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Studies on Interaction Effects of Combined Application of Magnesium and Potassium on Soil Properties and Yield of Tomato (*Solanum lycopersicum* L.) in an Alfisol

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A B S T R A C T

A field experiment was conducted at ICAR-Indian Institute of Horticultural Research, Bengaluru to assess the interaction effects of combined application of Magnesium (Mg) and Potassium (K) on soil properties and yield of tomato. Results showed that mean effect of applied Mg resulted in 23 per cent to 28 per cent higher yield up to a doze of 50 kg Mg ha^{-1} as compared to non-application of magnesium. The application of K also significantly influenced the yield. The dose of 100 kg K ha^{-1} along with 50 kg Mg ha^{-1} recorded the highest yield of 84.39 kg ha^{-1} which was 13 per cent higher compared to non-application of K. Graded levels of Mg and K did not have any significant effect on either soil pH, EC and OC. Application of Mg and K did not have any significant influence on soil available N. With an increase in the applied Mg levels, the mean available N content decreased. The results showed that with the increase in the applied Mg levels the mean available P content decreased upto 5 per cent. Similarly, the application of Mg and K together significantly had negative influence on soil available K and Ca. The mean available K content decreased with the increase of Mg level. These results indicated the existence of antagonism among Mg, K and Ca in the soil. Hence, when the soil is deficient in K and Mg, the deficiency of Mg should be corrected before applying K fertilizer for achieving higher yields.

Introduction

Tomato is one of the important vegetables grown throughout the world under open and controlled conditions. India produces 18.74 million tonnes of tomato from an area of 8.82 lakh hectares. The average productivity is 21.2 t ha^{-1}(NHB-2014). It serves as a daily component of diet in many countries and also an important source of minerals, vitamins and antioxidants (Grienrson and Kader, 1986).

It is rich in calories and vitamins A, B and C and a good source of Iron. Consumption of 230g of tomato can supplement daily requirement of vitamin C in adults and reduce the risk of developing colon, rectal and stomach cancer.

The steady increase in the population will intensify the use of natural resources such as land, water and air for achieving higher food production which is only possible by increasing the productivity per unit area by way of development of high yielding varieties/hybrids clubbed with intensive production practices. One of the primary causes of low productivity is the imbalanced use of plant nutrients which lead to soil mining and depletion of mineral elements in soils (Ganeshamurthy and Hegde, 1980). In India, the deficiency of secondary and micro nutrients increased with application of only N, P and K fertilizers, ignoring secondary and micronutrients (Shukla *et al.*, 2009) and application of N alone increased soil depletion of other nutrients including Ca, Mg and S (Nambiar and Abrol, 1989). Among the secondary nutrients, Mg plays a vital role in the formation of chlorophyll (as it contains about seven per cent of magnesium), fat, vitamins, amino acids and also involves in many biochemical and physiological functions including transport of phosphates, and phosphorylating enzyme in carbohydrate metabolism. It also influences earliness, ensures uniform maturity and improves the quality of fruits (Ganeshamurthy and Hegde, 1980).The important interactions of K, Ca and Mg in a soil or nutrient media play each other antagonistically in uptake of these elements by plants. As reported by Ananthanarayana and Hanumantharaju (1992), antagonism between Mg and K could be the differences in their ionic mobility. High K concentration in nutrient solution resulted in Mg deficiency in plant tissue (Jones, 1999) and vice-versa. The correct ratio of K and Mg in the soil is important because of excessive concentrations of either of the elements can negatively affect the plant growth (Bergmann, 1992). In Tomato Mg, K and Ca play a vital role in nutrition management and strongly interfere with each other in absorption mechanism of the plants (Hao and Papadopoulas, 2003). The ideal base saturation of cations Ca, Mg, K and H in the exchange complex is 40-50, 5-15, 2-5 and 20-30 per cent respectively. Deficiency of these elements occurs due to under supply or antagonistic effect on each other thus decrease the yield and quality of tomato. When Mg level was high, a high level of K was effective in reducing Mg content of spinach, but there was no effect when Mg level was low (Hohlt and Maynard, 1966). This suggests that cation interaction is more intense at high concentrations as compared to low ones. Antagonism between K and Mg was observed (Kolota and Orlowski, 1984) in tomato and the results showed that good plant growth and highest yields were obtained from the plants receiving K_2O and Mg each at 400 Mg l^{-1} soil. Adams *et al.*, (1978) studied tomato yield in relation to the N, K and Mg status of the plants and of the peat substrate. Maximum yields were obtained when the nutrient content in leaves was 4.5–5.1 per cent N, 4.4-5.6 per cent K and 0.31 – 0.40 per cent Mg. It was found that Mg content of 250 Mg l^{-1} was fully adequate for obtaining optimum yields. Mg and K interactions in plant and soils were studied by Ananthanarayana and Venkata Rao (1979) in pea crop. They found significant variations among different treatments in yield with increasing levels of Mg. It is paradoxical in the sense that on one hand application of K fertilizer increases the yield and also has antagonistic effect on Mg uptake. In tomato, Kolota and Orlwski (1984) observed antagonism between K and Mg at higher potassium rates. Therefore, in soil deficient in K and Mg, the deficiency of Mg should be corrected before applying K fertilizer.

Generally, Mg deficiency in plants will be noticed in older leaves. The leaves become abnormal and an inter-venal chlorosis starts on the lower leaves of plant. In advanced stage, the colour of leaves becomes purplish red; leaves become brittle with a tendency to curve upward. In these crops, twigs remain weak, and shed prematurely. The critical limit in plant is 0.1 to 0.2 per cent of Mg in terms of plant dry matter. For a healthy tomato leaf, the Mg concentration should be from 0.40 to 0.60 per cent (Ward and Miller, 1969).

In order to obtain higher yield with good fruit quality K, Mg and Ca nutrients must be made available in sufficient quantity in proper ratio. These important cations strongly interact with each other and excess of one element induces deficiency of another element. Thus good nutrition management is required to make these elements available in sufficient quantity in nutrient solution for obtaining higher yield in tomatoes with quality. Hence an attempt was made through this study to assess the interaction effects of combined application of Magnesium and Potassium on soil properties and yield of tomato.

Materials and Methods

The study was conducted at ICAR-Indian Institute of Horticultural Research, Hesaraghatta, Bengaluru, during the rabi of 2011-12. The Initial soil-chemical properties and nutrient status in the experimental site were: pH- 6.14, EC- 0.74 dsm^{-1}, OC- 0.74, N-119.88 ppm, P- 3.51 ppm, K- 731.20ppm, Ca-158 ppm and Mg- 61.6 ppm. The experiment was laid out in a Split plot design, with 12 treatments (four main plot treatments for magnesium and three sub plot treatments for potassium) and three replications.

Fertilizer application

The recommended dose of fertilizer (RDF) for tomato, 180:150:120 kg NPK kg ha^{-1}, was applied to all the treatments in the form of urea, Diammonium phosphate (DAP) and muriate of potash. The quantity of urea 263.71 kg ha^{-1}, DAP-(18:46:0) 326.08 kg ha^{-1} and muriate of potash-200 kg ha^{-1} were applied through soil application. Full dose of P and K was applied as soil application whereas, Nitrogen was applied in three splits, viz., 50% RDF at planting, 25% RDF each at 25 days after transplanting and 50 days after transplanting. Magnesium was applied as basal dose in the form of magnesium sulphate ($MgSO_4.7H_2O$). The quantity of magnesium was applied in the form of magnesium sulphate. The treatment details are given in table 1.

Tomato hybrid Arka Ananya of ICAR-Indian Institute of Horticultural Research was transplanted at a spacing of 100cm x 60cm. Fruits were harvested in 10 pickings, and weight of the fruits from each plant was recorded separately for obtaining fruit yield (t ha^{-1}). Soil samples were collected at three stages of crop for analysing pH, EC, OC and at the end of cropping period for N, P, K, Ca and Mg. Standard analytical methods were followed for the analysis of soil samples. The data on yield and other soil parameters were tabulated and statistical analysis was done as per the methods suggested by Sundaraja *et al.*, (1972).

Results and Discussion

Fruit Yield

The data pertaining to yield of tomato hybrid as influenced by four levels of Mg and three levels of K and their interaction is presented in table 2. Application of Mg and K produced significant treatment differences in the yield. The mean effect of applied Mg resulted in increasing the yield of tomato up to 50 kg Mg ha^{-1}. The lowest mean yield of 63.38 t ha^{-1} was observed in the plots where Mg was not applied Mg_1 (0 kg Mg ha^{-1}), on the other hand the highest mean yield of 80.46 t ha^{-1} was obtained through application of Mg_2 (50 kg Mg ha^{-1}). The application of K produced significant change in the yield. At lower levels of applied K, the mean yield of tomato increased up to 100 kg K ha^{-1} and decreased at higher levels beyond 100 kg K ha^{-1}. The lowest mean yield of 69.06 t ha^{-1} was obtained at K_1 (0 kg K ha^{-1}) and the highest yield of 75.48 t ha^{-1} was obtained at K_2 (100 kg K ha^{-1}). The interaction effect of Mg and K on yield showed that a combination of Mg_2 (50 kg Mg ha^{-1}) with K_2 (100 kg K ha^{-1}) resulted in highest yield (84.39 t ha^{-1}) and the combination of Mg_1 (0 kg ha^{-1}) with K_1 (0 kg K ha^{-1}) given the lowest yield of 57.71 t ha^{-1}.The important interactions of K, Ca and Mg in a soil or nutrient media were antagonistic to each other in uptake of these elements by plants. As reported by Ananthanarayana and Hanumantharaju (1992), antagonism between Mg and K could be due to the differences in their ionic mobility. High K concentration in nutrient solution resulted in Mg deficiency in plant tissue (Jones, 1999) and vice-versa. The correct proportion of K: Mg in the soil is important because of excessive concentrations of either element can negatively affect the plant growth (Bergmann, 1992). Sonneveld (1987) observed that in rockwool grown tomato, the Mg deficiency symptoms reduced due to high and low K/ Ca elements in the nutrient solution. A high K level was effective in reducing Mg content of spinach when Mg level was high, but no effect when Mg level was low (Hohlt and Maynard, 1966) this suggests that cation interaction was more intense at high concentrations than at low ones. Antagonism between K and Mg was observed (Kolota and Orlowski, 1984) in tomato. Good plant growth and highest yields were obtained from the plants applied with K_2O and Mg each at 400 Mgl^{-1} soil. Good nutritional status was observed when leaf contents of Mg and K were 0.59 and 4.67 per cent respectively. In corn as observed by Foy and Barber (1958), Mg additions essentially prevented the Mg deficiency symptoms, significantly increased the percentage of Mg and reduced the percentage of K in leaves. Adams *et al.*, (1978) studied tomato yield in relation to the N, K and Mg status of the plants and of the peat substrate. Maximum yields were obtained when the nutrient content in leaves was 4.5 – 5.1 per cent N, 4.4-5.6 percent K and 0.31 – 0.40 percent Mg. It was found that Mg content of 250 Mg l^{-1} was fully adequate for obtaining optimum yields. K and Mg have antagonistic relations with respect to availability of one over the other and their effect on crop performance. This study revealed that combined application of 50 kg Mg ha^{-1} and 100 kg K ha^{-1} is the optimum level for these nutrients for achieving higher yield.

Interaction effect of applied Mg and K on Soil pH and EC

The data pertaining to Soil pH and EC as influenced by four levels of Mg and three levels of K and their interaction is shown in Fig. 1 and 2 respectively. The application of Mg and K did not induce any significant change in soil pH and EC. The interaction effect of combined application of Mg (Mg_{1-}0 kg Mg ha^{-1})and K (K_{3-} 250 kg K ha^{-1}) resulted in the lowest soil pH of 5.81 and the highest soil pH value 5.85 was obtained at the combination of Mg_4 (250 kg Mg ha^{-1}) and K_1 (0 kg K ha^{-1}). The lowest soil EC value 0.38 dSm^{-1} was observed at the combined application of Mg_1 (0 kg Mg ha^{-1}) and K_1 (0 kg K ha^{-1}) and the highest soil EC of 0.43 dSm^{-1} was obtained at the combined application of Mg_4 (250 kg Mg ha^{-1}) with K_3 (250 kg K ha^{-1}), Mg_4 (250 kg Mg ha^{-1}) with K_2(100 kg K ha^{-1}) and Mg_4 (250 kg Mg ha^{-1}) with K_3 (250 kg K ha^{-1}). This is because; the levels of both Mg and K used in this study were small to cause any effect on pH and EC. It is expected that with increased levels of applied Mg and K the soil pH and EC should show an increase. Present study also indicated this trend, although the results were not statistically significant. Most of the tomato studies revealed that increasing electrical conductivity (EC) of the nutrient solution improves fruit quality (Adams, 1991; Gough and Hobson, 1990) and increases shelf life. Mizrahi and Mizrahi (1982) studied the effect of potassium magnesium chloride in the fertigation solution as partial source of potassium on growth, yield and quality of green house tomato, the study revealed that the fertigation of $Kcl.MgCl_2$ increased the yield of tomato.

Interaction effect of applied Mg and K on soil OC and Soil N

The application of Mg and K did not result in significant change in soil organic carbon and Soil Nitrogen. The highest soil OC mean value of 0.68 per cent was obtained at combined application of Mg_3 (100 kg ha^{-1}) with K_2 (100 kg ha^{-1}), Mg_3 (100 kg Mg ha^{-1}) with K_3 (250 K kg ha^{-1}) and Mg_4 (250 kg Mg ha^{-1}) with K_1 (0 kg K ha^{-1}) and the lowest soil organic carbon of 0.64 per cent was observed at combined application of Mg_1 (0 kg Mg ha^{-1}) with K_1(0 K kg ha^{-1}).

This might be due to the fact that the biomass production increased with application of desired levels of Mg and K but the effect on soil organic carbon could not be seen as the time was too short to obtain any such changes in soil organic carbon particularly in tropical soils like those under this experimentation.

The application of Mg and K did not have any significant influence on soil available N. It was also observed that, the increase in the Mg levels decreased the mean value of available N. As the level of applied K increased, the available N content remained at 124 kg N ha^{-1}. The combined application of Mg (Mg_4 - 250 kg Mg ha^{-1}) and K (K_1 -0 kg K ha^{-1}) resulted in lowest available N (123.60 kg N ha^{-1}) and the highest value of 126.23 kg N ha^{-1} was observed at the combination of Mg_2(50 kg Mg ha^{-1}) with K_3(250 kg K ha^{-1}). Subramanian *et al.,* (1976) reported an increase not only in the uptake of N and P and but also the yield of groundnut. Adams *et al.*, (1978) reported maximum yield of tomato when the nutrient content in leaves was 4.5 - 5.1 per cent N, 4.4-5.6 per cent K and 0.31-0.40 per cent Mg. They found that Mg content of 250 mg l^{-1} was very much adequate for obtaining optimum yields (Table 3).

Soil P and Soil K

The combined application of four levels of Mg and three levels of K significantly influenced the soil available phosphorus and potassium content (Table 4).With the increase in the applied Mg levels, the mean available P content decreased from 7.84 (control -0 kg Mg ha^{-1}) to 7.46 kg P ha^{-1} (Mg_4 -250 kg Mg ha^{-1}). As the level of applied K increased, the available P content increased from 7.57 to 7.76 kg P ha^{-1}. Interaction effects of applied Mg and K resulted in decrease of soil available P from 7.81 kg P ha^{-1} at the combination of Mg_1 (0 kg Mg ha^{-1}) with K_1 (0 kg K ha^{-1}) to 7.34 kg $^{-1}$ P ha^{-1} at Mg_4 (250 kg Mg ha^{-1}) with K_1 (0 kg K ha^{-1}).

This showed that the Mg has synergistic reaction with P upto certain level hence the results showed that the available P content increased as the level of Mg increased upto 50 kg Mg ha^{-1} thereafter started decreasing. In general it was observed that mean soil P content increased with the increase in level of application of Mg and K to the soil. Subramanian *et al.*, (1976) showed that as the level of Mg is increased the uptake of N and P increased the yield in groundnut.

According to Bergman (1992) high K indirectly causes damage to plants growth by inducing Ca and Mg deficiencies. The mean available K content decreased with an increase of application of Mg. As the level of applied K increased the available K content also increased.

Table.1 Treatment details of magnesium and potassium interaction experiment

Treatment	RDF $N:P_2O_5:K_2O$ kg ha^{-1}	Mg (kg ha^{-1})	Equivalent quantity of $MgSO_4$ (kg ha^{-1}) applied	K_2O (kg ha^{-1})	Equivalent quantity of MOP(kg ha^{-1}) applied
T_1	180:150:120	0	0	0	0
T_2	180:150:120	0	0	100	166.66
T_3	180:150:120	0	0	250	416.66
T_4	180:150:120	50	514	0	0
T_5	180:150:120	50	514	100	166.66
T_6	180:150:120	50	514	250	416.66
T_7	180:150:120	100	1028	0	0
T_8	180:150:120	100	1028	100	166.66
T_9	180:150:120	100	1028	250	416.66
T_{10}	180:150:120	250	2570	0	0
T_{11}	180:150:120	250	2570	100	166.66
T_{12}	180:150:120	250	2570	250	416.66

Table.2 Tomato (Arka Ananya) yield (t ha^{-1}) as influenced by interaction effect of Mg with potassium

Treatments	Yield (t ha^{-1})			
	K_1 (0 kg K ha^{-1})	K_2 (100 kg K ha^{-1})	K_3 (250 kg K ha^{-1})	Mean
Mg_1 (0 kg Mg ha^{-1})	57.71	66.23	66.19	**63.38**
Mg_2(50 kg Mg ha^{-1})	74.15	84.39	82.85	**80.46**
Mg_3(100 kg Mg ha^{-1})	73.64	79.31	69.01	**73.99**
Mg_4 (250 kg Mg ha^{-1})	70.73	71.97	64.84	**69.18**
Mean	**69.06**	**75.48**	**70.72**	**71.75**
	S. Em±		**C.D at 5%**	
Mg	**2.194**		**7.593**	
K	**1.244**		**3.731**	
Mg x K	**2.489**		**7.463**	

Table.3 Interaction effects of applied Mg and K on soil organic carbon (%) and soil nitrogen (kg ha^{-1})

Treatment	Organic Carbon (%)				Soil Nitrogen (kg ha^{-1})			
	K_1 (0 kg K ha^{-1})	K_2 (100 kg K ha^{-1})	K_3 (250 kg K ha^{-1})	Mean	K_1 (0 kg K ha^{-1})	K_2 (100 kg K ha^{-1})	K_3 (250 kg K ha^{-1})	Mean
Mg_1 (0 kg Mg ha^{-1})	0.64	0.67	0.67	**0.66**	125.29	123.82	124.24	**124.45**
Mg_2(50 kg Mg ha^{-1})	0.65	0.66	0.67	**0.66**	124.60	125.36	126.23	**125.40**
Mg_3(100 kg Mg ha^{-1})	0.67	0.66	0.68	**0.67**	125.11	125.59	123.98	**124.89**
Mg_4(250 kg Mg ha^{-1})	0.68	0.67	0.68	**0.68**	123.60	124.74	124.32	**124.23**
Mean	**0.66**	**0.67**	**0.68**		**124.65**	**124.88**	**124.69**	
	S. Em±		**C.D at 5%**		**S. Em±**		**C.D at 5%**	
Mg	**NS**		**NS**		**NS**		**NS**	
K	**NS**		**NS**		**NS**		**NS**	
Mg x K	**NS**		**NS**		**NS**		**NS**	

Table.4 Interaction effects of applied Mg and K on soil phosphorus and potassium

Treatment	Soil Phosphorus (kg ha^{-1})				Soil Potassium (kg ha^{-1})			
	K_1 (0 kg K ha^{-1})	K_2 (100 kg K ha^{-1})	K_3 (250 kg K ha^{-1})	Mean	K_1 (0 kg K ha^{-1})	K_2 (100 kg K ha^{-1})	K_3 (250 kg K ha^{-1})	Mean
Mg_1 (0 kg Mg ha^{-1})	7.81	7.83	7.89	**7.84**	119.3	122.0	125.1	**112.1**
Mg_2(50 kg Mg ha^{-1})	7.68	7.72	7.81	**7.74**	114.4	118.6	120.8	**118.0**
Mg_3(100 kg Mg ha^{-1})	7.46	7.50	7.69	**7.55**	106.9	112.4	117.1	**112.1**
Mg_4(250 kg Mg ha^{-1})	7.34	7.41	7.63	**7.46**	101.8	105.9	111.5	**106.4**
Mean	**7.57**	**7.61**	**7.76**		**110.6**	**114.7**	**118.6**	
	S. Em±		**C.D at 5%**		**S. Em±**		**C.D at 5%**	
Mg	**0.073**		**0.22**		**1.72**		**5.16**	
K	**0.100**		**0.30**		**2.09**		**6.26**	
Mg x K	**0.113**		**0.34**		**2.36**		**7.07**	

Table.5 Interaction effects of applied Mg and K on soil calcium and soil magnesium

Treatment	Soil Calcium (ppm)				Soil Magnesium (kg ha^{-1})			
	K_1 (0 kg K ha^{-1})	K_2 (100 kg K ha^{-1})	K_3 (250 kg K ha^{-1})	Mean	K_1 (0 kg K ha^{-1})	K_2 (100 kg K ha^{-1})	K_3 (250 kg K ha^{-1})	Mean
Mg_1 (0 kg Mg ha^{-1})	479.2	493.0	513.8	**495.3**	124.2	129.6	141.8	**131.9**
Mg_2(50 kg Mg ha^{-1})	451.6	466.4	475.1	**464.4**	169.8	185.7	197.6	**184.4**
Mg_3(100 kg Mg ha^{-1})	438.2	421.7	409.5	**423.1**	202.9	214.5	229.8	**215.7**
Mg_4(250 kg Mg ha^{-1})	406.3	398.5	380.4	**395.1**	227.1	241.8	263.6	**244.2**
Mean	**443.8**	**444.9**	**444.7**		**181.0**	**192.9**	**208.1**	
	S. Em±		**C.D at 5%**		**S. Em±**		**C.D at 5%**	
Mg	**09.8**		**29.36**		**6.34**		**19.00**	
K	**NS**		**NS**		**6.80**		**20.37**	
Mg x K	**12.1**		**36.2**		**8.36**		**25.04**	

Fig.1 Effect of combined application of different levels of magnesium and potassium on soil pH

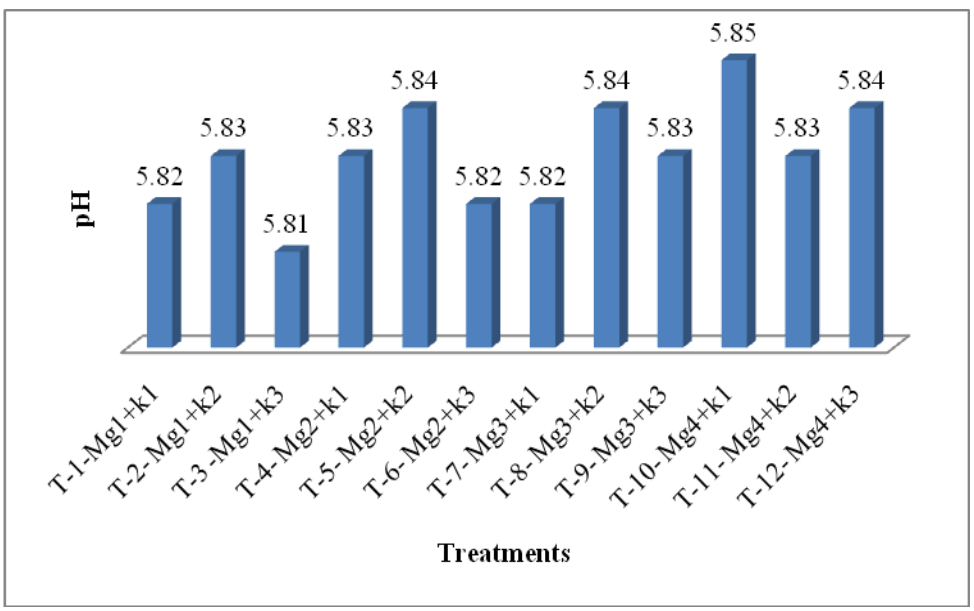
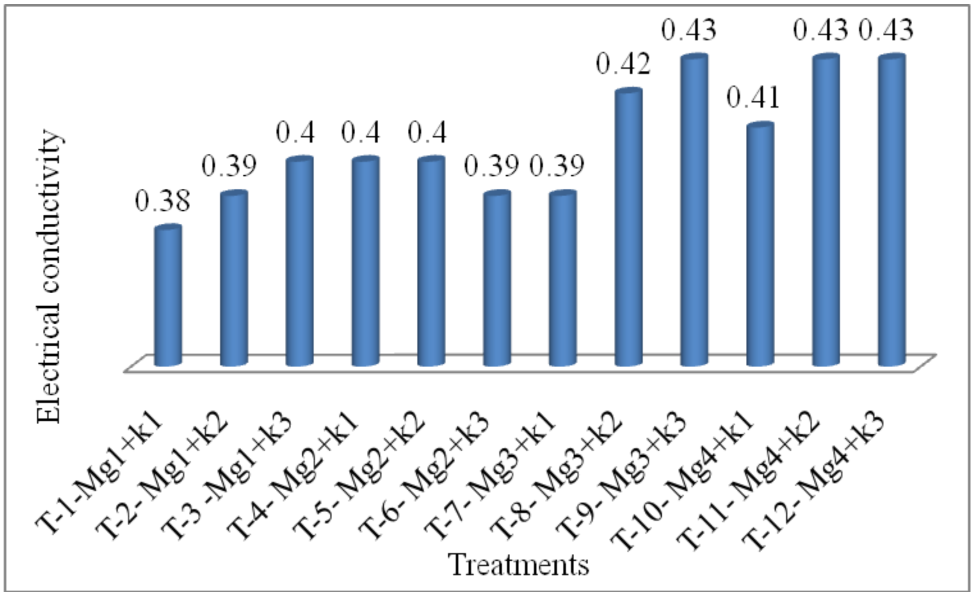


Fig.2 Effect of combined application of different levels of magnesium and potassium on soil EC



The lowest available K of 101.8 kg K ha^{-1} was recorded when Mg_4 (250kg Mg ha^{-1}) was combined with K_1(0kg K ha^{-1}). On the other hand, the highest available K of 125.1 kg K ha^{-1} was recorded at the combined application of Mg_1 (0kg Mg ha^{-1}) with K_3(250kg K ha^{-1}). These results indicated an antagonism between Mg and K availability in the soil. When the level of Mg is increased then it will try to occupy exchangeable K from the soil surface and vice versa.

As reported by Ananthanarayana and Hanumantharaju (1992), antagonism between Mg and K could be due to differences in their ionic mobility. High K concentration in nutrient solution resulted in Mg deficiency in plant tissue (Jones, 1999) and vice-versa. Kirkbym and Mengel (1976) reported that high Mg concentration in soil or plant is due to poor status of K in soil. In Tomato, Sonneveld (1987) observed that, Mg deficiency symptoms reduced due to high and low K/ Ca elements in the nutrient solution. This suggests that cation interactions are more intense at high concentrations than at low ones (table 4).

Soil Ca and Soil Mg

In a nutrient uptake process, K, Mg and Ca are strongly antagonistic. Similar to potassium, Mg also should have antagonistic relationship with Ca in the soil. However, no significant change in soil Ca was observed through the application of different combinations of Mg and K. But the trend indicated that with an increase in the Mg levels the mean exchangeable Ca content decreased. As the level of applied K increased the exchangeable Ca content slightly increased. The combined application of Mg and K resulted in reduction of soil exchangeable Ca from 479.2 ppm in Mg_1 (0kg Mg ha^{-1}) with K_1 (0kg K ha^{-1}) to 380.4 ppm in Mg_4 (250kg Mg ha^{-1}) with K_3(250kg K ha^{-1}). At very high concentration, Mg^{2+} will suppress K^+ uptake at the exchange site.

A study by tomato magnesium nutrition by Brun (1984) suggested that a nutrient solution with a (Ca + Mg): K ratio of 2.75 seems to be adequate for satisfactory tomato crop. The application of Mg and K significantly influenced the soil exchangeable Mg content.

When the Mg levels increased the mean exchangeable Mg content also increased from 131.9 ppm in control to 244.2 ppm in Mg_4 (250 kg Mg ha^{-1}). As the level of applied K increased the exchangeable Mg content slightly increased from 181.0 to 208.1 ppm. Interaction effects of applied Mg and K resulted in higher soil exchangeable Mg from 124.2 ppm in Mg_1 (0 kg Mg ha^{-1}) with K_1 (0 kg K ha^{-1}) to 263.6 ppm in Mg_4 (250 kg Mg ha^{-1}) with K_3 (250 kg K ha^{-1}).

In a study on tomato correct ratio of K and Mg in the soil is important because of excessive concentrations of either element can negatively affect the plant growth (Bergmann, 1992). High K concentration in nutrient solution resulted in Mg deficiency in plant tissue (Jones, 1999) and vice-versa. Antagonism between K and Mg observed (Kolota and Orlowski, 1984) in tomato. Good plant growth and highest yields were obtained from the plants recurring K_2O and Mg each at 400 Mg l^{-1} soil. Adams *et al.*, (1978) studied tomato yield in relation to the N, K and Mg status of the plants and of the peat substrate. Maximum yields were obtained when the nutrient content in leaves was 4.5 – 5.1 per cent N, 4.4-5.6 percent K and 0.31– 0.40 per cent Mg. The results shows that interactions K, Ca and Mg in a soil or nutrient media play each other antagonism in uptake of these elements by plants (Table 5).

The results of the above experiment shown that the important interactions of K, Ca and Mg in the soil or nutrient media were antagonistic to each other in the uptake of these elements by plants. Similarly Ca and Mg, K and Mg also have similar antagonistic relations with respect to their availability of one over the other and their effects on crop performance. This suggests that cation interactions are more intense at high concentrations than at low ones. The overall performance indicated that the application of Mg increased the yield of tomato up to a quantity of 50 kg Mg ha^{-1}. It was also observed that, the yield of tomato increased at lower levels of applied K with 50 kg of Mg ha^{-1} and decreased at higher levels beyond 50 kg Mg ha^{-1}. Graded levels of Mg and K did not have any significant effect on either soil pH, EC and OC.

Besides it was found that, application of Mg and K did not have any significant influence on the soil available N. An increase in the applied Mg levels has shown a reduction in the mean available N content. Further a synergistic reaction could be observed between Mg and P at lower levels of Mg. The application of Mg and K together had significant negative influence on soil available K and Ca. The mean available K content decreased with an increase in the level of Mg. These results clearly indicated the existence of antagonism between Mg and K and Ca in the soil. Interaction was also negative between Mg and K only at higher levels of Mg and K and at lower levels it was synergistic. Thus, it was concluded that for the soil which is deficient in K and Mg, the deficiency of Mg should be corrected before applying K fertilizer for achieving desirable yields in tomato.

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