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Interaction effect of applied calcium and magnesium on alfisols of Karnataka and its influence on uptake and yield levels of tomato (*Solanum lycopersium* L.)

B.L. Kasinath, A.N. Ganeshmurthy and A.T. Sadashiva
ICAR-Indian Institute of Horticultural Research
Hesaraghatta Lake Post, Bengaluru - 560089
E-mail : kasnath@iihr.ernet.in

ABSTRACT

In a field experiment, interaction effects of applied Ca, Mg and K on yield and quality of tomato and soil nutrient levels was studied in Alfisols of Karnataka. The results showed application of Mg enhanced fruit yield up to 100 kg Mg ha^{-1} and decreased at higher levels of Mg. The application of Ca also enhanced the yield of tomato but their combined application at different levels had negative effect of one on the other. The results indicated that optimum combination of Mg and Ca was 100 and 250 kg ha^{-1} respectively for obtaining higher yield in tomato. Soil P content enhanced with application of both Ca and Mg. However, applied Ca and Mg showed significant negative effect on both soil and K content. Interaction effect was however, non-significant on soil pH, EC, OC and Soil N content.

Key words: Acid, soils, calcium, magnesium, nutrient interaction, tomato

INTRODUCTION

Tomato is one of the important vegetable crops grown throughout the world under open and controlled conditions. It serves as a daily component of diet in many countries and also an important source of minerals, vitamins A, B, C good source of iron and antioxidants (Grierson and Kader, 1986). India produces 12.43 MT. of tomato from an area of 6.34 lakh ha with an average productivity of 19.60 t ha^{-1}. Recent hybrids of tomato have shown open field yield potential as high as 100 t ha^{-1}. In order to obtain this high yield levels of new tomato hybrids, farmers' have to adopt better crop husbandry practices which include balanced and desired levels of nutrient management.

Calcium is an essential nutrient that plays a key role in the structure of cell walls and cell membranes, fruit growth and development, as well as general fruit quality (Kadir, 2004). It enhances resistance to bacterial and viral diseases (Usten *et al*, 2006). The Ca taken up from the soil is translocated to the leaves but very little goes from the leaves to the fruit causing imbalance in source sink relationship (Kadir, 2004). Therefore, plants need a constant supply of Ca for vigorous leaf and root development and canopy growth (Del-Amor and Marcelis *et al*, 2003). Magnesium is also a major constituent of cell wall (Jones, 1999). It is vital for the process of photosynthesis and therefore for the life of the plant in general. It acts as a cofactor and activator of many enzymes and substrate transfer reactions (Bergmann, 1992). Plants inadequately supplied with Mg show delay in reproductive phase. Clear understanding of the ratios' of nutrients such as Ca:Mg, Ca:B, Mg:K etc., along with their obsolute content both in soil and plant on growth and quality is lacking (Ganeshamurthy and Srinivasarao, 2001) and excess of one element induces deficiency of another element. Although a lot of research work has been done on the requirement of tomato for major nutrients but insufficient data is available on secondary nutrients such as Mg and Ca and their interactions effects on yield of tomato under field conditions. Hence the study was carried out to evaluate the combined effect of K, Ca and Mg applications on availability of K, Ca and Mg and further their effect on the growth and yield of tomato.

MATERIAL AND METHODS

The experiment was conducted at ICAR-IIHR, Hesaraghatta, Bengaluru during the *rabi* season of 2011-12. The experiment was laid out in split plot design with three replications. There were four levels of Mg as the main plot treatment and three levels of Ca as sub-plot treatment. The 12 treatment combinations are presented in Table 1.

Tomato var. Arka Ananya (F_1) was transplanted at 100cm x 60cm after incorporation of fertilizers as per the Table 1. The crop was grown up to maturity and fruits were harvested at regular intervals and yield recorded as sum total of all pickings.

Soil and plant analysis

Soil samples were collected and these samples were analysed for N, P, K, Ca and Mg. Analytical methods followed for the analysis of soil samples and plant samples are presented in Table 2. Whole plant sampling was done from each treatment for recording total biomass production. Five plants from each replication were sampled including fruit, leaf and stem. The plant samples were partitioned into leaf, stem and fruit and processed for plant analysis. Weight of each plant was recorded separately and dried at 60^0C in a hot air oven. Samples were powdered and processed for estimation of nitrogen, phosphorous, potassium, calcium and magnesium using standard procedures. Analytical procedure followed for the analysis of plant samples are presented in Table 2.

Table 1: Layout of treatment details of magnesium and calcium interaction experiment

Treatment	$N:P_2O_5:K_2O$ kg ha^{-1}	Mg (kg ha^{-1})	Quantity of $MgSO_4$ used as (kg)	Ca (kg ha^{-1})	Quantity of applied Gypsum (Kg)
T_1	180:150:120	0	0	0	0
T_2	180:150:120	0	0	100	342.46
T_3	180:150:120	0	0	250	856.15
T_4	180:150:120	100	1028	0	0
T_5	180:150:120	100	1028	100	342.46
T_6	180:150:120	100	1028	250	856.15
T_7	180:150:120	150	1542	0	0
T_8	180:150:120	150	1542	100	342.46
T_9	180:150:120	150	1542	250	856.15
T_{10}	180:150:120	200	2056	0	0
T_{11}	180:150:120	200	2056	100	342.46
T_{12}	180:150:120	200	2056	250	856.15

Statistical analysis

The data on various observations such as growth, yield and other parameters were tabulated and subjected to statistical analysis (Sundaraja *et al*, 1972).

RESULTS AND DISCUSSION

Fruit yield

Optimum yield of tomato can be obtained at optimum Mg:Ca ratio in the soil. Any deviation from the optimum would affect adversely the yield of tomato (Bombita Nzanza, 2006). However, this optimum ratio depends on soil native Mg and Ca content and other related properties. The data pertaining to yield of tomato hybrid as influenced by four levels of Mg and three levels of Ca and their interaction is presented in Table 3. Application of both Mg and Ca significantly enhanced the fruit yield of tomato. The yield of tomato increased with increasing levels of applied Mg up to 100kg Mg ha^{-1} at lower levels of applied Ca. However, at higher levels of Ca the fruit yields decreased with increasing levels of Mg. The lowest mean yield value 64.36 t ha^{-1} was observed at Ca_1 (0 kg Ca ha^{-1}) application and the highest mean yield of 73.97t ha^{-1} was obtained at application of Mg_2 (100kg Mg ha^{-1}). A combination of Mg_2 (100kg Mg ha^{-1}) Ca_3 (250 Ca kg ha^{-1}) resulted in highest yield (82.05t ha^{-1}). The results indicate that optimum combination of Mg and Ca was 100 and 250kg ha^{-1}

Table 2: Analytical methods followed for analysis of soil and plant samples

Sl. No.	Parameters	Methodology	Reference
Soil Analysis			
1.	Mechanical Analysis	Hydrometer method	Piper (1966)
2.	pH (1:2.5)	Potentiometer method	Jackson (1973)
3.	Electrical conductivity (EC)	Conductivity method	Jackson (1973)
4.	Organic carbon	Walkley and Black's Wet oxidation	Jackson (1973)
5.	Cation exchange capacity	Leaching with ammonium acetate	Black (1965)
6.	Available nitrogen	Alkaline potassium permanganate method	Subbiah and Asija (1956)
7.	Available phosphorous	Molybdo phosphate blue colour method	Jackson (1973)
8.	Available potassium	Flame photometer method	Jackson (1973)
9.	NH_4OAc extractable calcium (PPM)	Versanate titration method	Black (1965)
10.	NH_4OAc extractable magnesium (PPM)	Versanate titration method	Black (1965)
Plant Analysis			
1.	Nitrogen	Micro Kjeldahl method	Jackson (1973)
2.	Phosphorous	Vanadomolybdo phosphoric method	Jackson (1973)
3.	Potassium	Flame photometer method	Jackson (1973)
4.	Calcium	Atomic absorption spectrophotometer method	Lindsay and Norwell (1978)
5.	Magnesium	Atomic absorption spectrophotometer method	Lindsay and Norwell (1978)

respectively for obtaining highest yield in tomato. Several workers have reported similar results. Hao and Papadopoulos (2004) in a factorial experiment with nutrient solutions containing calcium (150 and 300mg l^{-1}) in combination with three levels of magnesium (20, 50 and 80mg l^{-1}) showed that at 300mg Ca l^{-1} and Mg 80mg l^{-1} significantly increased total fruit yield and dry matter. On a sandy loam acidic soil (pH 4.9) Charles and Jeffery (1983) studied the effects of Mg and Ca lime sources on yield, quality and up take of tomato. In a two year experiment (1980 and 1981), results showed that marketable fruit yields were lower with the 100% $Ca(OH)_2$ or 100% MgO. Highest fruit yields were obtained over a relatively narrow range of leaf Ca and Mg mole ratio. The best yield was reported in Ca: Mg ratio of 15:5 by Bombiti Nzanza (2006).

Table 3: Interaction effects of Mg with Ca on yield of tomato

Treatments	Yield (t ha^{-1})			
	Ca_1 (0 kg Ca ha^{-1})	Ca_2 (100 kg Ca ha^{-1})	Ca_3 (250 kg Ca ha^{-1})	Mean (kg ha^{-1})
Mg_1 (0 kg Mg ha^{-1})	61.45	67.05	64.84	64.45
Mg_2 (100 kg Mg ha^{-1})	67.14	72.71	82.05	73.97
Mg_3 (150 kg Mg ha^{-1})	65.79	74.00	75.60	71.80
Mg_4 (200 kg Mg ha^{-1})	63.06	77.03	69.21	72.10
Mean	64.36	72.70	72.92	69.76
	S. Em±	C.D at 5%		
Mg	1.885	6.526		
Ca	1.022	3.065		
Mg x Ca	2.045	6.131		

Interaction of Mg and Ca on soil and plant nutrients

Soil nutrients

Applied Mg and Ca did not influence the properties of soils like pH, EC and organic carbon (Table 4). Applied Mg and Ca had negative effect on soil N levels. With increasing applied Mg and Ca levels the mean available N content decreased. Interaction effects of the combined Mg and Ca effect found that the lowest available N 109.38kg $ha^{-1}$was recorded in Mg_4Ca_3 treatment and the highest N 125.14kg ha^{-1} in Mg_1 Ca_1 treatment. Similar results were observed in groundnut crop by Ananthanarayana and Hanumantharaju (1992). Applied Ca and Mg significantly influenced soil available P. Available P levels increased from 7.2kg/ha^{-1} in Mg_1Ca_1 to 7.95kg ha^{-1} in Mg_4Ca_3 treatment. This indicated synergistic relationship of Ca and Mg on soil available P. Halbrooks and Wilcox (1980) also observed in tomato a positive correlation between Mg and P absorption in water cultures supplied with 4, 20, 80ppm of P_2O_5 and 1, 8, 40ppm of Mg.

The application of Mg and Ca had significant negative influence on soil available K. Applied Mg and Ca increased exchangeable Mg and decreased exchangeable K and Ca. As the level of applied Ca increased the available K content decreased. Interaction effects of applied Mg and Ca resulted in the lowest available K of 101.8kg K ha^{-1} in plots that received combined application of 200kg Mg ha^{-1} and 250 kg Ca ha^{-1}. Highest available K of 124.3kg K ha^{-1} was recorded

Table 4. Interaction effects of different levels of magnesium and calcium on soil nutrients

Treatment	pH	EC (dsm^{-1} at 25°c)	OC (%)	Soil N (kg ha^{-1})	Soil P (kg ha^{-1})	Soil K (kg ha^{-1})	Soil Cappm	Soil Mgppm
Mg_1Ca_1	5.41	0.39	0.64	125.14	7.22	124.3	430.17	92.98
Mg_1Ca_2	5.44	0.39	0.67	123.18	744	121.4	493.21	95.41
Mg_1Ca_3	5.45	0.40	0.67	120.70	7.59	115.3	558.67	110.06
Mg_2Ca_1	5.43	0.40	0.66	122.92	7.43	121.7	477.83	102.60
Mg_2Ca_2	5.45	0.41	0.67	119.66	7.52	117.3	526.80	113.32
$Mg2Ca_3$	5.45	0.39	0.65	118.42	7.72	113.4	585.92	132.46
Mg_3Ca_1	5.47	0.39	0.67	120.58	7.65	116.1	514.26	119.86
Mg_3Ca_2	5.48	0.43	0.68	115.46	7.69	111.0	582.63	136.93
Mg_3Ca_3	5.48	0.43	0.68	113.88	7.87	108.9	636.18	178.62
Mg_4Ca_1	5.50	0.40	0.68	117.70	7.79	110.6	565.39	122.70
Mg_4Ca_2	5.53	0.43	0.67	112.62	7.83	106.4	641.20	150.51
Mg_4Ca_3	5.57	0.43	0.67	109.38	7.95	101.8	694.67	213.64
S.Em+								
Mg	NS	NS	NS	NS	0.073	1.72	20.60	8.933
Ca	NS	NS	NS	NS	0.100	2.09	22.88	11.677
Mg x Ca	NS	NS	NS	NS	0.113	2.36	27.75	16.680
CD at 5%								
Mg	NS	NS	NS	NS		5.16	61.72	26.770
Ca	NS	NS	NS	NS		6.26	68.54	34.987
Mg x Ca	NS	NS	NS	NS		7.07	83.15	49.974

Table 5. Interaction effects of different levels of magnesium and calcium on plant nutrients

Treatment	Plant N (%)		Plant P (%)		Plant K (%)		Plant Ca (%)		Plant Mg (%)	
	Fruits	Leaf & stem	Fruits	Leaf & stem	Fruits	Leaf & stem	Fruits	Leaf & stem	Fruits	Leaf & stem
Mg_1Ca_1	2.59	2.10	0.16	0.09	4.63	1.37	2.46	2.73	0.38	0.91
Mg_1Ca_2	2.42	2.52	0.17	0.13	5.57	1.37	2.05	2.67	0.35	0.87
Mg_1Ca_3	2.60	2.37	0.19	0.13	5.54	2.01	1.74	2.49	0.31	0.83
Mg_2Ca_1	2.63	2.50	0.18	0.13	4.95	1.98	2.00	2.65	0.41	0.98
Mg_2Ca_2	2.44	2.22	0.19	0.16	4.94	2.35	1.88	2.61	0.39	0.91
Mg2Ca_3	2.52	2.55	0.17	0.12	4.64	1.47	1.42	2.57	0.35	0.86
Mg_3Ca_1	2.70	2.10	0.16	0.19	4.87	2.09	1.55	2.54	0.45	1.18
Mg_3Ca_2	2.66	2.45	0.18	0.09	5.42	1.71	1.58	2.50	0.43	1.10
Mg_3Ca_3	2.55	2.70	0.16	0.13	4.04	2.14	1.19	2.44	0.40	1.25
Mg_4Ca_1	2.48	2.43	0.18	0.18	5.10	2.50	1.12	2.30	0.47	1.24
Mg_4Ca_2	2.41	2.34	0.19	0.10	4.84	1.70	1.06	2.23	0.44	1.07
Mg_4Ca_3	2.39	2.00	0.17	0.10	4.85	1.99	1.02	2.17	0.40	1.01
S.Em+										
Mg	0.061	0.054	0.003	0.003	0.126	0.058	0.127	0.059	0.054	0.019
Ca	0.046	0.042	0.006	0.005	0.113	0.031	0.170	0.053	0.029	0.016
Mg x Ca	0.093	0.085	0.012	0.010	0.226	0.062	0.340	0.106	0.058	0.033
CD at 5%										
Mg	0.213	0.189	0.013	0.013	0.436	0.200	0.442	0.205	0.189	0.066
Ca	0.139	0.128	0.018	0.016	0.340	0.093	0.510	0.159	0.087	0.050
Mg x Ca	0.278	0.256	0.036	0.032	0.680	0.186	1.020	0.319	0.174	0.101

when no Ca and Mg were applied. Potassium is a monovalent cation while both Ca and Mg are divalent. Hence, antagonistic relations are expected naturally among these nutrient elements both in soil and crops (Ganeshamurthy, 1983). Interaction effects of applied Mg and Ca resulted in enhancing the soil Ca from 430.17ppm in Mg_1Ca_1 to 694.67ppm in Mg_4Ca_3 treatments, on the other hand it was observed that interaction effects of applied Mg and Ca resulted in enhancing soil Mg from 92.98ppm in Mg_1Ca_1 to 213.64ppm in Mg_4Ca_3 treatments. Ca uptake was affected by major cation even though it is available in soil or nutrient media in sufficient quantity as observed by Barber (1995). On the other hand K and Mg can restrict the uptake of Mg from the roots to upper plant parts (Schimanski, 1981). According to Bergman (1992) high K indirectly causes damage to plants growth by inducing Ca and Mg deficiencies

Plant nutrients

Application of graded levels of Ca and Mg in different combinations showed significant changes in plant nutrient contents (Table 5). The interaction of Mg and Ca resulted in lowest fruit N content of 2.39% in Mg_4 Ca_3 treatment. Similar results were reported by Adams *et al* (1978). The interaction of Mg and Ca resulted in lowest fruit P content of 0.16% in Mg_1 Ca_1 and treatments and the highest P content of 0.19% was observed in Mg_2 Ca_2 and Mg_4Ca_2 combination. Halbrooks and Wilcox (1980) in a field experiment studied the elemental uptake pattern in tomato and obtained similar trends.

The interaction of Mg and Ca resulted in lowest fruit K of 4.04 and 5.57% in Mg_3 Ca_3 and Mg_1Ca_2 treatments respectively. In general the fruit Ca content decreased with increased levels of Mg and Ca. The Interaction effect of applied Mg and recorded highest fruit Ca of 2.46% in Mg_1Ca_1 (Control) and lowest of 1.02% was found in Mg_4Ca_3 combination. A combined application of Mg_1 and Ca_3 recorded 0.31% fruit Mg_1 on the other hand 0.47% was found in Mg_4 Ca_1. The nutrient content in plant leaf and stem showed significant differences as in fruit nutrient content. Interaction effects of Mg and Ca application showed lowest N of 2.10% in Mg_1 Ca_1 and Mg_3Ca_3 treatments and the highest of 2.70% was observed in Mg_3Ca_3 treatment. The P content in leaf and stem found lowest 0.09% and highest 0.19% in Mg_1Ca_1 and Mg_3Ca_1 treatments. The highest K 2.35% was recorded in Mg_2Ca_2 combination. Barber (1995) and Bergmann (1992) found similar results. The Ca content in leaf and stem decreased with increased levels of Mg and Ca application. The highest Ca content (2.73%) in leaf and stem was found in Mg_1Ca_1 and lowest (2.17%) was observed in Mg_4Ca_3 combination. The results indicated antagonism between Mg and Ca in uptake process. Similar results were found by many workers viz., Bergmann (1992) Osman and Gerald (1985); Asiegbu and Uzo (1983).

The Mg content in leaf stem as affected different levels of Mg and Ca application resulted lowest Mg 0.83% and Mg_3Ca_3 treatments respectively. Similar results were found by Micaela Carvajal *et al* (1999). In nutrient uptake process K, Mg and Ca are strongly antagonistic (Voogt, 1998) resulting in deficiency of depressed element. Ca uptake was affected by major cation even though it is available in soil or nutrient media in sufficient quantity as observed by Barber (1995). On the other hand K and Mg can restrict the uptake of Mg from the roots to upper plant parts (Schimanski, 1981) According to Bergmann (1992) high K indirectly causes damage to plants growth due to Ca and Mg deficiencies.

No significant influence was observed on plant Ca content by the application of Mg and Ca. With increasing applied Mg levels the mean fruit Ca content decreased. As the level of applied Ca increased the plant Ca content decreased. The lowest fruit Ca of 1.02% was recorded in Mg_4 (250kg Mg ha^{-1}) Ca_3 (250kg Ca ha^{-1}) treatment. In a study on Mg uptake by tomato plants Schwartz and Baryosef (1983) observed that enhanced Ca concentration reduced the Mg concentration but increased Mg concentration had no effect on Ca concentration. Mirabdulbaghimitra (1993) found that leaf and root Ca contents decreased with increasing Mg supply there were higher concentration of Ca and Mg in the leaf compared to fruit, while P was higher in fruit than leaf, with the leaf age Ca and Mg content increased (Asiegbu and Uzo, 1983).

Application of Mg and Ca had significant negative influence on plant Mg content. With increasing Mg levels the mean fruit Mg content increased in tomato fruits, leaves and stem. In fruits the Mg content decreased as the level of Ca application increased. Similar trend was noticed in leaves and stem. Combined application of Mg_1Ca_3 resulted in lowest fruit Mg of 0.31% in tomato fruits and 0.83% in leaves and stem. Paiva *et al* (1998) while working in tomato crop showed antagonistic effect between Ca and Mg and reported that the rate of Mg uptake depressed by Ca. Micaela Carvajal *et al* (1999) observed decreased uptake of Mg due to cationic antagonism.

In order to achieve desired yield and quality levels with hybrid tomato varieties nutrition management of NPK and other nutrients like calcium and magnesium play a vital role. As these nutrient elements are antagonistic to each other, proper corrections can to be done through foliar sprays in proper ratios. Application of Mg and Ca produced significant treatment differences in yield. The results indicated that a combination of 100 and 250kg ha^{-1} of Mg and Ca respectively was found optimum to obtain higher yields of tomato. Interaction effect of Ca and Mg application at different levels showed positive correlation with soil P and an antagonistic effect on both soil and plant K, but had no significant effect on soil pH, EC, OC and soil N contents. Application of different levels of Mg and Ca showed significant changes in plant nutrient contents.

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