986).

These bio-stimulants can have many effects on the plant. They could be involved in: hormonal action, membrane transport, in enhancing photosynthesis, regulation of nutrient availability, reduction of toxic elements, and systemic induction of resistance to stress (Russo and Berlyn , 1990, Hervé, 1994; Kloareg et al, 1996).. Thus, these bio-stimulants applied to crops under certain conditions and at very low doses, could reduce the use of fertilizers to increase the yield, or improve plant resistance to stress (Castro et al ., 1988; Rai, 2002). This report will describe the effect of several micro nutrients composition associated with and without specific Amino-acids on the tomato crop yield and quality.

OBJECTIVES

The goal of this experiment is to compare Metalosate® Crop-Up chelated Amino Acid, foliar liquid micronutrient fertilizer to the standard practices of the farmers; our specific objectives are to answer several questions:

1) Does the Metalosate® Crop-Up micronutrients solution increase the yield of tomato crops and improve fruit quality compared to standard practices of the farmer?

2) Are there any differences between the application of Metalosate® Crop-Up micronutrient solution and the water sprayed plants?

3) Do Metalosate® Crop-Up micronutrient mixtures have a positive effect on tomato crops in terms of plant growth, productivity and fruit quality and how it performs compared to standard micronutrient mixes used by the farmers and to a control using only irrigation water?

MATERIALS AND METHODS

Our trial was conducted under a plastic greenhouse (a surface area of 2500 m²) in the experimental station of the Institute of Agronomy and Veterinary Hassan II, in southern part of Morocco, in the region of Agadir (see photo 1).

The soil is loamy type moderately rich in organic matter (1.6%), with a pH of 8.3 and an EC of 0.17 dS / m. The moisture at field capacity (Hcc) is equal to 30%, and the moisture at permanent wilting point (HPFB) is 15%, these data will be useful for irrigation management. The ambient temperature of the greenhouse and the soil temperature were recorded.

The test results were subjected to statistical tests with StatBox software in order to validate and compare the measured parameters.

Photo 1 tomato crops at different stages of growth under plastic multi-span greenhouse

CROP MANAGEMENT

The tomato variety used in our experiment is Pristyla grafted on Beaufort, it was transplanted at the stage of four leaves the first of January and the first foliar application was on the first of February. The plant was conducted on a single arm, with a plant density of 20,000 plants / ha.

IRRIGATION MANAGEMENT

The crop water requirements were calculated based on the continuum soil plant atmosphere. The soil moisture at field capacity (HFC) and that at wilting point (HPWP) were taken in calculation as specific characteristics of the growing medium.

➢ **Calculation of the net maximum dose:** NMD

NMD = AD* (HFC - HPWP)*, where

- AD: allowable depletion = 15%
- HFC: soil moisture at field capacity = 12%
- HPWP: soil moisture at permanent wilting point = 3%

So NMD = 0.243 l

➢ **Calculation of irrigation (I) time required to provide a NMD**

In this experiment, Spaghetti drippers have been used with 2.2L/ha as hourly discharge. Each dripper irrigated an area of 0.13 m2. So the irrigation time required to provide a NMD is:

Irrigation time= **NMD * 60/ 2.2 = 7 min**

So we need around 7 minutes of irrigation to satisfy the allowable depletion (AD = 15%) of the effective storage and to reach the soil moisture level to field capacity.

➢ **Calculation of Net irrigation requirements (NIR)**

NIR =Ii= (Ii-1-Di-1) × 1.2

The net irrigation requirements was calculated basing on the difference between the supplied water and the drained water in term of volume, taking into consideration 20% as the leaching fraction of the investigated growing medium. That means the next irrigation will occur when 20% of the supplied water will be drained.

➢ **Calculation of irrigation frequency number**

For better irrigation management and in order to avoid water stress, we must supply the water frequently to avoid water losses by evaporation and drainage. The irrigation frequency is one of the most important factors in the management of crops cultivated under greenhouse conditions. For example the Tomato Net irrigation requirement for plants grown in our trial for day 35 was 0.9 l so the irrigation frequency of this day was:
F = NIR / NMD

F = 0.9 / 0.243 = 4, so we have to irrigate four times with an irrigation time of 7 min.
So the daily irrigation time for plants grown for day 35

I = irrigation time =7*4= 28min

FERTIGATION PROGRAM

The fertigation program adopted for growing our tomato crops is summarized in Table 1

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Table 1. fertigation program of the tomato crop				
Growing stages	N	P	K	Nitrogen level
-Transplanting to flowering 1st Cluster	1	1	1	100mg/m²
- Flowering 1st Cluster to flowering 5th Cluster	1	0,3-0,5	1,5-2	200mg/ m²
- Flowering 5th Cluster to 1st Harvest	1	0,3-0,5	2	400mg/m²
-1st Harvest to topping	1	0,3	2	500mg/m²
-Topping to end of the Harvest	1	0	2	300mg/m²

EXPERIMENTAL DESIGN

The design adopted is complete randomly blocs with 4 replications by treatment. We had 6 treatments, each treatment is represented by 4 plots, and for each plot we have 16 plants, so finally we will have 64 plants per treatment. Table 2 shows the various adopted treatments, and figure 1 below shows the experimental design at large scale.

Bloc 1	Bloc 2	Bloc 3	Bloc 4
T2	T1	T1	T1
T1	CU	T2	CU
CU	T2	CU	T2

Figure 1: Experimental design (6 treatments with 4 blocs)

Applied treatments

Table 2 is a summary of all investigated treatments and indicates the concentration of the micronutrients in each treatment. Applications were made every 15 days beginning one month after transplanting (first flowering) until the first harvest. An ionic surfactant was added to each treatment to allow for better coverage of the materials applied.

Table 2: applied treatments, using foliar applications

Treatments	**Content**	**Dose**
T1 (control 1)	Foliar application of irrigation water	1.5 ml/L
T2 (control 2) Standard practices of the farmers	Foliar application of a commercial solution B 0.66%, Cu 0.28%, Fe 6.79%, Mn 3.15%, Zn 0.57%, Mo 0.14%	1,5ml/L
CU (Crop- Up)	Solution of Metalosate® Crop-Up chelated Amino Acid, foliar Liquid micronutrients Fertilizer Mg 0.5%, B 0.025%, Cu 0.25%, Fe 0.25%, Mn 2.5%, Zn 1.25%	1,5 ml/L

In total there are 12 experimental units, for growth and quality parameters we took four plants per plot and 10 plants per plot for yield.

PARAMETERS OBSERVED

Growth, flowering rate and fruiting: carried out every week after we started the treatment application; and the observed parameters were:

- ✓ Plant height
- ✓ Plant diameter
- ✓ Number of clusters
- ✓ Number of flowers per cluster
- ✓ Number of fruit per cluster

Yield and quality parameters include:

- ✓ Yield (after every harvest).
- ✓ Fruit size distribution
- ✓ Fruit firmness
- ✓ Acidity and Brix index

Foliar analysis in terms of micronutrients (4 to 5 flowering)

In order to determine if the plants have different levels of micronutrients in response to tested treatments, leaf analysis was performed. Five leaves were collected by treatment and per plot and then they are dried (60 ° C for 48 h) and crushed.

Fruit analysis in terms of micronutrients (in progress)

RESULTS

Plant Growth development

Vegetative growth of tomato crop in terms of plant height for the different treatments is represented in Fig 2. There was significant difference ($P < 0.05$) between all treatments in terms of height of the plant. Tomato plants receiving Metalosate® Crop-Up and standard practices of the farmer foliar application had similar shoot length (SL) and were higher compared to the water sprayed treatment with an increment of 12%.,

Plant Height

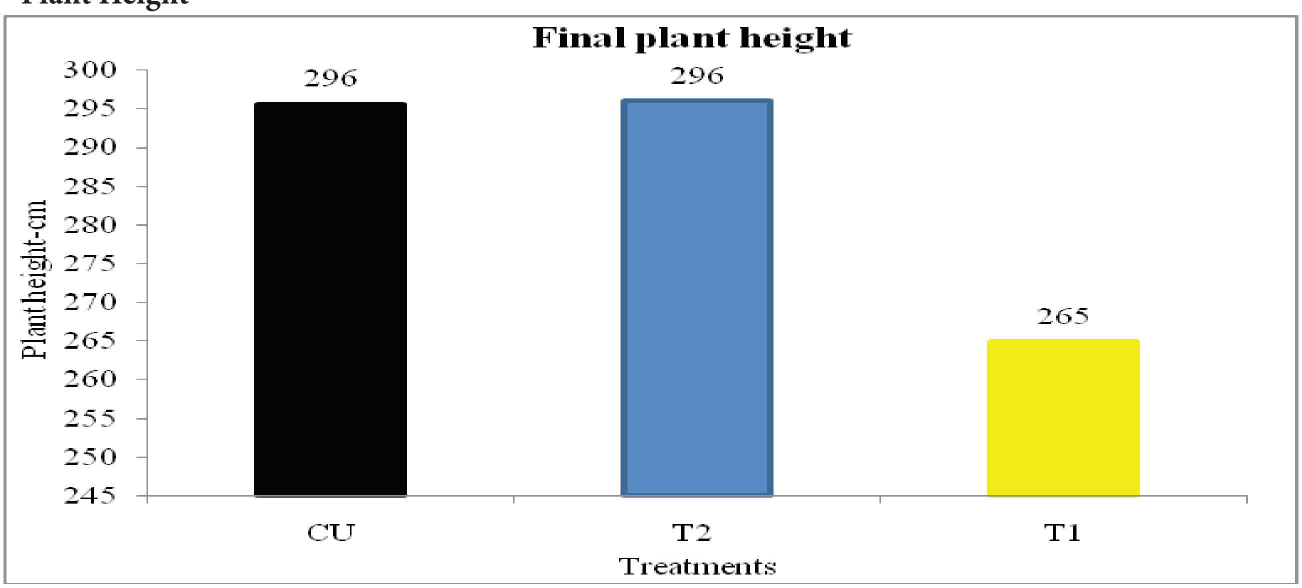

Fig 2. Plant height at the end of the cycle of tomato crops for the different treatments

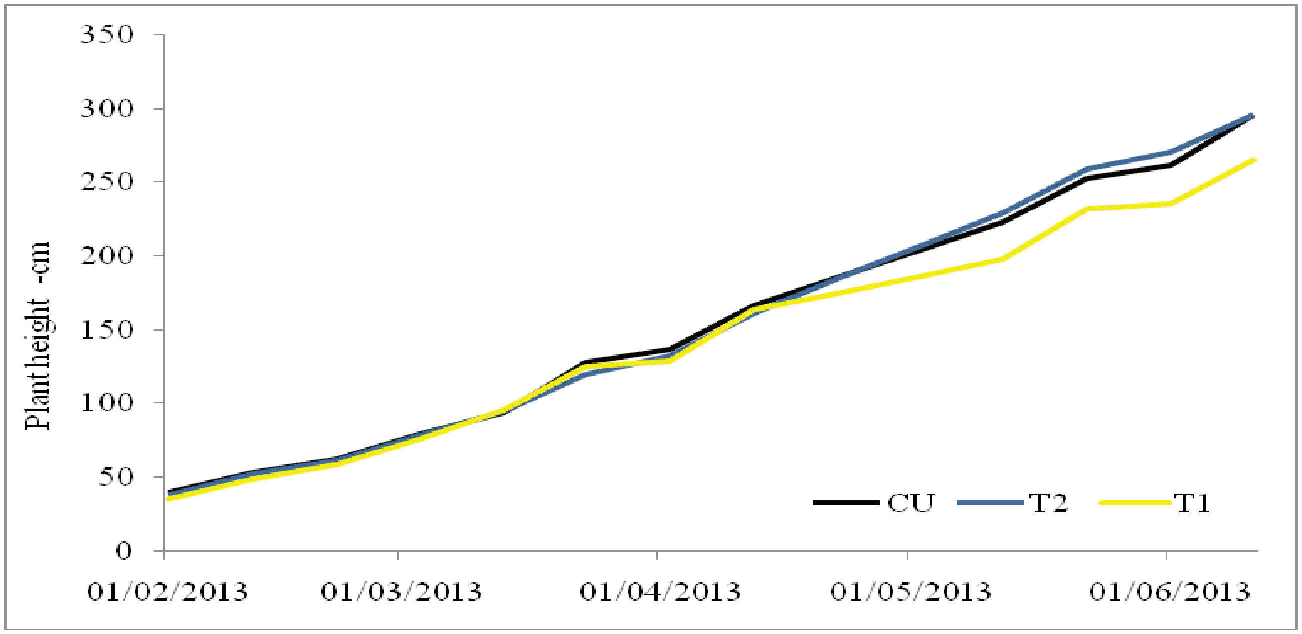

Fig 3. Plant height variation during the growing cycle of tomato crops and for the different foliar application of micronutrients

Nevertheless, we could observe a certain tendency of higher plant diameter for the control (water sprayed), No significant differences ($p>0.05$) between all treatments were observed in the growth parameters (Fig. 4 & 5).

Mean stem diameter

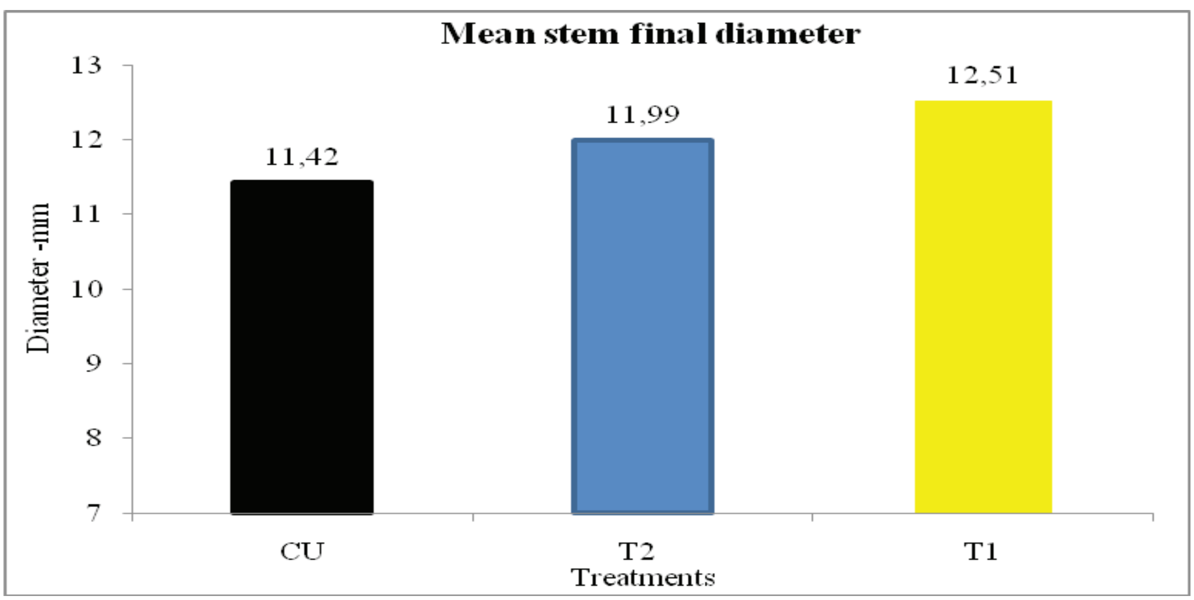

Fig 4: Mean stem diameter at the tomato cycle for the different treatments

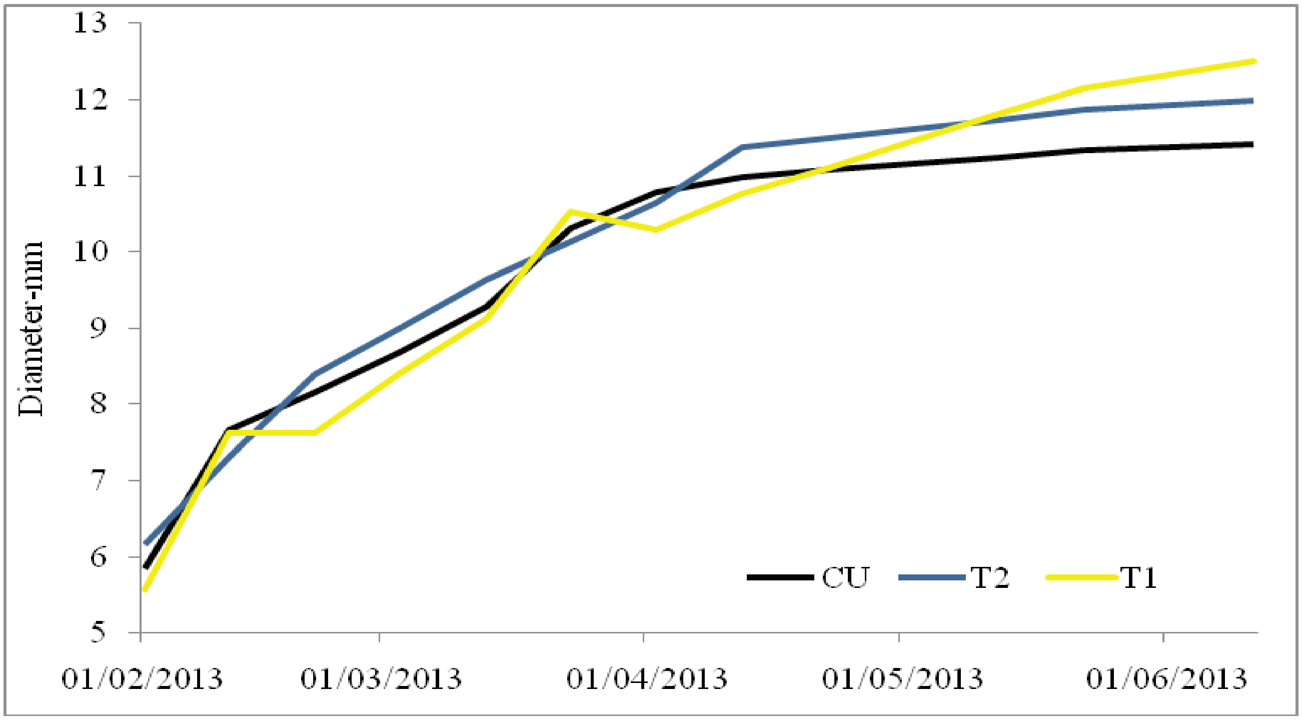

Fig 5 Plant Diameter variation during the growing cycle of tomato crops and for the different foliar application of micronutrients

Number of formed flowers

The number of formed flowers per Cluster for the water sprayed application was lower than the Metalosate® Crop-Up and standard practices of the farmer foliar application, and an increase of 16% was recorded with the Metalosate® Crop-Up foliar application (Fig. 6 & 7).

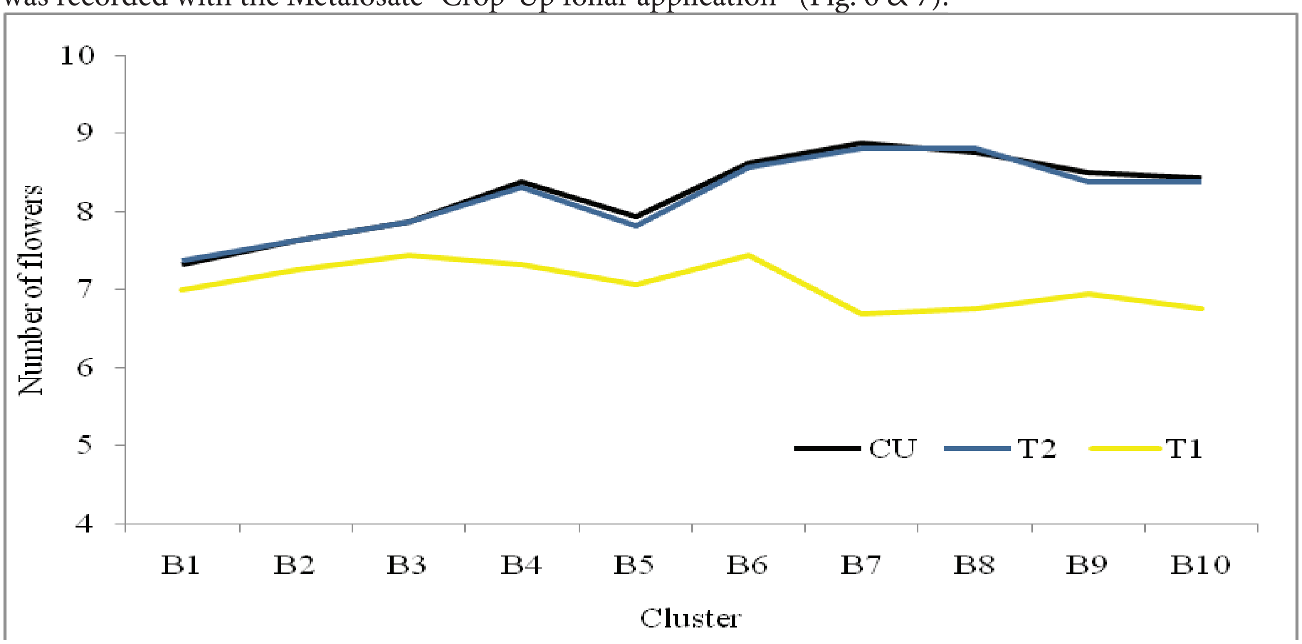

Fig 6 : Number of formed flower variation during the growing cycle of tomato crops and for the different foliar application of micronutrients

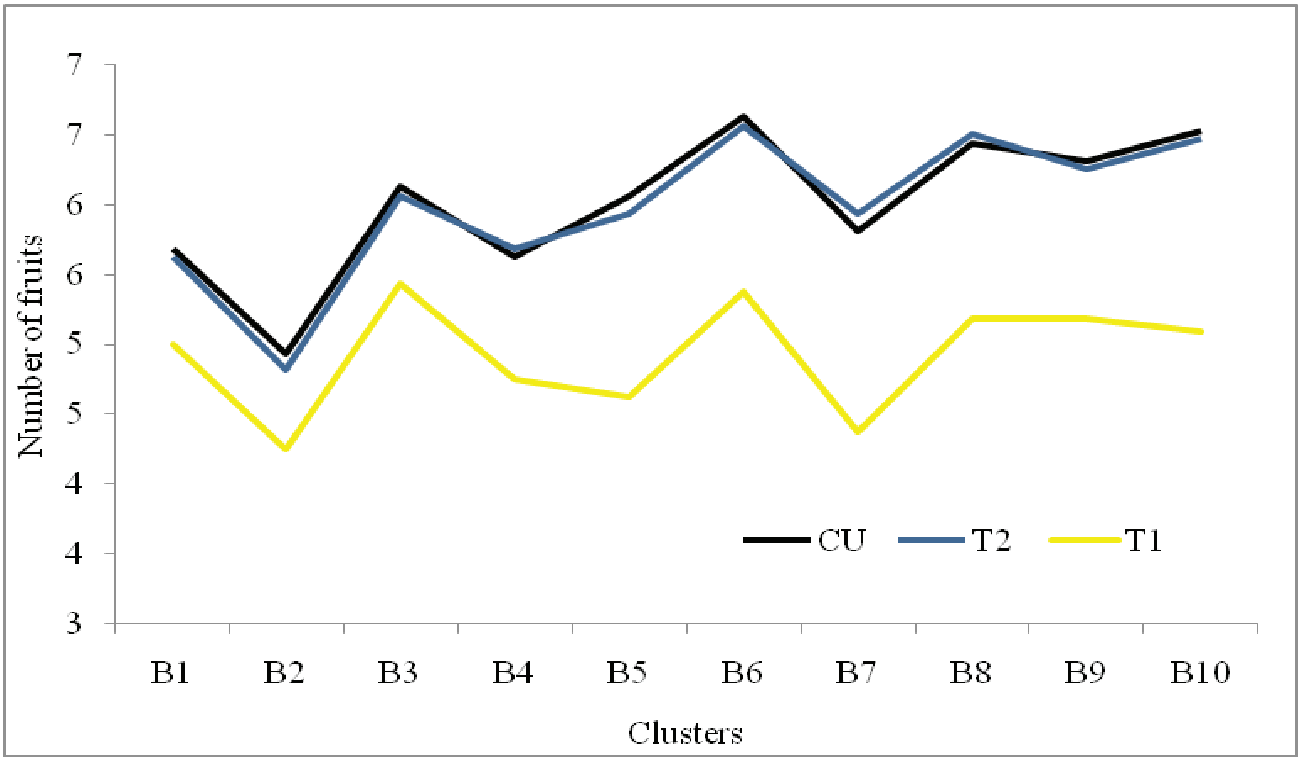

Fig 8: Number of formed fruit variation during the growing cycle of tomato crops and for the different foliar application of micronutrients.

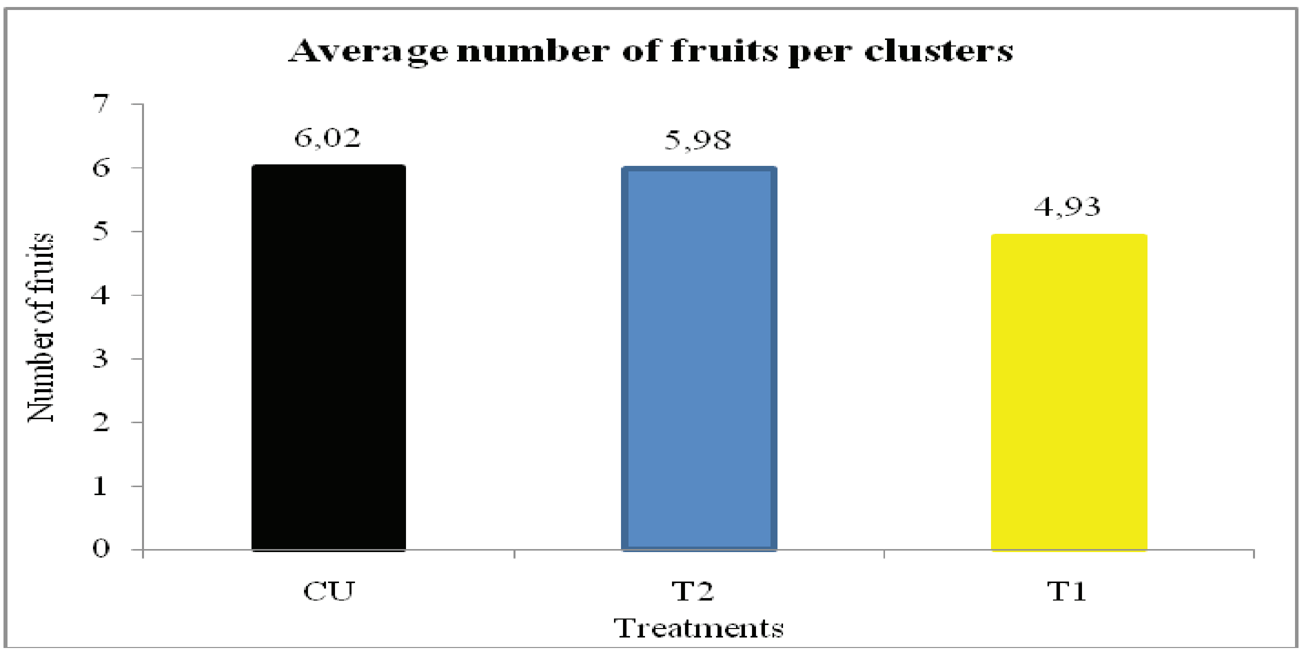

Fig 9: Average tomato formed fruit per cluster for the different foliar application of micronutrients

Yield

The plants sprayed with Metalosate® Crop-Up and standard farmer solution (T2) produced the higher tomato yield than the control (water sprayed). Based on figure 10 and the statistical analysis there was a very highly significant difference between tested foliar treatments in terms of harvested yield. There was an improvement in terms of yield of about 34% when applying Metalosate® Crop-Up or the commercial product compared to foliar treatment with irrigation water (control). (Fig. 11 & Table 3).

Table 3 Evolution of tomato fruit yield under different foliar treatments.

Kg/ plant	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	Total Yield Ton/ ha
CU	0.21	0.38	0.88	2.29	3.29	4.30	5.49	6.73	8.44	10.51	210 a
T2	0.18	0.37	0.95	2.35	3.44	4.54	5.72	6.89	8.52	10.49	210 a
T1	0.19	0.39	0.85	2.06	2.77	3.67	4.47	5.30	6.44	7.83	157b

Final yield

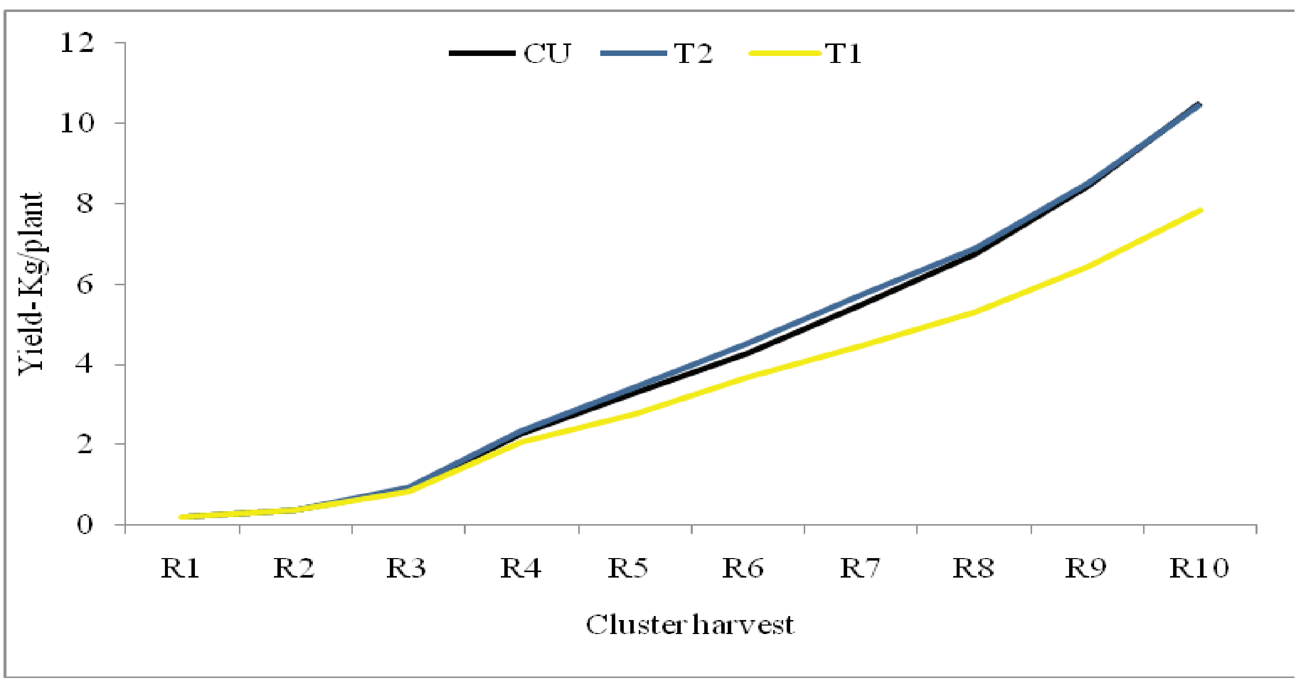

Fig 10: Evolution of harvested yield during the growing period of tomato and for the different foliar application of micronutrients

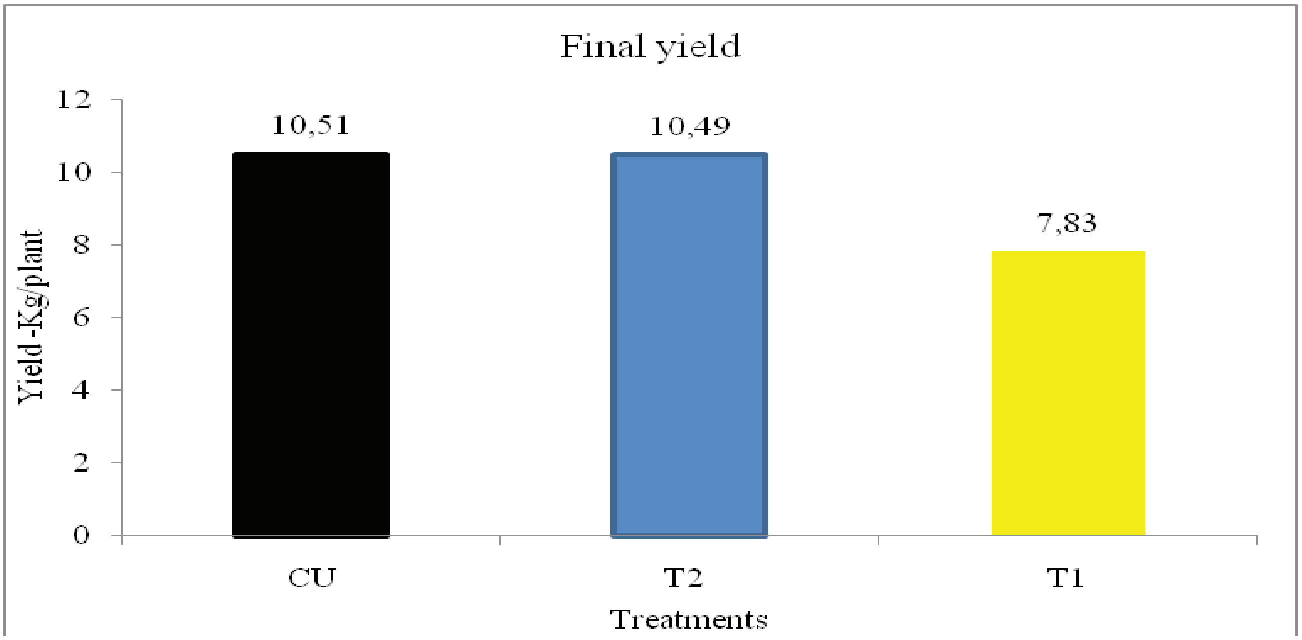

Fig. 11 Final harvested yield (kg/plant), of tomato crops and for the different foliar application of micronutrients (small letters indicates the statistically homogenous groups)

Photo harvesting tomato fruit per plant and for the different micronutrients foliar applications

Cumulated yield

Figure 10 shows the variation of harvested yield during the growing period of tomato. Presented results indicate that before the harvest of the 4th cluster there was no difference between treatments, and all treatments have similar yield. But since the harvest of the 5th cluster the difference starts to be appeared and becomes larger during the rest of the growing period in which 2 homogeneous groups were formed. The first group recording the highest yield was formed by treatment T2 and CU, the second group was formed by the water sprayed treatment (Control).

Fruit Size Distribution

Figure 12 presents the diameter distribution for each treatment. The big diameter was formed by diameter 1, 2 and 3 and the small formed by 4 and 5 (Annex Table 8).

The statistical analysis carried out on the effect of tested foliar treatments on fruit diameter of tomato has not revealed any significant difference. As general trend, the treatment sprayed with Metalosate® Crop-Up and the farmer practice solutions recorded the highest percentage of big diameters among all harvested fruits; while the water sprayed treatment (Control) T1 recorded the highest percentage of small and non commercial diameter. When converted to weight (Tons/Ha), the Metalosate® Crop-Up treatment yielded 188 tons/Ha of large size, whereas the commercial solution yielded 176 tons/Ha and the water treatment, 124 tons/Ha (table 3A). This indicates an increment of 12 tons in the large size fruits, and therefore more income to the grower. Even though, there was no statistical difference between the Crop Up and the commercial farmer's practices in terms of the total yield of the large fruit size, we can conclude that the Crop Up allow the farmers to gain €5,600 per hectare more than the growers standard treatment based on the export tomatoes price €0.70 per Kg. Also, our results indicate there was a very significant difference between the plants sprayed with Metalosate® Crop-Up and the plants sprayed with irrigation water, which allowed the farmers to gain €44,800 per hectare.

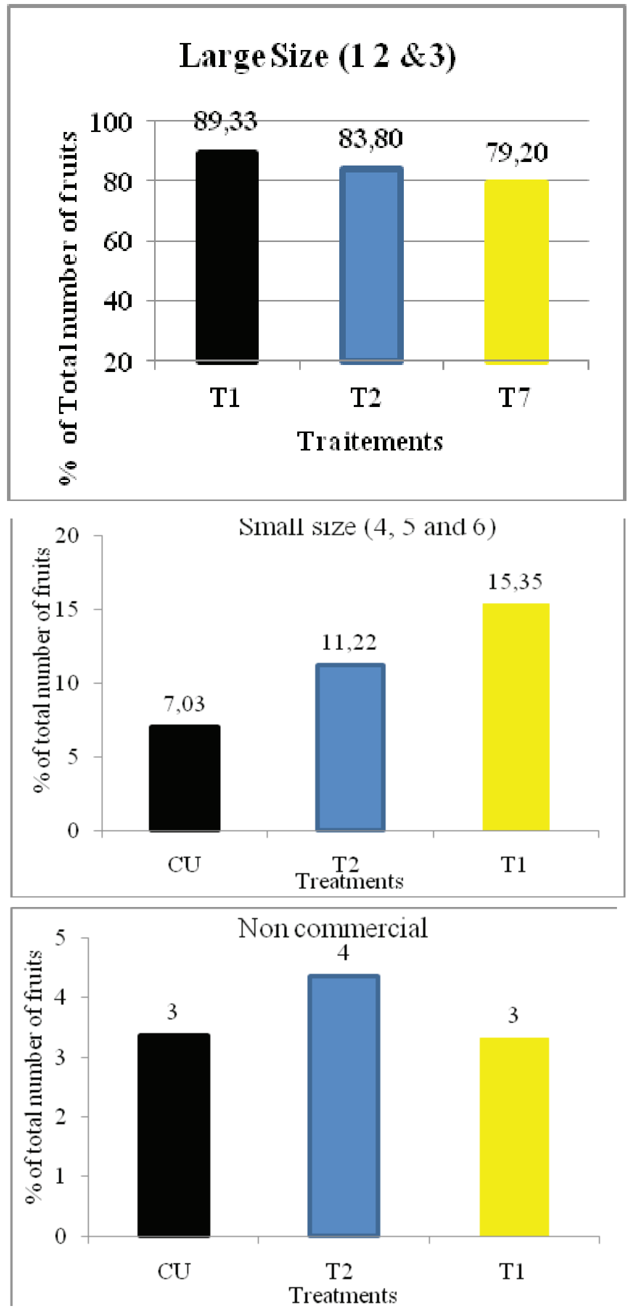

Fig. 12 Percentage of the fruits size and Non commercial fruit per treatment

Table 3A: Distribution of Fruit Size and Yield of Large Sizes/Ha

	Large Diameter	Small Size	Non Commercial	Yield of Large Diameter T/Ha
CU	89.33%	7.03%	3%	188 a
T2	83.80%	11.22%	4%	176 a
T1	79.20%	15.35%	3%	124 b

Firmness

According to Figure 13, treatment treated by the Crop up product recorded the highest firmness for the 4th Cluster while treatment T1 treated only by irrigation water showed the lowest firmness. However, for the 8th cluster there was no significant difference between the Crop up product and the commercial solution. This indicates that foliar treatments improved the fruit firmness compared to the control.

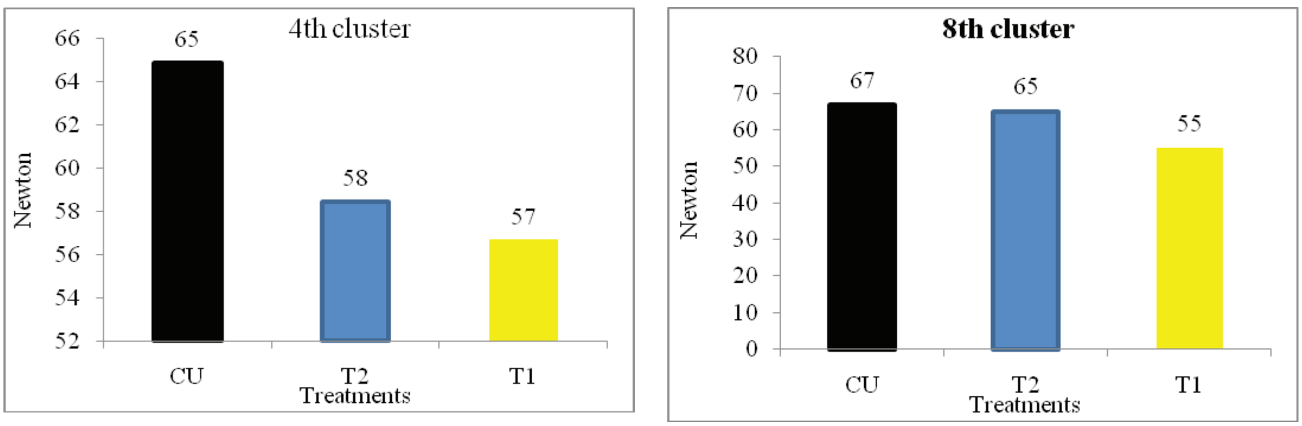

Fig. 13 Effect of the different foliar treatments on the firmness of tomato fruits at the 4th and the 8th Clusters**.**

Photo 2 stage of fruit coloration; firmness was measured for tomato crops

Fruit Acidity

Fruit acidity was low for all the treatment and Fig 14 indicates similar acidity for all foliar micronutrients with no significant differences with the control.

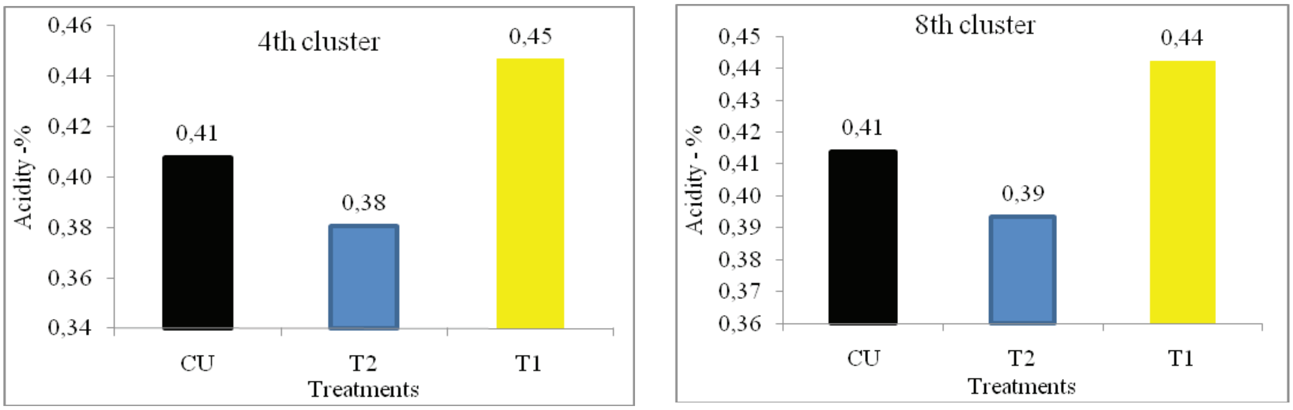

Fig 14 Effect of the different foliar treatments on the Acidity of tomato fruits at the 4th and the 8th Clusters

Soluble Solid Extract (SSE)

Tested foliar Micronutrients did not significantly affect the sugar content of the tomato fruits. Measurements of fruit quality of tomato are shown in Fig 15. It is known that fruit quality is better when °Brix, is high and the pH is low (Niedziela et al., 1993). Desirable °Brix is normally over 5. All treatments produced fruits at all clusters with °Brix close to 5, indicating a medium fruit quality.

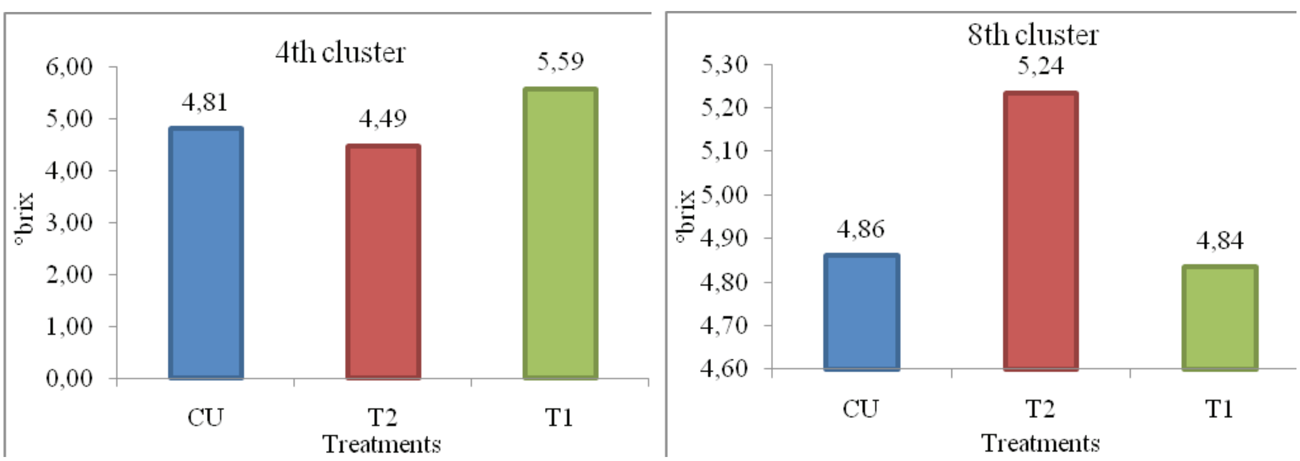

Fig 15 Effect of the different foliar treatments on the Soluble Solid Extract of tomato fruits at the 4th and the 8th Clusters.

Foliar analysis

Table 4 shows the foliar analysis data obtained for sampled leaves during the flowering of the 3rd cluster. There was no significant difference between tested treatments for all major elements. For the micronutrients concentration, the only difference has been obtained for Iron (Fe), for which the treatment T2 recorded the highest Fe concentration in leaves and this can be explained by the high concentration of Fe in the commercial product T2 (6.79% compared to less 0.25% for the Crop up treatment).

Leaves sprayed with the commercial product (T2) had a significantly higher content of Fe and Zn than the leaves sprayed with water. The leaves treated with Metalosate® Crop-Up solution presented significantly higher Fe concentration in the leaves than the control leaves.

Table 4: Foliar analysis

Treatments	N	S	P	K	Mg	Ca	Fe	Mn	B	Cu	Zn
	% Of dry matter						ppm				
T2	4.52	0.78	0.31	4.09	0.64	3.46	2774.00 a	69.75	30.00	32.75	119.00a
CU	4.53	0.81	0.35	4.23	0.64	3.46	647.25 b	63.75	28.25	31.25	70.25b
T1	4.61	0.81	0.32	3.45	0.53	2.26	166.00 c	64.67	25.00	30.33	76.33b

Conclusions

The aim of this experiment was to investigate the effects of Metalosate® Crop-up on tomato crops in terms of plant growth, performance, productivity, and fruit quality compared to standard micronutrient mixes used by local farmers and a control solution using only irrigation water.

The results indicate that applying Metalosate® Crop Up as a foliar application resulted in the highest percentage of large fruit diameter among harvested yield with an increase of 12 MT/Ha over the commercial solution and 64 MT/Ha over the water treatment. At an export price of € 0.7/Kg this represents an additional income of € 5,600/Ha to the grower generated by the Crop-Up treatment over the grower's traditional treatment and € 44,800/Ha over the water control. The Crop-Up treatment also yielded the highest firmness. These results indicate that Metalosate® Crop Up is an efficient foliar material which is highly recommended especially for the tomato cropping system destined for export, providing increased income for the farmers.

Our findings also indicate that the grower's commercial solution accounted for increase of marketable yield by 34 %, and slightly higher mean fruit weight compared to water treatment. This commercial product is very rich in Fe and Mn, and contains B. This high level of micronutrients is reflected in the foliar analysis results at the third cluster stage.

ANNEXES

Table 5 Plant height evolution during the growing cycle of tomato crops and for the different foliar application of micronutrients.

	01/02/2013	11/02/2013	21/02/2013	03/03/2013	13/03/2013	23/03/2013	02/04/2013
CU	39.38	53.63	62.38	79.16	93.44	127.50	136.69
T2	38.19	52.25	61.56	78.19	94.81	120.00	132.25
T1	35.28	48.69	58.44	75.84	95.75	125.19	128.69

	12/04/2013	22/04/2013	02/05/2013	12/05/2013	22/05/2013	22/05/2013	11/06/2013
CU	166.00	185.03	204.06	223.09	252.41	261.59	296
T2	161.25	184.03	206.81	229.59	258.59	270.84	296
T1	163.25	174.66	186.06	197.47	232.03	235.53	265

Table 6 Number of Fruit per size (diameter 1 to 6) for each treatment and for each Bloc

Bloc	Treat-ment	Non com-mercial	Diameter 1	Diameter 2	Diameter 3	Diameter 4	Diameter 5	Diameter 6	Total fruits
1	CU	2	24	212	104	15	1	0	360
	2	2	16	61	116	97	9	0	303
	1	8	61	146	107	31	6	0	367
2	CU	19	77	208	67	2	0	0	374
	2	29	149	160	67	16	0	0	423
	1	15	54	147	75	17	5	0	320
3	CU	5	26	130	179	79	1	0	421
	2	18	100	114	51	17	3	0	305
	1	10	53	152	123	31	2	0	378
4	CU	21	109	103	8	0	0	0	242
	2	7	124	110	5	2	0	0	250
	1	10	18	28	72	104	5	0	244

Table 7 Average Flower per cluster

	B1	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**B8**	**B9**	**B10**	**Average**
CU	**7.31**	**7.63**	**7.88**	**8.38**	**7.94**	**8.63**	**8.88**	**8.75**	**8.50**	**8.44**	**8.23**
T2	**7.38**	**7.63**	**7.88**	**8.31**	**7.81**	**8.56**	**8.81**	**8.81**	**8.38**	**8.38**	**8.19**
T1	**7.00**	**7.25**	**7.44**	**7.31**	**7.06**	**7.44**	**6.69**	**6.75**	**6.94**	**6.75**	**7.06**

Table 8 Relative Percentage of the flower number per cluster compared to the control (T1)

%/T1	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	Average
CU	104	105	106	115	112	116	133	130	123	125	117
T2	105	105	106	114	111	115	132	131	121	124	116
T1	100	100	100	100	100	100	100	100	100	100	100

Table 9 Tomato Fruit number per cluster for the different foliar treatments

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	Average
CU	5.69	4.94	6.13	5.63	6.06	6.63	5.81	6.44	6.31	6.53	6.02
T2	5.63	4.81	6.06	5.69	5.94	6.56	5.94	6.50	6.25	6.47	5.98
T1	5.00	4.25	5.44	4.75	4.63	5.38	4.38	5.19	5.19	5.09	4.93

Table 10 Relative Percentage of the Fruit number per cluster compared to the control (T1)

%/T1	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	Average
CU	114	116	113	118	131	123	133	124	122	128	122
T2	113	113	111	120	128	122	136	125	120	127	121
T1	100	100	100	100	100	100	100	100	100	100	100

Table 11 Relative Percentage of the harvested Fruit compared to the control (T1) during the growing cycle

% / T1	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**	**R10**
CU	**110**	**97**	**104**	**111**	**119**	**117**	**123**	**127**	**131**	**134.25**
T2	**95**	**96**	**112**	**114**	**124**	**124**	**128**	**130**	**132**	**134.00**
T1	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Table 12 Effect of the different foliar treatments on the tomato Fruit Size distribution

%	Large size 1,2 and 3	Small size 4 and 5	Non commercial	Extra large	Size 1	Size 2	Size 3	Size 4	Size 5	Size 6
CU	89.33	7.03	3	3	17	47	26	7	0	0
T2	83.80	11.22	4	4	30	35	19	10	1	0
T1	79.20	15.35	3	3	14	36	29	14	1	0

Table 13 Effect of the different foliar treatment on the Firmness of Tomato Fruits (Newton)

Firmness	**4th cluster**	**8th cluster**
CU	**6.61**	**6.80**
T2	**5.96**	**6.63**
T1	**5.78**	**5.60**

Table 14 Relative Percentage of the tomato fruit firmness of the different treatment compared to the control (T1)

% / T1	4th cluster	8th cluster
CU	114.50	121.43
T2	103.16	118.30
T1	100.00	100.00

Table 15 Effect of the different foliar treatment on the Acidity of Tomato Fruits (%)

% Acidity	**4th cluster**	**8th cluster**
CU	**0.41**	**0.41**
T2	**0.38**	**0.39**
T1	**0.45**	**0.44**

Table 16 Relative Percentage of the tomato fruit Acidity of the different treatment compared to the control (T1)

% / T1	4th cluster	8th cluster
CU	91.37	93.63
T2	85.21	88.99
T1	100.00	100.00

Table 17 Effect of the different foliar treatment on the Soluble solid extracts of Tomato Fruits (Brix)

SSE 23°C	4th cluster	8th cluster
CU	4.81	4.86
T2	4.49	5.24
T1	5.59	4.84

Table 18 Relative Percentage of the tomato fruit Soluble solid extracts of the different treatment compared to the control (T1)

% / T1	4th cluster	8th cluster
CU	86.12	100.52
T2	80.30	108.27
T1	100.00	100.00