Contribution of Fertilizer Application (Fertigation) to Improve Tomato Crop Production in the Souss-Massa Region

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ABSTRACT

Intensification of vegetable crop systems in the Souss-Massa has resulted in high qualitative and quantitative production. As a matter of fact, huge efforts have been deployed to reach high levels of productivity. Fertigation is among the techniques that have largely contributed to yield and fruit quality improvement. In 2004, the area presently under fertigation in Souss-Massa region is about 37500 ha (vegetables: 25000 ha; citrus: 9000 ha; banana: 3500 ha). Potassium supply is at least twice that of nitrogen. Nowadays the main crops (especially tomato) rarely show any K deficiency. However, fertilizer mismanagement is noticeable at certain periods of the year. This work (i) establishes a qualitative analysis linking potassium fertilization with environmental conditions (ii) presents some research results and (iii) suggests some practical recommendations aiming to optimize fertigation.

1. Introduction

During the last 20 years fertilizing irrigation (commonly called "fertigation") has known an outburst in the Souss-Massa region. Vegetable crop production farms equipped with a fertilizer injecting systems actually sum up to 25,000 ha whilst there were only 300 ha in 1990-1991. Citrus and bananas are the main other crops that use such a technology with 9,000 and 3,500 ha respectively.

Fertigation is in fact among other techniques that contributed to improve the productivity of vegetable crops. In addition to favorable climatic conditions, the use of greenhouses, the general utilization of drip irrigation –at least for protected crops-, the use of highly productive varieties, the increasing use of grafted seedlings and the good plant protection practices as well as the improved crop maintenance are factors that enabled the increase in yield. Technical supervision is improved. The export sector has been a real incentive towards the development of winter crops. Some figures illustrate the tendency: 191,045 tons of tomatoes were exported in 2003-2004 compared to 165,311 tons in 2002-2003; fresh beans occupy the second place with 76,550 tons exported in 2003-2004 compared to 52,453 tons in 2002-2003; melon is the main exported fruit with 28,127 tons in 2003-2004 (EACCE, 2004).

This paper is meant to present some problems related to the management of tomato crop fertigation. This will be done through the presentation of the results of a study conducted in 3 farms located in the Massa irrigated perimeter (Lakloumi et Merzouk, 1999). This qualitative approach will show the principal patterns observed in performing farms producing exportable crops. Other research results obtained at the IAV Hassan II, Agadir will also be presented as well as the efforts deployed by the professionals of the sector in order to optimize fertilizer application through irrigation.

2. Fertigation of tomato

The study was carried out in 3 vegetable crop production farms in the Massa. In these farms, called n°1, 2 and 3 respectively, the area of greenhouse tomato was 7, 3 and 3,2 ha respectively.

2.1. Production conditions: in the 3 farms, sowing was done in mid August and the crop was established under greenhouse during the first week of September. ‘Gabriella’ is the name of the variety. It is an F1 hybrid known to be vigorous, highly productive and resistant to N.V.K.F2. Plant density ranged from 15,000 to 18,000 plants per ha. It is a monoculture succeeding to another tomato crop. Prior to planting the soil was treated with methyl bromide. Drip irrigation was applied and the planting was in single rows under plastic mulch. Plants were conducted on a single stem and preventive treatments were applied for pest control. The life cycle of the crop can be divided into 4 phases:

- I: from the planting to the forming of the first fruit bunch
- II: from end I to the harvest of the 4^{th} fruit bunch
- III: from end II to the harvest of the 9^{th} fruit bunch
- IV: from end III to the harvest of the 16^{th} fruit bunch

The first fruits were observed in mid November and production continued until June.

2.2. Crop follow-up: fertigation was studied through regular sampling of soil and tomato petioles twice a month in each farm without interfering with their fertilizers programs. The objective was to qualitatively assess the technique of fertigation in these leading farms. Soil samples were taken on a 30 cm profile at mid distance between two drippers. Ten different soil samplings constituted a sample. Petioles were taken on the 5^{th} leaf from the apex. One sample is composed of 25 to 30 petioles. Parallel to soil and petiole sampling, tomatoes harvested were regularly weighed.

2.3. Initial status of the soil and water quality: in the studied farms, the soil has a sandy texture, fine sand representing on average 61%; coarse sand 27%, silt 9% and clay 3%. At the end of the preceding crop greenhouses were cleaned and the soil treated. The level of soil fertility was in general good and therefore none of the farms used slow release mineral fertilizers. Table 1 shows the fertility status of the soil in the 3 farms prior to planting.

Tableau 1. Fertility status of the soil in the 3 farms prior to planting

	EC (extrait1/5)	pH	$N\text{-}NH_4$	$N\text{-}N0_3$	P_20_5	K_2O	MgO	CaO	Fe	Mn
units	dS/m	-	ppm	ppm	‰	‰	‰	‰	ppm	ppm
value	0,062	8,53	408	18,16	0,307	0,515	4,661	2,863	12,101	23,186
optimum	0,2 to 0,3	6 to 7	10 to 20	50 to 80	0,05 to 0,12	0,3 to 0,9	0,2 to 0,4	0,8 to 3,2	4 to 15	4 to 15

Table 1 shows that the soil is clearly alkaline, low in nitric nitrogen but has a high concentration of ammonia. It is rich in phosphorous but low in potash. Calcium and Magnesium concentrations are very high.
Water for irrigation is supplied from the dam and from the water table with different quality: dam water has an EC below 0.4 dS/m and water table has an EC ranging from 0.7 and 1.22 dS/m.

2.4. Fertigation management: Table 2 presents the timetable for the application of the major fertilizing elements, in relation with the cycle phases of the crop. Figures are average of data taken from the 3 farms. Fertigation started immediately after crop planting. Fertilizer injector is a simple Venturi. It is important to note that the supply in potash was highest since it represented almost twice as much as that of nitrogen. The first growing phase, which lasted 1 month, corresponding to the establishment of the crop, used 10% of the total supply. Over 40% of total nitrogen supply happened during the 2nd phase, which lasted 6 weeks. Phases 2 and 3 were the most demanding in terms of potassium, phosphorous and magnesium. Each phase received 1/3 of the total input in these 3 elements. Each one of the phases 3 and 4 lasts 3 months on average. Total supply in nitrogen, P_2O_5, K_2O and MgO were respectively 865, 716, 1615 and 144 kg/ha.

Table 2: Timetable supply of major fertilizing element for a tomato crop in relation to growing stages

growing stages	N		P_20_5		K_2O		MgO	
	Kg/ha	%	Kg/ha	%	Kg/ha	%	Kg/ha	%
I	67,7	7,8	96,8	13,5	89,5	5,5	10,8	7,5
II	352,5	40,7	255,3	35,6	577,5	35,8	50,2	35,0
III	235,1	27,2	219,9	30,7	520,3	32,2	47,6	33,2
VI	210,0	24,3	144,3	20,2	428,0	26,5	34,8	24,3
Total	865,3	100,0	716,3	100,0	1615,3	100,0	143,8	100,0

As stated earlier, fertilizers were applied through irrigation. Water supplies during the 10-months-duration of the crop were 585, 555 and 412 for the 1rst, 2nd and 3rd farms. Irrigation was applied on a daily basis; doses ranging from 500 ml/plant/day at the establishment of the crop in September to 1.5 ml/plant/day in mid-November. Peaks of 1.7 ml/plant/day were recorded during hot periods. Dam water was used preferentially unless there is a shortage, in which case water is pumped from the aquifer.
Fertigation was controlled using indications from the electrical conductivity of the daughter solution. On average EC values approached 2 dS/m before fruit setting and once the crop was in full production they were above 3 dS/m.

2.5. Fertigation and the Environment: It is important to point out that tomato production in winter means that the crop is established at the end of summer; production starting at the beginning of autumn and peak production is reached in winter. If conditions are favorable, sustained harvesting lasts until June.
Growth and development of the plant coincides with midday temperatures above 30°C in the greenhouse and night temperatures above 17°C. This is due to solar radiation above 1,500 j/cm2 and daylight lasting more that 15 hours. Plants evolve from a vegetative phase to a generative one in almost optimal micro-climatic conditions. Water and nutrient requirements are consequently high (over 1 L/plant/day).

After mid November, a noticeable drop in temperature occurs when plants are at the 8^{th} or 9^{th} fruit bunch fully formed. Temperature is less than 25°C during the day and below 10°C during the night. Solar radiation is less than 1,000 j/cm2 and night periods are longer with higher relative air humidity. Plants etiolate, pollination is deficient and the metabolism is slowed down at a period when fruit setting is high. In most cases farmers continue to give high irrigation doses enriched with fertilizers.

2.6. Fertigation and yield: Figure 1 shows tomato yields in the 3 farms of the study over periods of 15 days. Production started in mid November with an average yield of 11.2 t/ha, which lasted until end November. Average yield peak was observed between 26 December and 10 January when it reached 21.4 t/ha. Farm 1 had a maximum yield of 25 t/ha at 2 different periods (January and March). Total yield was 262, 220 and 212 t/ha in the three farms respectively over a harvesting period of 7 months. Average yield of the 3 farms was 231 t/ha.

3. Discussion

The results show that for the production of 1 ton of fruits, farmers have supplied (in kg/ha) 3.71 N; 3.10 P_2O_5; 6.99 K_2O and 0.62 MgO. According to SASMA standards as reported by Hartiti and Goumih (1991) these figures are in conformity for nitrogen and potassium but are 37 % in excess for phosphorous and 67 % in defect for magnesium. Such patterns are quite normal since efficiency in the use of phosphorous hardly reaches 50 %.
In spite of the important supply in fertilizers, the yield pattern shows a decrease in mid winter (Fig. 1). Unfavorable environmental conditions can partly explain this decrease. Fruit quality is also affected. Among the causes blossom end rot is due to an induced calcium deficiency brought about by an excess in potassium. Phosphorous deficiency is also noticeable and induces a reduction in fruit quality thus increasing a high percentage of fruits not meeting export standards (discarded fruits), reaching 30 to 50 % of total yield.

Nutritional imbalance is illustrated in Figure 2 showing that in the soil the K_2O/MgO ratio decreases regularly from December to January. This ratio should be 1 to 1 (Letard et al, 1995). The ratio of K to Ca+Mg had values below 0.5 during winter whilst it should be above 0.5. Nevertheless research carried out on tomatoes in soil less culture (Cooper, 1981) show that the crop tolerates variations in the ratios between elements as the N to K ratio. Brun and Blanc (1987) have shown that in a tomato crop conducted in soil less culture during autumn, the balance between fertilizing elements N,P,K are 1:0.21:1.43 during the first phase, 1:0.22:1.60 during the second and 1:0.32:3.00 during the third.

In order to compensate low absorption potential of the roots during the cold period, farmers regularly spray foliar fertilizers based on calcium, phosphorous and trace elements (especially iron). We have decided to study the case of Farm 1. Results are presented in Figure 3. Although potassium concentration in the petioles declined between October and February, it remained in a rather optimal interval (3 to 6% of dry matter). On the other hand, between end January and end April the concentration of calcium was below 2% and therefore the plants were deficient since the optimal should be between 2 and 4%. The concentration of phosphorous and magnesium was also below the optimum (0.4 to 0.9%) from January to March, keeping a value below 0.4%.

Foliar diagnosis is an important procedure to assess the nutritional status of the plants and hence a statistical study was carried out using the multiple regression method with the aim of showing a possible relationship between yield and concentration of major elements in the petioles (N, P, K). Results show that there is a highly significant linear correlation between yield and the concentration of these elements in the petioles. Correlation equations obtained during phases 3 and 4 of the crop are:

Phase III : Yield (T/ha/week) = 17,11 NO_3 + 3,54 P + 2,02 K (n= 28 ; r=0,99)
Phase IV : Yield (T/ha/week) = 24,13 NO_3 – 6,63 P + 2,36 K (n= 28 ; r=0,99)

It can be asserted that yield can be explained through nutritional elements in the leaves. This is an important result since it can enable farmers predict their yield through leaf analyses.

4. Conclusion

Autumn and winter periods are critical for tomato crop production as there is an important issue for water and mineral absorption. Unfavorable microclimatic conditions disturb nutritional balance of plants. Unable to control and adapt the climate inside greenhouse shelters, farmers endure this situation. In addition soil cannot be easily turned into a favorable factor for water and mineral plant nutrition as it has a low buffer potential due to sandy texture, low CEC and above all very low organic matter content (less than 1% on average). During cold periods farmers inject humic acid in order to improve physic-chemical soil properties. Shoot part of the plants is regularly sprayed with different nutritive solutions. Fruits are thinned to improve their quality.

Acknowledgements

Results presented in this paper were compiled from a thesis jointly conducted by Lakloumi and Merzouk in 1999. The author is thankful to Mr. Mohmoh, Saïdi and Baâlla, engineers and farmers, for their amiable co-operation. The author would also like to thank Professor MC Harrouni for reviewing and translating the text.

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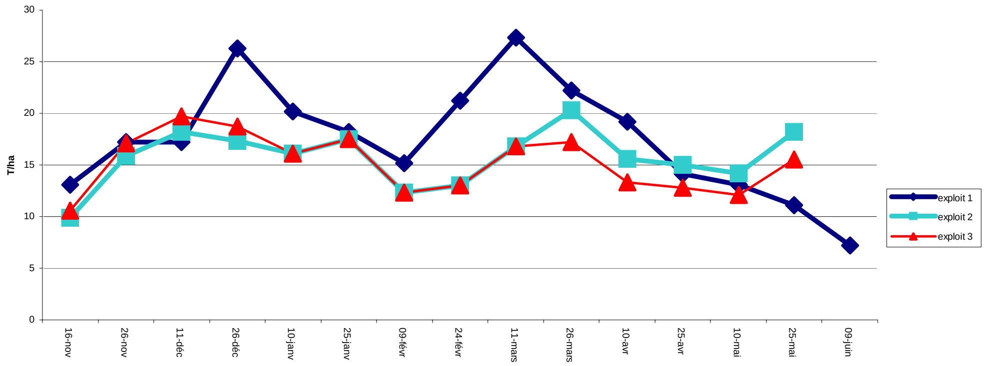

Figure 1: Tomato yield evolution (T/ha) in the tree farms studied

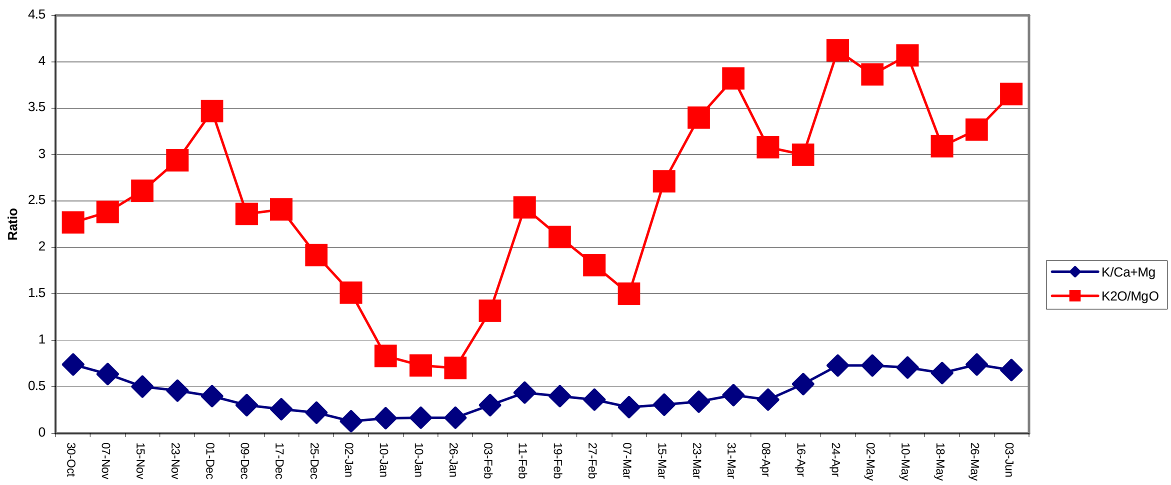

Figure 2:Evolution of K/Ca+Mg and K2O/MgO soil ratio

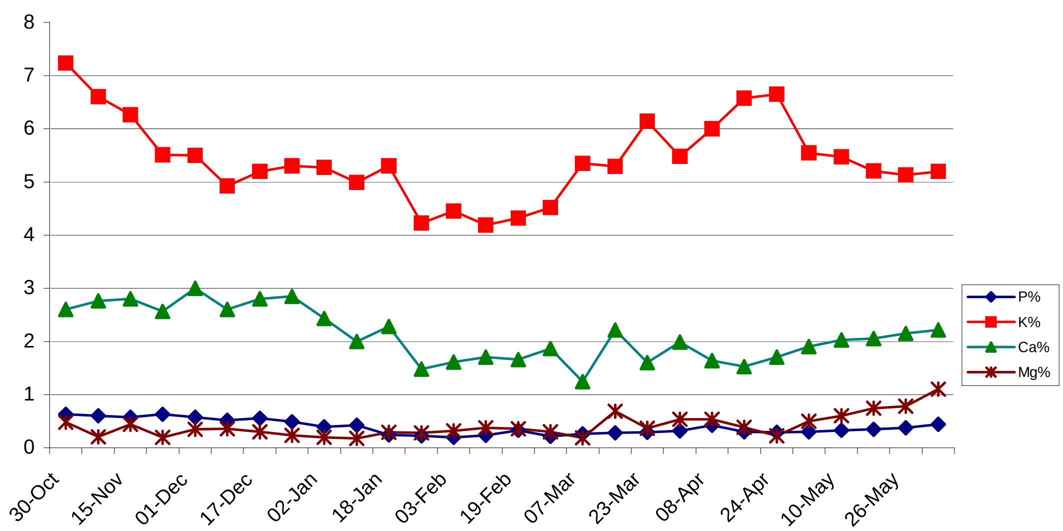

Figure 3: Evolution of tomato foliar P.K.Ca.Mg elements (% Dry Weight)