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MINERAL FOLIAR NUTRITION IN HORTICULTURAL PLANTS.
 II - THE CONTROL OF BLOSSOM - END ROT IN TOMATO FRUITS
 (*Lycopersicon esculentum* L. cv Rossol Mejorado INTA) AND ON
 PRODUCTIVITY OF THE POTATO (*Solanum tuberosum* L.
 cv Claustar) ¹

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I. INTRODUCTION

Blossom-end rot in tomato fruits considerably affects its quality and yield.

The disease, which produces dry apical necrosis of corklike appearance in the fruits, is considered to be of physiological origin. In general, it has been poorly studied in relation to the mechanism concerned, though it would be related with the fixation of Ca in the middle lamella of cells as organic salts of uronic acids (24).

Nevertheless, there are some factors which contribute to the onset of the disease. In that sense, periods of water stress during flowering and fruit set favors its occurrence which is correlated with a decrease of Ca in the foliage and clusters (2, 7, 8, 21).

It has also been demonstrated that a shortage of Ca in the soils favours the appearance of the disease (8, 15). Moreover, the presence of certain cations like NH_4^+ and Mg^{2+} in soil antagonise the uptake of

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Ca and disturb its translocation toward the fruits. Nevertheless, this does not happen if the available nitrogen is in the form of NO_3^- (1, 11, 19, 20, 30).

It has also been observed that cultivars show different behaviours in relation to the uptake and translocation of Ca. Some of them show certain difficulties to absorb and translocate this cation. On the contrary, some others are moderately resistant because they need little Ca in its metabolism (9).

Foliar sprays of Ca were used to compensate a decrease on yields as a consequence of a fertilization with ammonium sulphate (1).

Few works deal with foliar nutrition with Ca in order to compensate low levels and availability of this cation in the soil. Contradictory results on the subject were obtained. Some authors support the idea that foliar sprays with $\text{Ca}(\text{NO}_3)_2$ or CaCl_2 effectively reduce blossom-end rot while others have not found a positive response (3).

In the potato (*Solanum tuberosum* L.) the productivity depends on the photosynthetic potential of a well developed foliage and on the physiological age of the "seed-tuber" (10, 27). It also depends on a good supply of P, K and B which play important roles on sugar translocation and on starch synthesis in the tubers.

P is an essential nutrient for sugar phosphorylations and for the synthesis of sugar-nucleotides like uridinediphosphate-glucose (UDPG) and adenosinadiphosphate-glucose (ADPG) which transfert glucose to amylose and amylopectin in starch grains (4, 12).

K exerts a strong stimulating effect on the incorporation of glucose to amylose and amylopectin from ADPG (18). This fact would explain low levels of starch synthesis in plants growing in soils poor in K. Nevertheless, NH_4^+ may replace the action of this cation (25). This fact brings about the question whether the absence of K in certain soils is the principal reason for a low synthesis of this carbohydrate (26).

K seems to exert an important role in the translocation of carbohydrates in cassava. Plants deficient in K showed a lower starch content in roots, in relation to the normal ones (13).

The translocation of sugars seems to depend to a great measure on the presence of borate in the foliage. This nutrient would form sugar-borate complexes with a negative charge in the molecule which would be capable to move-through the membranes easily (16, 17, 23).

On the other hand, BO_3^- could be located into the cellular membranes where it would acts as a ionic carrier (5, 6).

Foliar absorption and translocation of ^{14}C -saccharose is considerably delayed on plants deficient in boron (23). Other authors think that the lack of this nutrient promotes phloem necrosis which would affect the translocation of photosynthates (14).

The aim of the potato trial was to study a possible increase on yields with foliar sprays of a mineral nutrient solution containing high levels of P, K and B.

II. MATERIALS AND METHODS

Tomato. Young plants of *Lycopersicon esculentum* Mill cv Rossol Mejorado INTA previously grown on glasshouse conditions, were transplanted to the field in blocks at random. Each plot had four rows with five plants per row. The distance between rows was 0,75 m and 0.30 m between plants. The soil had a silty-sandy structure with a Ca content of 8-8,7 Meq/100 g of soil.

The treatments were performed with four repetitions as follows:

- 1 – Control, sprayed with a solution of Tween 20 0,04%;
- 2 – Sprayed with a mineral solution containing CaCl_2 2000 ppm, KH_2PO_4 3000 ppm, MgSO_4 3000 ppm, K_2SO_4 1500 ppm, H_3BO_3 500 ppm, ZnSO_4 500 ppm, $\text{MnSO}_4 \cdot 4\text{H}_2\text{O}$ 300 ppm, $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ 50 ppm, $\text{Na}_2\text{MoO}_4 \cdot 2\text{H}_2\text{O}$ 14 ppm and Fe and Na EDTA 15 ml/l with Tween 20 0,04% as a wetting agent;
- 3 – Sprayed with the same solution but deprived of CaCl_2 which was replaced with an equivalent molar concentration of KCl.

In all cases the pH of the solutions was adjusted to 5,2 with NaOH 1 N.

Foliar sprays were done on three occasions between the beginning of blooming in the first cluster and the third one. Special care was taken in order to wet the clusters taking into account that Ca sprayed on leaves is not translocated out (28).

The harvest spans from early maturity of fruits of the first cluster to early maturity of the fruits of the third one. Small fruits were discarded.

The following parameters were analysed: a) number of flowers and young fruits of the first and second clusters; b) mean number of seeds per fruits; c) percentage of fruits with 2, 3 or four loculus; d) number of diseased fruits, and e) yield in fresh weight of healthy fruits at early maturity.

Potato. Sprouted middle size tubers (70-90 mm) of the cv Claustar of first multiplication in La Carrera, department of Tupungato, province

of Mendoza, Argentine, were used. The plantation was done in a comparative yield trial on random blocks in the region of La Carrera (2300 m). Four treatments were performed:

- A – Without soil fertilization (OSF); without foliar fertilization (OFF);
- B – With soil fertilization (WSF); without foliar fertilization (OFF);
- C – Without soil fertilization (OSF); with foliar fertilization (WFF);
and,
- D – With soil fertilization (WSF); with foliar fertilization (WFF).

Ten repetitions were made for each treatment. Each repetition represented a plot of two rows 10 m long with 25 plants per row. Distance between rows was 0,70 and 0,20 m between plants.

Two untreated rows were left within the plots in order to prevent the migratoin of the fertilizers by irrigation and to avoid the spread of the sprayed solutions.

Soil fertilization was carried out at planting with a mixture of $(\text{NH}_4)_2\text{HPO}_4$ and $(\text{NH}_4)_2\text{SO}_4$ 300 kg/He each one as is usually employed it that region. The fertilizers were sprayed in two small furrows on both sides of the tubers.

Foliar fertilization was applied on three occassions. The first was done when the plants were 20-25 cm tall. The others spaced 15 days.

The mineral nutritive solution contained urea 3000 ppm, K_2HPO_4 3500 ppm, MgSO_4 3000 ppm, KCl 1500 ppm, H_3BO_3 1000 ppm, $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ 1500 ppm; ZnSO_4 500 ppm. $\text{MnSO}_4 \cdot 4\text{H}_2\text{O}$ 300 ppm, $\text{Na}_2\text{MoO}_4 \cdot 2\text{H}_2\text{O}$ 100 ppm, and $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ 50 ppm.

The pH of all solutions were adjusted to 5,6 with NaOH 1N.

The soil had a slime-sandy structure. During the vegetative cycle a moderate attack of *Fusarium* was observed which produced a 20% of failures.

III. RESULTS

Tomato. The results of table 1 concerning the number of flowers and young fruits of the first and second cluster were analysed by means of Wilcoxon test (31). The results show no significant differences in the number of flowers. Nevertheless, it was observed a significant decrease (at 5 and 10% levels of significance) in the number of young fruits of the first cluster in the treatment with Ca in relation to the control and the treatment with the nutrient solution deprived of this cation. These results are in agreement with those obtained by Baker (1). This

T A B L E 1

MEAN NUMBER OF FLOWERS AND FRUITS OF THE FIRST AND SECOND CLUSTERS OF TOMATO PLANTS

C V: ROSSOL. MEJORADO INTA.

Treatment	First Cluster		Second Cluster	
	Nº Flowers	Nº of Fruits	Nº of Flowers	Nº of Fruits
Control	5.6	3.6	5.6	3.6
Cl ₂ - Ca	5.4	4.6	5.5	4.2
Cl ₂ + Ca	4.7	3.1	5.3	3.8

References:

* Mean number of 12 plants.

C - Cl₂ Ca Complete nutrient solution without Ca.C + Cl₂ Ca Complete nutrient solution with Ca.

T A B L E 2

YIELD IN FRESH WEIGHT AND NUMBER OF NORMAL, HEALTHY FRUITS OF TOMATO PLANTS C.V. ROSSOL MEJORADO INTA

Treatment	Nº of Normal healthy fruits	Yield in * fresh weight (kg)	Nº of di- * seased Fruits	Mean fruit * weight
Control	2540	96,3	315	37,90
C - Cl ₂ Ca	2812	108,2	266	38,48
C + Cl ₂ Ca	2570	97,1	150	37,78

References:

* ————— 80 plants per treatment.

C - Cl₂ Ca Complete nutrient solution without Ca.C + Cl₂ Ca Complete nutrient solution with Ca.

author found that a high content of Ca at cluster level reduced the number of fruits. These differences were not observed in the second cluster.

No differences were observed in relation to the mean number of seeds and on the number of loculus per fruit. The statistical analysis of these results was carried out with the test of multiple proofs of Tuckey(29).

The statistical analysis of diseased fruits was performed with the CHI² test (22). The treatment with the nutrient solution containing Ca has produced a highly significant decrease (at 0,001% level of significance) in the number of diseased fruits. Moreover, it is evident that the treatment with the nutrient solution deprived of Ca has also reduced significantly the number of fruits affected by blossom-end rot but only at 5% level of significance in respect to the control.

The yield in fresh weight of fruits was statistically analysed with the test of multiple comparaisons of Tuckey (29). No significant differences between treatments were observed (table 2).

Potato. The results of table 3 and 4 clearly show that soil fertilization increases yield significantly (at 1% level of significance), which is correlated with a similar significant increase in tuber number per plot.

It can also be observed that foliar fertilization significantly increases (at 5% level of significance) yield but only if this treatment is preceded by soil fertilization. In this case the increase in yield is only in agreement with a higher tuber weight, because there are not significant difference in tuber number between WSF-WFF and WSF-OFF treatments.

IV. DISCUSSION

Tomato. The absence of differences in yield of healthy fruits means that though Ca significantly reduces the number of diseased fruits, it does not increase their production. This fact seems to be correlated with a significant decrease in the number of young growing fruits of the first cluster induced by the same cation.

It is interesting to point out that though the nutrient solution deprived of Ca significantly reduces the number of diseased fruits (but only at 5% level of significance), it is the deficiency of Ca the principal factor which determines the development of the disease, whose action seems not to be completely replaced by another nutrients.

The absence of results observed in that sense by other authors after spraying tomato plants with Ca solutions seems to suggest that the action of this nutrient depends on the presence or interaction with other ions.

T A B L E 3
POTATO YIELD
ANALYSIS OF VARIANCE

	\bar{X} (in kg)	A	B	C	D
A	35.75	—	xx	—	xx
B	66.65	—	—	xx	x
C	35.90	—	—	—	xx
D	72.10	—	—	—	—

SOURCE OF VARIATION	DEGRESS OF FREEDOM	SS	MS	F
BETWEEN BLOCKS	9	697.28	77.48	
BETWEEN TREATMENTS	3	11.346.32	378.11	191.4 xx
ERROR	27	533.50	19.76	
TOTAL	39	1.257.11		

$$5\% \Delta 3.87 \times 1.40 = 5.42 \text{ Kg}$$

$$1\% \Delta 4.85 \times 1.40 = 6.79 \text{ Kg}$$

REFERENCES

- = NON SIGNIFICATIVE DIFFERENCE
 x = SIGNIFICATIVE DIFFERENCE
 xx = HIGHLY SIGNIFICATIVE DIFFERENCE

T A B L E 4
NUMBER OF TUBERS
ANALYSIS OF VARIANCE

	X (Nº OF TUBERS)	A	B	C	D
A	314.3	—	xx	—	xx
B	401	—	—	xx	—
C	314.6	—	—	—	xx
D	419.6	—	—	—	—

SOURCE OF VARIACION	DEGRESS OF FREEDOM	SS	MS	F
BETWEEN BLOCKS	9	14.397	1.599.7	
BETWEEN TREATMENTS	3	93.603	3.120.1	22.99 xx
ERROR	27	36.650	1.357.4	
TOTAL	39	144.650		

1% $\Delta = 4.85 \times 11.69 = 56.70$ TUBERS

5% $\Delta = 3.87 \times 11.69 = 45.24$ TUBERS

REFERENCES

- x = SIGNIFICATIVE DIFFERENCE
 — = NON SIGNIFICATIVE DIFFERENCE
 xx = HIGHLY SIGNIFICATIVE DIFFERENCE

Potato. The correlation between increased yield and tuber number in treatments with soil fertilization would be a consequence of a higher photosynthetic efficiency of treated plants, taking into account that no differences were observed in plant height and size between treatments. On the contrary, the significant increase in yield of the treatment WSF-WFF is in agreement with an increased size of tubers. This fact would indicate a higher efficiency in the translocation of photosynthates towards the growing tubers, possibly due to a better disponibility at foliar level of P, K and boron.

The absence of significant differences between the treatments OSF-OFF and OSF-WFF clearly shows that foliar nutrition does not replace soil fertilization at least in the conditions of performance of this trial.

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VI. SUMMARY

Ca Cl₂ 2000 ppm in a nutritive mineral solution of KH₂PO₄ 3000 ppm, K₂SO₄ 1500 ppm, H₃BO₃ 500 ppm, ZnSO₄ 500 ppm, MnSO₄ 4H₂O 300 ppm, CuSO₄ 5H₂O 50 ppm, Na₂MoO₄ 2H₂O 14 ppm and Fe and Na EDTA 15 ml/l was sprayed on foliage of tomato plants cv Rossol Mejorado INTA on three occasions starting before blooming in the first cluster. The treatment yielded a highly significant decrease (at 0,001% level of significance) on fruits affected by blossom end rot. No significant differences were observed in the fresh weight of healthy fruits in relation to the control and the treatment with the nutrient solution deprived of Ca. This could be due to the fact that Ca diminishes the number of growing fruits in the first cluster. In potato, three foliar sprays of a nutrient solution containing urea 3000 ppm, K₂HPO₄ 3500 ppm, MgSO₄ 3000 ppm, KCl 1500 ppm, H₃BO₃ 1000 ppm, FeSO₄ 7H₂O 1500 ppm, ZnSO₄ 500 ppm, Na₂MoO₄ 2H₂O 100 ppm and CuSO₄ 5H₂O 50 ppm, applied on young plants at intervals of 15 days produced a significant increase (at 5% level of significance) in yield only in the case of a previous edaphic fertilization based on a combination of (NA₄)₂HPO₄ and (NH₄)₂SO₄ 300 kg/He each one. In this case, the increase in yield was due to a higher tuber weight.

RESUMEN

Aspersiones por vía foliar de CaCl₂ 2000 ppm acompañadas de una solución nutritiva compuesta de KH₂PO₄ 3000 ppm, MgSO₄ 3000 ppm, K₂SO₄ 1500 ppm, H₃BO₃ 500 ppm, ZnSO₄ 500 ppm, MnSO₄ 4H₂O 300 ppm, CuSO₄ 5H₂O 50 ppm, Na₂MoO₄ 2H₂O 14 ppm y EDTA de Fe y Na 15 ml/l, aplicadas en tres oportunidades a partir del inicio de la apertura floral del primer racimo de tomate cv Rossol Mejorado INTA, producen una reducción altamente significativa (a nivel del

0,001%) en el número de frutos afectados por necrosis apical. No se observaron diferencias significativas en el rendimiento en peso fresco de frutos no afectados por la enfermedad en relación al testigo y a la variante solución nutritiva carente de Ca. Ello se debería a que el tratamiento con este catión produce un número significativamente menor de frutos cuajados en el primer racimo. En papa, tres aspersiones foliares de una solución nutritiva compuesta de urea 3000 ppm, K_2HPO_4 3500 ppm, $MgSO_4$ 3000 ppm, KCl 1500 ppm, H_3BO_3 1000 ppm, $FeSO_4 \cdot 7H_2O$ 1500 ppm, $ZnSO_4$ 500 ppm, $Na_2MoO_4 \cdot 2H_2O$ 100 ppm y $CuSO_4 \cdot 5H_2O$ 50 ppm, aplicadas sobre jóvenes plantas a intervalos de 15 días, produjeron un aumento significativo (a nivel del 5%) en los rendimientos del cv Claustar. Dichos aumentos sólo se produjeron si previamente las plantas se fertilizaron por vía edáfica con $(NH_4)_2HPO_4$ y $(NH_4)_2SO_4$ a razón de 300 kg/Ha de cada fertilizante. Los aumentos en los rendimientos se debieron a un mayor tamaño de los tubérculos y no a un mayor número de los mismos.

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