International Journal of

Agricultural Research

ISSN 1816-4897

Academic Journals Inc.

www.academicjournals.com

International Journal of Agricultural Research 5 (10): 821-831, 2010
ISSN 1816-4897

Effects of Fertilizers Containing Calcium and/or Magnesium on the Growth, Development of Plants and the Quality of Tomato Fruits in the Western Highlands of Cameroon

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Abstract: The study was undertaken to determine the effects of calcium and magnesium nutrients on the development of plants and subsequent postharvest conservation of tomato fruits. Tomato plants were treated by applications of N/P/K (9.5/8/10) and fertilizers containing Ca^{2+} and/or Mg^{2+}. Control plants received only N/P/K. Two fertilizer combinations (N/P/K + foliar spray of Manvert Magnesium and N/P/K + calcium nitrate at 800 kg ha^{-1} + foliar spray of Manvert Magnesium) induced a significant delay in the flowering of plants. Combinations of soil applications of N/P/K and calcium nitrate at 200 kg ha^{-1} with foliar sprays of Manvert Calcium and/or Manvert Magnesium led to significant increases in the content of Ca^{2+} in mature-green fruits and subsequently to the delay of their ripening and the prolongation of the conservation period. Combinations of N/P/K + calcium nitrate at 200 kg ha^{-1} + Manvert Magnesium and N/P/K + calcium nitrate at 400 kg ha^{-1} + Manvert Calcium + Manvert Magnesium led to significant increases in the Mg^{2+} content in fruits. Fruits produced by plants that received these fertilizer combinations also showed a prolongation of the duration of ripening period and that of the conservation. The longest shelf-life was obtained after simultaneous applications on soil of N/P/K and calcium nitrate at 200 kg ha^{-1} and foliar sprays of Manvert Calcium and Manvert Magnesium. These results indicated that calcium and magnesium could be considered as key elements of fertilizers with regard to the delay of ripening of mature-green tomato fruits and to the prolongation of the shelf-life of the red-ripe ones.

Key words: Ca^{2+}, Mg^{2+}, ripening, shelf-life, *Solanum lycopersicum*

INTRODUCTION

In the course of the past decades, coffee was the main source of income for most of farmers in the western highlands of Cameroon. But now, these farmers have to face the problems of the drastic price reduction and the decrease in the production of these cash crops due to the exhaustion of cultivated soils (Kuete, 2008; Gillermou and Kamga, 2004). It therefore becomes urgent to search for alternative income generating products. In this context, seasonal cultures such as vegetables and fruits are gaining more and more interest.

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Indeed, fruits like tomatoes can be cultivated as well during the raining season on lands as during the dry season on marshes. Thus, farmers can harvest tomato fruits twice a year (Uwizeyimana, 2009).

The tomato fruit is one of most widely grown fruits for consumption with more than 122 million tons being produced worldwide in 2005 (FAOSTAT, 2005). It plays an important role in human nutrition due to its content in flavonoids, carotenoids and vitamins (Abushita *et al*., 2000; Scalbert and Williamson, 2000; Rodriguez-Amaya, 1999). β-Carotene found in tomatoes is the most potent dietary precursor of vitamin A, the deficiency of which leads to blindness and premature death (Mayne, 1996). Carotenoids and flavonoids, when taken regularly and in considerable quantities, provide health benefit by decreasing the risk of disorders (e.g., certain cancers and cardiovascular diseases) and the incidence of age-related degeneration (Santagelo *et al*., 2007; Giovannucci, 1999; Weisburger, 1998; Seddon *et al*., 1994).

Although, new cultivars are already known, most of the developing countries are still facing enormous postharvest losses in quality (appearance, firmness, flavor and nutritional value) and quantity of tomato fruits mainly due to the inaccessibility of genetically ameliorated seeds and inadequate fruit conservation methods (Kader, 1986, 2005). Generally, the productivity of plants and quality of fruits can be ameliorated either through genetic engineering or cultivation practices. In this regard, applications of fertilizers containing calcium and/or magnesium concomitantly with standard N/P/K-fertilizers could positively influence the growth and development of plants as well as the ripening and ageing of fruits produced. Calcium participate in the regulation of many processes related to plant growth and development including biomass partitioning and fruit yield (Hao and Papadopoulos, 2004), signal transduction (Hepler, 2005; Navarro-Avino and Bennett, 2005; Trewavas, 2000; Malho, 2000; Raz and Flur, 1992), induction of early auxin-responsive genes (Singha *et al*., 2006), resistance to pathogens (Ho and White, 2005; Ehret *et al*., 2002), stress-tolerance (Jiang *et al*., 2005; Jiang and Huang, 2001), chlorophyll biosynthesis (Jiang and Huang, 2001), pollination (Dumas and Gaude, 2006), senescence (Hepler and Wayne, 1985; Leshem, 1991) and fruit ripening (Aghofack-Nguemezi and Dassie, 2007; Park *et al*., 2005; Aghofack-Nguemezi and Yambou, 2005). While intracellular Ca^{2+} concentration is submicromolar, the concentration of closely related divalent cation Mg^{2+} is millimolar. Despite the concentration difference that would favor Mg^{2+}, cellular processes display enormous selectivity for Ca^{2+} (Hepler, 2005). It has recently been reported that although Mn^{2+} and Mg^{2+} enhanced the nitrate uptake and growth of barley seedlings under saline conditions, none of them was as effective as Ca^{2+} (Ward *et al*., 2005).

Notwithstanding the positive physiological roles of Ca^{2+} and Mg^{2+} in plant growth and development the use of conventional fertilizers such as N/P/K mixtures or urea is still, to the best of our knowledge, a common agricultural practice in the western highlands of Cameroon. The present study was thus undertaken to examine the influence of different fertilizers containing Ca^{2+} and Mg^{2+} applied either by spraying on aerial plant parts or by application on the soil on the growth, crop yield and some parameters related to the quality, ripening and senescence of tomatoes.

MATERIALS AND METHODS

Description of the Experimental Site

The experiment was conducted at the research farm of the Institute of Agricultural Research for Development in Dschang from September 2006 to March 2007. Dschang is

Table 1: Means of the daily duration of sunshine, of monthly pluviometry and daily temperature during the experimental period as recorded by the meteorological station of the Institute of Agricultural Research for the development in Dschang

	2006				2007		
Parameters	September	October	November	December	January	February	March
Sunniness (h)	3.1	3.2	5.8	7.3	7.2	4.8	4.7
Pluviometry (mm)	11.7	5.3	3.5	0.0	0.0	7.6	9.3
Temperature (°C)	20.7	20.8	20.4	19.9	20.2	21.8	22.6

Table 2: Compositions of different fertilizer combinations

Abbreviations of treatments	Composition of treatments
T_0	Soil application of urea, super phosphate and potassium chloride respectively at doses of 95, 80 and 100 kg ha^{-1}
T_1	T0 + soil application of calcium nitrate at 200 kg ha^{-1}
T_2	T0 + soil application of calcium nitrate at 400 kg ha^{-1}
T_3	T0 + soil application of calcium nitrate at 800 kg ha^{-1}
T_4	T0 + spray of water on aerial parts of plants
T_5	T0 + spray of Manvert Calcium™ solution (3 mL L^{-1}) on aerial parts of plants (SMCS)
T_6	T0 + spray of Manvert Magnesium™ solution (3 mL L^{-1}) on aerial parts of plants (SMMS)
T_7	T0 + SMCS + SMMS
T_8	T1 + SMCS
T_9	T1 + SMMS
T_{10}	T1 + SMCS + SMMS
T_{11}	T2 + SMCS
T_{12}	T2 + SMMS
T_{13}	T2 + SMCS + SMMS
T_{14}	T3 + SMCS
T_{15}	T3 + SMMS
T_{16}	T3 + SMCS + SMMS

located in the western highlands of Cameroon at 5.26°N latitude, 10.26°E longitude and 1400 m altitude. The experimental period coincided with least rainfall and highest sunniness in the locality (Table 1).

Experimental Design and Plant Materials

Seeds of *Solanum lycopersicum* Mill. var. Rio Grande were sowed in a nursery on a soil enriched with urea and hen droppings at the doses of 300 and 26.1 g m^{-2}, respectively. Seedlings in the nursery were treated with the fungicides Banko Plus™ (chlorothalomil + carbendazime) and Beauchamp™ (metalaxyl + mancozebe). Forty eight days after sowing, seedlings were pricked out in a soil previously enriched with 3 t ha^{-1} hen droppings according to a randomized complete bloc design with seventeen treatments (Table 2) and four replications. Urea, super phosphate and potassium chloride were applied on the soil respectively 11, 14 and 15 days after planting out of seedlings at doses of 95, 80 and 100 kg ha^{-1}, respectively. Control tomato plants received only N/P/K (9.5/8/10) whereas other plants received N/P/K, calcium nitrate and/or liquid fertilizers containing Ca^{2+} or Mg^{2+}. Liquid fertilizers were of the trademark Manvert (BIOVERT, Spain). The Manvert™ solutions (3 mL L^{-1}) were sprayed weekly on the aerial parts of tomato plants from 24 days after pricking out onwards till the harvest of the first mature fruits. Tomato plants were in case of need watered; they were treated with the insecticide Calllidim™ (dimethoate) and the fungicides Banko™ and Beauchamp™. A manual weeding was done when necessary.

Determination of the Number Days after Pricking out Required for the Flowering of 50% of Plants and of the Percentage of Abortion of Floral Buds and Flower

The time in days passed between the pricking out of seedlings and the flowering of 50% of plants in each plot was recorded.

Floral buds were counted from 38 days after pricking out onwards. Seven days before the harvest of the first mature fruits, the total numbers of floral buds, flowers and fruits in each plot were recorded. The percentage of floral bud and flower abortion was calculated according to Tarchoun and Dridi (Tarchoun and Didri, 2005).

Determination of the Diameter and Height

The diameter and height of plants were measured at the sixth week after pricking out. The height was measured from the first branching upwards. The diameter of the stem was measured at the level of collar. At harvest, the diameter of fruits was also measured both laterally and longitudinally. The measurement of the diameter was done using a vernier caliper.

Determination of Water Content in Fruits and Estimation of Crop Yield

Fresh tomato fruits were weighed and dried in an oven successively at 65 and 105°C for 5 day and 24 h, respectively. They were then weighed for the determination of dry matter weight according to Chapman (1976). The crop yield was obtained by calculating the total fresh weight of tomato fruits harvested in all the plots that received the same treatment.

Determination of Carotenoid Content

The 0.5 g of the peel of mature green tomato fruits was ground and extracted with a mixture of benzene/acetone/water (15/75/10, v/v). The extract was centrifugated at 400 rpm for 30 min. The absorbance of the extract was then measured at 477 nm. The carotenoid content in peel extract of tomato fruits was calculated according to Armenta *et al*. (2006).

Determination of Calcium and Magnesium Contents

Fresh tomato fruits were dried in an oven at 105°C for 24 h. One gram of the dried samples was then calcined at 405°C for 24 h. Ten milliliter of 1 N nitric acid solution were added to the ash and the mixture was heated till the evaporation of half of the volume. The residue was completed to 50 mL with distilled water. This solution was further threefold diluted before use. Ca^{2+} and Mg^{2+} contents were determined by the complexometric method as described by Pauwels *et al*. (1992).

Determination of the Duration of the Ripening Period and of the Shelf-Life

Tomato fruits at mature green stage were harvested and stored at 25°C. The number of days elapsed between the mature green stage and the red-ripe stage for 100% of tomato fruits in each lot was recorded. The shelf-life was considered as the length of time between the red-ripe stage and the trickling of 100% of fruits.

Statistical Analysis

This analysis was done with the GraphPad InStat software. Group comparisons were made using One-way Analysis of Variance (ANOVA) to see if variations among the means were significantly greater than expected by chance. The Student-Newman-Keuls Test was used to compare means differences, whereby a p value of <0.05 was considered as statistically significant. The Linear Regression Test was used to determine the correlation coefficients between some relevant parameters.

RESULTS AND DISCUSSION

Growth and Development

No significant effect of fertilizers containing calcium and/or magnesium on stem diameter and height of tomato plants, on the percentage of abortion of floral buds and the percentage of abortion of flowers could be observed (Table 3). Treatments of tomato plants with T_6 (N/P/K application on the soil and spray of Manvert Magnesium solution on aerial plant parts (SMMS)) or T_{15} (simultaneous application of N/P/K and 800 kg ha^{-1} calcium nitrate on the soil and SMMS) induced significant increases in the number of days after planting out required by 50% of tomato plants to flower (Table 3). Obviously, calcium and magnesium ions could regulate the flowering duration in tomato plants. This finding corroborated with previous results obtained from *Pharbitis nil*. It has thus been reported that Ca^{2+} was involved in the photoperiodic flower induction process of this species and that its endogenous level may be a limiting factor (Friedman *et al*., 1989). Furthermore, based on results of the analysis of ion distribution in shoot apex of *Pharbitis nil*, Kobayashi *et al*. (2006) suggested for the first time that Mg^{2+} plays an important role in flower induction.

Fruit Quality and Yield

There was no significant alteration in water and total carotenoid contents in tomato fruits produced by plants that received fertilizers containing Ca^{2+} and/or Mg^{2+} in comparison to fruits from control plants (Table 4). The calcium content in tomato fruits from plants that received fertilizers containing Ca^{2+} and/or Mg^{2+} were generally higher than that found in fruits produced by control plants. However, this increase trend was not overall statistically confirmed. Thus, calcium contents in tomato fruits produced by plants that received T_{12} (N/P/K + calcium nitrate at 400 kg ha^{-1} + SMMS), T_{13} (N/P/K + calcium nitrate at 400 kg ha^{-1} + spray of Manvert Magnesium solution on aerial plant parts (SMCS) + SMMS) and T_{15} did not change significantly when compared to fruits produced by control plants. No synergistic effect of soil application of $Ca(NO_3)_2$ and foliar spray of Manvert Calcium on Ca^{2+} content in fruits could be observed. A slight negative correlation (r = -0.21) between the dose of $Ca(NO_3)_2$ applied on the soil and the Ca^{2+} content in fruits was found (Table 4). These results

Table 3: Effects of fertilizers containing calcium and/or magnesium on stem diameter and height of tomato plants, on the number of days after planting out required for the flowering of 50% of plants (D50F), the percentage of abortion of floral buds (PAFB) and the percentage of abortion of flowers (PAF)

Treatments	Diameter (mm)	Height (cm)	D50F (d.a.p)	PAFB (%)	PAF (%)
T_0	8.2±1.1	34.7±4.8	45±3	10.8±12.1	6.4±9.7
T_1	8.7±0.9	35.0±2.9	46±4	8.6±1.3	3.2±2.0
T_2	8.2±0.6	34.6±5.2	44±1	5.6±3.3	2.7±3.1
T_3	7.6±0.6	37.5±2.5	44±2	10.6±5.4	3.0±3.0
T_4	7.3±0.6	34.5±1.8	46±3	11.9±1.5	5.0±4.5
T_5	8.3±0.2	35.9±1.8	44±1	7.5±1.7	6.4±4.1
T_6	7.9±0.6	32.4±2.1	49±1*	6.8±1.2	1.8±2.3
T_7	8.0±0.8	35.7±2.2	43±1	5.2±3.6	3.1±2.7
T_8	8.1±0.8	34.7±1.9	45±2	8.2±7.3	10.8±4.0
T_9	8.1±0.6	36.0±4.4	43±1	5.6±3.4	2.0±1.6
T_{10}	8.0±0.2	35.3±2.1	45±2	6.6±2.8	4.5±6.5
T_{11}	8.0±0.5	34.5±3.2	47±2	6.3±3.8	4.6±4.5
T_{12}	8.2±1.3	35.1±3.4	46±2	4.5±3.7	1.7±1.6
T_{13}	7.7±0.3	35.2±3.9	45±3	7.5±3.7	5.2±5.1
T_{14}	7.9±0.4	34.1±4.5	43±1	7.7±3.7	1.1±0.7
T_{15}	7.6±0.9	33.2±3.0	49±1*	10.4±7.5	4.6±6.2
T_{16}	7.9±0.7	34.5±2.6	45±2	6.4±5.6	5.1±5.1

Values are Mean±SD (n = 4). d.a.p.:days after pricking out, *Values are statistically different from T_0 at $p<0.05$

Table 4: Effects of fertilizers containing calcium and/or magnesium on contents of water, carotenoids, calcium and magnesium ions in tomato fruits, and the correlation between the dose of $Ca(NO_3)_2$ applied on the soil and the Ca^{2+} content in fruits

			Ion content (meq kg^{-1})	
Treatments	Water content (%)	Carotenoid content (µg g^{-1} f.w.)	Calcium	Magnesium
T_0	95.7±0.3	29.9±11.1	9.0±4.7	139.0±52.9
T_1	96.0±0.1	25.2±2.0	47.7±10.6*	246.7±49.1*
T_2	95.3±0.6	25.1±3.4	35.7±3.9*	163.7±56.8
T_3	95.6±0.3	26.1±1.2	37.5±6.2*	109.0±39.5
T_4	95.3±0.2	27.1±0.2	18.7±5.5	140.7±53.7
T_5	95.7±0.3	26.6±0.3	30.2±11.4*	310.7±23.1*
T_6	95.7±0.1	24.3±4.4	31.5±7.7*	413.7±63.9*
T_7	95.6±0.2	26.5±1.0	36.5±14.7*	203.5±41.6
T_8	95.6±0.2	26.5±0.7	38.0±2.8*	93.0±58.3
T_9	95.3±0.8	26.1±0.7	27.5±12.3*	863.0± 41.6*
T_{10}	95.5±0.3	27.0±0.7	34.5±9.3*	135.0±41.2
T_{11}	95.9±0.1	26.4±0.4	39.0±11.9*	133.5±39.1
T_{12}	95.1±0.6	26.5±0.2	22.7±13.6	666.0±151.7*
T_{13}	95.4±0.2	27.0±0.5	25.0±12.5	827.5±464.2*
T_{14}	95.6±0.2	26.4±0.6	37.0±7.4*	104.5±24.4
T_{15}	95.2±0.2	26.7±0.3	20.0±4.3	734.2±177.7*
T_{16}	95.5±0.2	27.2±1.3	27.7±17.3*	254.7±75.4

Correlation	Correlation coefficient (r)
Dose of $Ca(NO_3)_2$ applied on the soil *x* Ca^{2+} content in fruits	-0.21

Values are Mean±SD (n = 4). f.w.: fresh weight, *Values are statistically different from T_0 at $p<0.05$

demonstrated that applications of fertilizers containing Ca^{2+} either on the soil at doses = 400 kg ha^{-1} or on aerial plant parts led to increases in the Ca^{2+} concentration in fruits. In a similar study, foliar applications of calcium salts were also shown to increase Ca^{2+} levels in tomato fruits (García *et al*., 1995). It is well known that mineral ions absorbed by roots are transported in long distances in the xylem concurrently with water (Opik *et al*., 2005). Most plants can also absorb mineral nutrient applied to their leaves as sprays and this mode of uptake is most effective when the nutrient solution remains on the leaf as a thin film (Taiz and Zeiger, 2006). As indicated by the negative correlation between the dose of $Ca(NO_3)_2$ used and the Ca^{2+} content in fruits, the former was in inverse ratio to the latter. Thus, tomato plants could no longer absorb calcium ions or transport them in growing fruits when high doses of $Ca(NO_3)_2$ were applied on the soil. The mechanisms whereby Ca^{2+} or NO^{3-} could at high concentration inhibit the absorption of the former ion by roots of tomato plants are not known. Nevertheless, Ca^{2+} has been shown to be very effective in the enhancement of the uptake of nitrate by barley seedlings under saline conditions. At 800 kg ha^{-1} of $Ca(NO_3)_2$ Ca^{2+} might thus, to the detriment of its own absorption, enhance the uptake of NO^{3-} by tomato plants. The mechanisms whereby liquid fertilizers containing Mg^{2+} triggered an increase in Ca^{2+} content in tomato fruits are not yet known. An increase in the level of Ca^{2+} in banana fruits after treatment by dipping in $MgSO_4$ solution has also previously been observed (Aghofack-Nguemezi and Dassie, 2007).

In most of cases where tomato plants received fertilizers containing Mg^{2+}, magnesium ion contents in fruits produced by these plants were significantly higher than those observed in the extracts of fruits from control plants (Table 5). In this context, when compared to the control, higher contents in Mg^{2+} ions were found in fruits produced by tomato plants that received T_9 (N/P/K + calcium nitrate at 200 kg ha^{-1} + SMMS), T_{12} (N/P/K + calcium nitrate at 400 kg ha^{-1} + SMMS), T_{13} (N/P/K + calcium nitrate at 400 kg ha^{-1} + SMCS + SMMS) or T_{15} (N/P/K + calcium nitrate at 800 kg ha^{-1} + SMMS). However, the content of Mg^{2+} also significantly increased in tomato fruits produced by plants that received only

Table 5: Effects of fertilizers containing calcium and/or magnesium on the yield, diameter, duration of the ripening period (DRP) and that of shelf-life (DSL) of tomato fruits, and correlations between ion contents and DRP or DSL

		Diameter (cm)			
Treatments	Yield (t ha^{-1})	Median	Longitudinal	DRP (d.a.h.)	DSL (d.a.r.)
T_0	31.9±6.7	4.2±0.1	5.5±0.1	6±1	38±0
T_1	37.4±10.7	4.5±0.2	5.7±0.1	11±0*	35±1
T_2	35.1±7.1	4.3±0.1	5.8±0.1	10±1*	38±2
T_3	32.0±7.1	4.3±0.1	5.9±0.2	8±1	38±2
T_4	33.2±5.7	4.5±0.1	5.9±0.3	8±0	36±2
T_5	33.2±7.0	4.5±0.2	5.7±0.0	11±1*	36±4
T_6	41.2±6.9	4.5±0.1	5.8±0.1	10±2*	33±4
T_7	41.7±8.1	4.5±0.1	5.9±0.1	9±1*	38±3
T_8	30.6±7.8	4.4±0.2	5.7±0.1	10±2*	40±2*
T_9	46.6±12.1	4.5±0.2	5.9±0.2	10±0*	42±2*
T_{10}	42.9±3.5	4.4±0.1	5.9±0.1	11±3*	45±1*
T_{11}	36.1±6.5	4.3±0.2	5.8±0.3	10±1*	43±3*
T_{12}	47.8±11.9	4.5±0.1	6.1±0.2	10±1*	40±3
T_{13}	35.1±6.7	4.5±0.1	5.9±0.1	9±1*	42±2*
T_{14}	36.5±6.7	4.4±0.1	5.9±0.1	11±5	28±6
T_{15}	38.2±8.4	4.6±0.1	6.1±0.2	9±2	31±7
T_{16}	36.8±10.7	4.4±0.1	5.8±0.1	9±2	30±7

Correlation	Correlation coefficient (r)
Ca^{2+} content in fruits *x* DRP	0.68
Mg^{2+} content in fruits *x* DRP	0.05
Ca^{2+} content in fruits *x* DSL	0.05
Mg^{2+} content in fruits *x* DSL	0.10

Values are Mean±SD (n = 4), d.a.h.: Days after harvesting, d.a.r.: Days after ripeness, *Values are statistically different from T_0 at $p<0.05$

fertilizers containing Ca^{2+}, namely T_1 (N/P/K + calcium nitrate at 200 kg ha^{-1}) or T_5 (N/P/K + SMCS). These results indicated that as it generally the case for most of mineral nutrients (Taiz and Zeiger, 2006; Opik *et al*., 2005), Mg^{2+} could be absorbed through the leaves of plants and then transported into developing tomato fruits. The mechanisms whereby fertilizers containing Ca^{2+} triggered an increase in Mg^{2+} content in tomato fruits are not yet known.

No significant difference could be observed between the total yield and the diameter of tomato fruits produced by plants which received fertilizers containing Ca^{2+} and/or Mg^{2+} and that of fruits produced by control plants (Table 5). In contradiction to these results, Hao and Papadopoulos (2003) reported that Ca^{2+} at 300 mg L^{-1} and Mg^{2+} at 20 mg L^{-1} nutrient solutions led, respectively to increase and decrease in tomato fruit yield. In a ferrallitic sandy loam soil, tomato fruit yield was significantly increased by liming with CaO at a pH of 5.2 while at a pH of 5.7 and above liming had little effects; under those conditions applied Mg^{2+} had no effect on fruit yield (Asiegbu and Uzo, 1983). Suplementary calcium enhanced fruit yield in strawberry cultivars grown at high NaCl salinity (Kaya *et al*., 2002).

Ripening and Senescence of Fruits

The number of days elapsed between the mature green stage and the red-ripe stage of fruit ripening was greatly affected by treatments of tomato plants in the farm with fertilizers containing Ca^{2+} and/or Mg^{2+} (Table 5). Nearly all these fertilizers combinations induced a prolongation of the duration of the ripening period of tomato fruits. Apart from tomato fruits produced by plants that received T_3 (N/P/K + calcium nitrate at 800 kg ha^{-1}), T_{14} (N/P/K + calcium nitrate at 800 kg ha^{-1} + SMCS), T_{15} and T16 (N/P/K + calcium nitrate at 800 kg ha^{-1} + SMCS + SMMS), fruits produced by plant that received all other fertilizers containing Ca^{2+} and/or Mg^{2+} had a longer duration of ripening period than those from control plants. The length of time between the red-ripe stage and the trickling of 100% of tomato fruits (the shelf-life) was mostly significantly prolonged by the applications of T_8 (N/P/K + calcium nitrate at 200 kg ha^{-1} + SMCS), T_9 (N/P/K + calcium nitrate at 200 kg ha^{-1} + SMMS), T_{10} (N/P/K + calcium nitrate at 200 kg ha^{-1} + SMCS + SMMS), T_{11} (N/P/K + calcium nitrate at 400 kg ha^{-1} + SMCS), T_{12} (N/P/K + calcium nitrate at 400 kg ha^{-1} + SMMS) and T_{13}.

The positive correlation between Ca^{2+} content and the duration of ripening period of tomato fruits was more pronounced (r = 0.68) than that found between the magnesium content and this period (r = 0.05). The positive correlation between the Mg^{2+} content and the duration of the shelf-life was more marked (r = 0.1) than the correlation found between Ca^{2+} content and the duration of the shelf-life (r = 0.05) (Table 5).

Obviously, calcium nitrate at doses $\leq$400 kg ha^{-1} or foliar spray of Manvert Calcium induced increases in Ca^{2+} content and subsequently a delay of the ripening process of tomato fruits. When soil application of $Ca(NO_3)_2$ was associated to foliar spray of Manvert Calcium and/or Manvert Magnesium, both the ripening of mature green tomato fruits and the trickling of red ripe fruits were subsequently retarded. This means that even if no synergistic effect of soil application of $Ca(NO_3)_2$ and foliar spray of Manvert Calcium on Ca^{2+} content in fruits was observed, the combination of both types of fertilization could lead to an increase in the duration of ripening period as well as a delay of the onset of senescence of red-ripe tomato fruits. It has previously been demonstrated that fruit from tomato plants expressing Arabidopsis Thaliana H+/cation exchangers have more Ca^{2+} and prolonged shelf life when compared to controls (Park *et al*., 2005). Postharvest calcium applications on loquat (Akhtar *et al*., 2010) and peach fruits (Manganarisa *et al*., 2007) retained their firmness, thereby delaying the ripening process. It is well established that calcium ion can delay the ripening and senescence by stabilizing cell membrane and increasing the rigidification of monolayers. Moreover, the Ca^{2+}-mediated cross-linking may occur as bridging between phospholipids, between phospholipids and corboxyltails of embedded membrane proteins and between phospholipids and cytoskeletal. Magnesium ion affects the electrostatic cross-linking between membranes components to a lesser extend than calcium ion (Leshem, 1991). There are also several calcium-pectate interactions which make the cell wall firmer (Carpita and McCann, 2000). It is not yet known why combination of application on the soil and foliar spray of fertilizers containing Ca^{2+} (e.g., T_8 and T_{11}) induced a retardation of both the ripening and the senescence of tomato fruits while soil application of $Ca(NO_3)_2$ (e.g., T_1 and T_2) or foliar spray of Manvert Calcium (e.g., T_5) alone led only to the increase in duration of the ripening period. The fact that combinations of soil application of $Ca(NO_3)_2$ with foliar spray of Manvert Magnesium (e.g., T_9) also led to increases in both the duration of ripening period and that of shelf-life could be explained by the additional effects of Mg^{2+}. Indeed, due to their divalent character, Mg^{2+} and Mn^{2+} can with lesser effectiveness play physiological roles ascribed to Ca^{2+} (Ward *et al*., 2005; Leshem, 1991) or quite different roles (Fanasca *et al*., 2006). The appropriate Mg^{2+} concentration in the nutrient solution required for the production of winter greenhouse tomato crop was lower than that of Ca^{2+} (Hao and Papadopoulos, 2004). High proportion of Ca^{2+} as related to K/Ca/Mg ratio in the nutrient solution was reported to improve fruit yield and reduce the incidence of blossom-end rot whereas high proportion of Mg^{2+} rather resulted in the increase of total antioxidant activity in tomato fruits (Fanasca *et al*., 2006). The retarding effect of foliar spray of Manvert Magnesium alone on the ripening process could be related to increases in Mg^{2+} and Ca^{2+} contents in tomato fruits.

CONCLUSION

The most striking features of field application of fertilizers containing Ca^{2+} and/or Mg^{2+} were increases in the duration of flowering of plants and in calcium contents in the extracts and the subsequent prolongation of the duration of mature green stage of tomato fruits. Combinations of soil application of $Ca(NO_3)_2$ at doses $\leq$400 kg ha^{-1} with foliar spray of Manvert Calcium and/or Manvert Magnesium solutions were the most efficient in inducing the delay of ripening and senescence of tomato fruits. Calcium ion seemed to be a key player in the modulation of the ripening process while Mg^{2+} could rather play an important role in the regulation of the senescence of tomato fruits.

REFERENCES

Abushita, A.A., H.G. Daood and P.A. Biacs, 2000. Changes in carotenoids and antioxidant vitamins in tomato as function of varietal and technological factors. J. Agric. Food Chem., 48: 2075-2081.

Aghofack-Nguemezi, J. and T.N. Yambou, 2005. Effects of calcium chloride and magnesium sulphate treatments on the shelf-life of climacteric banana and non-limacteric pineapple fruits. Cam. J. Exp. Biol., 1: 34-38.

Aghofack-Nguemezi, J. and B. Dassie, 2007. Effects of salts and edible oils on calcium and water contents in ripening banana fruits. J. Plant Sci., 2: 302-309.

Akhtar, A., N.A. Abbasi and A. Hussain, 2010. Effect of calcium chloride treatments on quality characteristics of loquat fruit during storage. Pak. J. Bot., 42: 181-188.

Armenta, R.E., A. Burja, H. Radianingtyas and C.J. Barrow, 2006. Critical assessement of various techniques for the extraction of carotenoids and co-enzyme Q_{10} from the thraustochytrid strain ONC-T18. J. Agric. Food Chem., 54: 9752-9758.

Asiegbu, J.E. and J.O. Uzo, 1983. Effect of lime and magnesium on tomato (*Lycopericon esculentum* Mill.) grown in a ferrallitic sandy loam tropical soil. Plant Soil, 74: 53-60.

Carpita, N. and M.C. McCann, 2000. The Cell Wall. In: Biochemistry and Molecular Biology of Plants, Buchanan, B. and M.D. Rockville (Ed.). Am. Soc. Plant Physiologists, UK., pp: 52-108.

Chapman, S.B., 1976. Methods in Plant Ecology, Physiology and Nutrition. Blackwell Scientific Publications, Oxford, UK.

Dumas, C. and T. Gaude, 2006. Fertilisation in plant: Is calcium a key player? Semin. Cell Dev. Biol., 17: 244-253.

Ehret, D.L., J.G. Menzies, C. Bogdanoff, R.S. Utkhede and B. Frey, 2002. Foliar applications of fertilizer salt inhibit powdery mildew on tomato. Can. J. Plant Pathol., 24: 437-444.

Fanasca, S., G. Colla, G. Maiani, E. Venneria, Y. Rouphael, E. Azzini and E. Saccardo, 2006. Changes in antioxidant content of tomato fruits in response to cultivar and nutrient solution composition. J. Agric. Food Chem., 54: 4319-4325.

FAOSTAT, 2005. FAOSTAT Statistics Division. FAOSTAT, Food and Agriculture Organization of the United Nations, United Nations.

Friedman, H., E.E. Goldsmidt and A.H. Halevy, 1989. Involvement of calcium in the photoperiodic flower induction process of *Pharbitis nil*. Plant Physiol., 89: 530-534.

Garcia, J.M., J.M. Ballesteros and M.A. Albi, 1995. Effects of foliar applications of $CaCl_2$ on tomato stored at different temperatures. J. Agric. Food Chem., 43: 9-12.

Gillermou, Y. and A. Kamga, 2004. Rural organizations in the west-cameroon: Palliative for crisis. Rural Stud., 169: 61-76.

Giovannucci, E., 1999. Tomatoes, tomato-based products, lycopene and cancer: Review of the epidemiologic literature. J. Nat. Cancer Inst., 91: 317-331.

Hao, X. and A.P. Papadopoulos, 2003. Effects of calcium and magnesium on growth, fruit yield and quality in fall greenhouse tomato crop grown on rockwool. Can. J. Plant Sci., 83: 903-912.

Hao, X. and A.P. Papadopoulos, 2004. Effects of calcium and magnesium on plant growth, biomass partitioning and fruit yield of winter greenhouse tomato. Hort. Sci., 39: 512-515.

Hepler, P.K. and R.O. Wayne, 1985. Calcium and plant development. Ann. Rev. Plant Physiol., 36: 397-439.

Hepler, P.K., 2005. Calcium: A central regulator of plant growth and development. Plant Cell, 17: 2142-2155.

Ho, L.C. and P.J. White, 2005. A cellular hypothesis for the induction of blosom-end rot in the tomato fruits. Ann. Bot., 95: 571-581.

Jiang, T., X. Zhan, Y. Hu, L. Zhou and L. Zong, 2005. Roles of calcium in stress-tolerance of plants and its ecological significance. Ying Yong Sheng Tai Xue Bao., 16: 971-976.

Jiang, Y. and B. Huang, 2001. Effects of calcium and antioxidant activities and water relations associated with heat tolerance in two cool-season grasses. J. Exp. Bot., 52: 341-349.

Kader, A.A., 1986. Effects of postharvest handling procedures on tomato quality. Acta Hort., 190: 209-221.

Kader, A.A., 2005. Increasing food availability by reducing postharvest losses of fresh produce. ISHS Acta Hort., 682: 2169-2176.

Kaya, C., H. Kirnak, D. Higgs and K. Saltali, 2002. Supplementary calcium enhances plant growth and fruit yield in strawberry cultivars grown at high (NaCl) salinity. Sci. Hortic., 93: 65-74.

Kobayashi, N.I., K. Tanoi and T.M. Nakanishi, 2006. Magnesium localization in shoot apices during flower induction in *Pharbitis nil*. Can. J. Bot., 84: 1908-1916.

Kuete, M., 2008. Coffee, coffee culture and political life within the western highlands of Cameroon. Cahiers d'Outres Mer., 243: 285-302.

Leshem, Y.Y., 1991. Plant Membrane Senescence. In: Plant Signaling, Plasma Membrane and Change of State, Penel, C. and H. Greppin (Eds.). University of Geneva Press, Geneva, pp: 31-59.

Malho, R., 2000. Coding Information in Plant Cells using Ca^{2+} as a Second Messenger: The Cell as Minimum Unity for Complexity. In: Integrated Plant Systems, Greppin, H., C. Penel, W. Broughton and R. Strasser (Eds.). University of Geneva, Geneva, pp: 311-339.

Manganarisa, G.A., M. Vasilakakisa, G. Diamantisida and I. Mignanib, 2007. The effect of postharvest calcium application on tissue calcium concentration, quality attributes, incidence of flesh browning and cell wall physicochemical aspects of peach fruits. Food Chem., 100: 1385-1392.

Mayne, S.T., 1996. Beta-carotene, carotenoids and disease prevention in humans. FASEB. J., 10: 690-701.

Navarro-Avino, J.P. and A.B. Bennett, 2005. Role of Ca^{2+}-ATPase induced by ABA and IAA in the generation of specific Ca^{2+} signals. Biochem. Biophys. Res. Commun., 329: 406-415.

Opik, H., S.A. Rolfe and A.J. Willis, 2005. The Physiology of Flowering Plants. 4th Edn., Cambridge University Press, Cambridge, ISBN-13: 978-0-521-66251-6.

Park, S., N.H. Cheng, J.K. Pittman, K.S. Yoo, J. Park, R.H. Schmidt and K.D. Hirschi, 2005. Increase calcium levels and prolonged shelf life in tomatoes expressing Arabidopsis H^+/Ca^{2+} transporters. Plant Physiol., 139: 1194-1026.

Pauwels, J.M., E. van Ranst, M. Verloo and A.M. Ze, 1992. Manuel de laboratoire de pedologie. Methodes d'analyses des sols et des plantes, equipements, gestion des stocks de verrerie et de produits chimiques. Administration Generale de la Cooperation au Developpement, Bruxelles.

Raz, V. and R. Flur, 1992. Calcium requirement for ethylene-dependent responses. Plant Cell, 4: 1123-1130.

Rodriguez-Amaya, D.B., 1999. Latin American food sources of carotenoids. Arch. Latinoam. Nutr., 49: 74S-84S.

Santagelo, C., R. Vari, B. Scazzochio, R. di Benedetto, C. Filesi and R. Masella, 2007. Polyphenols, intracellular signaling and inflammation. Ann. Ist. Super Sanita, 43: 394-405.

Scalbert, A. and G. Williamson, 2000. Dietary intake and bioavailability of polyphenols. J. Nutr., 130: 2073-2085.

Seddon, J.M., U.A. Ajami, R.D. Sperato, R. Hiller and N. Blair *et al.*, 1994. Dietary carotenoids, vitamin A, vitamin C and vitamin E and advance age-related macular degeneration. J. Am. Med. Ass., 272: 1413-1420.

Singha, B., A. Chugh, J.P. Khurana and P. Khurana, 2006. An early auxin-responsive Aux/IAA gene from wheat (*Triticum aestivum*) is induced by epibrasssinolide and differentially regulated by light and calcium. J. Exp. Bot., 57: 4059-4070.

Taiz, L. and E. Zeiger, 2006. Plant Physiology. 4th Edn., Sinauer Associates Inc. Publishers, Massachusetts, ISBN-10: 0-87893-856-7.

Tarchoun, N. and B. Didri, 2005. Effect de l'acide indole butyrique, de l'acide gibberique et d'un inhibiteur de l'ethylene sur la fructification et la qualite des fruits du piment cultive sous serre froide. Tropicultura, 23: 162-168.

Trewavas, A., 2000. Signal Perception and Transduction. In: Biochemistry and Molecular Biology of Plants, Gruissen, W. and R.L. Jones (Eds.). American Society of Plant Physiologists, Maryland, pp: 930-986.

Uwizeyimana, L., 2009. Destabilization of ancient forms of organization of space hence a new territorial construction in western highlands of Cameroon: coffee cultivation and intensive food crop polyculture. Cahiers d'Outres-Mer, 247: 331-344.

Ward, M.R., M. Aslam and R.C. Huffacker, 2005. Enhancement of nitrate uptake and growth of barley seedlings by calcium under saline conditions. J. Agric. Food Chem., 53: 1539-1545.

Weisburger, J.H., 1998. Evaluation of the evidence on the role of tomato products in disease prevention. Proc. Soc. Exp. Biol. Med., 218: 140-143.