Asian Journal of **Biochemistry**

ISSN 1815-9923

Academic Journals Inc.

www.academicjournals.com

Asian Journal of Biochemistry 6 (3): 273-281, 2011
ISSN 1815-9923 / DOI: 10.3923/ajb.2011.273.281

Impact of Different Sources and Doses of Magnesium Fertilizer on Biochemical Constituents and Quality Parameters of Black Tea

[1]S. Jayaganesh, [2]S. Venkatesan and [3]V.K. Senthurpandian
[1]UPASI Tea Research Foundation, Valparai 642 127, Tamil Nadu, India
[2]Cavinkare Research Centre, Ekkaduthangal, Chennai-600 032, Tamil Nadu, India
[3]Department of Chemistry, Anna University of Technology, Tiruchirappalli, Tiruchirappalli-620 024, Tamil Nadu, India

Corresponding Author: Dr. V.K. Senthurpandian, Department of Chemistry, Anna University of Technology, Tiruchirappalli, Tiruchirappalli-620 024, Tamil Nadu, India

ABSTRACT

A study was conducted with different sources of magnesium fertilizers on biochemical parameters like chlorophyll, carotenoids, polyphenols, catechins and amino acid of green leaves in tea. Amino acid and polyphenols are increased due to magnesium sulphate application. Among the various treatments, the application of magnesium sulphate along with reduction of potassium input decreased the biochemical parameters. The content of chlorophyll and carotenoids were higher in magnesium sulphate applied blocks followed by kieserite application. Catechin content was higher due to kieserite and magnesium sulphate applications. After one year of experimentation, the leaf samples collected from the experimental blocks were mini manufactured and analysed for their quality parameters. Theaflavins, thearubigins, total liquor colour and highly polymerised substances were higher in magnesium sulphate and kieserite applied plots. TLC and HPS were higher due to magnesium sulphate application. The different sources of soil applied magnesium directly influenced the amino acid content made of tea and it was higher in magnesium sulphate and magnesium nitrate applied blocks. Flavor index was also estimated for price realization in made tea and it increased due to soil application of magnesium. Among different sources, magnesium sulphate has yielded higher amount of flavor followed by kieserite application. Application as per standard practices along with 50% reduction of potassium fertilizer yielded higher amount of CFC. Water extract content was higher in magnesium sulphate applied blocks and lower in magnesium nitrate application. Green leaf yield and organoleptic evaluation revealed that among different source like magnesium sulphate, magnesite, magnesium nitrate and kieserite, the cost benefit ratio was higher for magnesium sulphate.

Key words: Magnesium, polyphenols, flavour index, magnesite, kieserite

INTRODUCTION

Magnesium ranks third after N and K, in terms of the importance for economic growth of tea plants. It is the only mineral constituent in the chlorophyll molecule that regulates photosynthesis. In addition, it acts as an activator of many enzyme systems involved in carbohydrate metabolism and synthesis of nucleic acids and helps in translocation of sugar. On average, the harvestable tea crop contains between 0.05 and 0.25% Mg on dry weight basis (Venkatesan, 2006). To meet the magnesium nutrition in mature tea in Sri Lanka 500 kg of dolomitic lime is recommended after pruning (Jayaganesh and Venkatesan, 2006; Venkatesan and Jayaganesh, 2010). In north-east India besides application of dolomitic lime, foliar spray of magnesium sulphate at 1 to 2% concentration between autumn and spring (October to March) and it helps preventing Mg deficiency (Venkatesan and Jayaganesh, 2010). Field trails on mature tea in Indonesia showed that the desirable rate of Mg was 25-50 kg ha^{-1} as MgO with K :Mg ratio 3 to 4 : 1 and P:Mg ratio 0.5 to 1:1. Higher level of potassium application along with nitrogen fertiliser reinforce the antagonism leading to magnesium deficiency and it was appeared in many parts of the south Indian tea gardens. It is characterized by the yellowing of old leaves and an inverted V shaped yellow tint, between the veins. There is premature leaf fall from the affected bushes. It is an absolute necessity to come across the magnesium deficiency in high yielding fields to apply soil application of magnesium sulphate was recently recommended (Venkatesan, 2006). Magnesium is supplemented in the form of carbonate, oxide and sulphate. In general, sulphate fertilizers are more rapidly effective than carbonates (Ishijima *et al*., 2003). Application of dolomite is particularly useful in acid soils, which need regular liming. Decomposition of the dolomite is also assisted by low soil pH. On more neutral soils $MgSO_4$ in the form of kieserite is more advantageous particularly in arable lands. The various form of $MgSO_4$ differs considerably in terms of its solubility. Epsom salt, $MgSO_4.7H_2O$ is more soluble than kieserite ($MgSO_4.H_2O$). However, there has been no document on impact of different sources of magnesium fertilizers on biochemical and quality constituents of black tea with particular reference to south Indian tea gardens. Hence we made on attempt. Amino acids are responsible for flavour profile of made tea, it was noticed in Chinese tea gardens (Ma *et al*., 2005; Ruan *et al*., 1998; Ruan *et al*., 1999). But there is no study in this grey area in particular reference to south Indian conditions. The main objective of the study is to find out the impact of different sources of magnesium fertilizer on biochemical and quality constituents of black tea in south Indian tea gardens and calculate the optimum dosage as well as interval.

MATERIALS AND METHODS

The experiment was laid out in randomized block design, had six treatments and four replications. The source of nitrogen was urea and source of potassium was murite of potash. Four different sources of magnesium fertilizer was used in this study namely magnesium sulphate, kieserite, magnesium nitrate and magnesite. The control blocks have received the NPK fertilizer alone. Other nutrients, such as Phosphorus (P), Calcium (Ca), Magnesium (Mg), Zinc (Zn), Manganese (Mn) and Boron (B), were given at a uniform rate in all the treatments according to the standard recommendations of United Planters Association of South India Tea Research Foundation (UPASI TRF) (Verma and Palani, 1997). Investigations were carried out by collecting flush shoots (between 2006 and 2008), consisting of three leaves and a bud, from long term fertilizer trails plots at UPASI tea experimental farm in clone UPASI 9. Collecting flush shoots carried out the biochemical constituents, consisting of three leaves and a bud. A portion of collected leaf samples were subjected to analysis for total polyphenols (Dev-Choudhury and Goswami, 1983), catechins (Swain and Hillis, 1959), total chlorophyll, carotenoids (Wellburn, 1994) and free amino acids (Moore and Stein, 1948).

The remaining sample was dried at 55°C and analysed for potassium, magnesium and phosphorus content (Bhargava and Raghupathi, 2001).

Approximately, 2.5 kg of leaf samples were mini manufactured in the CTC unit and analysed for their theaflavins, thearubigins, total liquor colour and highly polymerized substance (Thanaraj and Seshadari, 1990). Volatile Flavour Compounds (VFC) were analysed using a gas Chromatograph (GC) (Perkin-Elmer Auto System XL). About 2.0 g of made tea sample were analysed through a headspace sampler (Turbomatrix 16) of the GC for VFC using a Flame Ionization Detector (FID). The compounds were identified by comparison of their GC retention times with those of authentic chemicals (sigma). The flavor index (Obanda and Owuor, 1995) was calculated from the flavour profile, which is the ratio of the sum of VFC Group II to that of VFC group I.

The plot wise yield data was recorded and converted into made tea per hectare, using the following formula:

$$\text{Made tea yield} = \frac{(\text{Green leaf weight} \times \text{No. of bushes per hectare} \times 22.5)}{(\text{No. of bushes per plot} \times 100)}$$

Statistical analysis was carried out by the standard method (Gomez and Gomez, 1984). The correlation coefficients were worked out using Special Purpose Software for Statistics (Ver. 7.5).

RESULTS AND DISCUSSION

Soil analysis: The increase in soil available potassium in control blocks where no magnesium was supplied could be due to the antagonism between Mg and K and the results are in line with earlier laboratory findings (Table 1). It is first time we confirmed the antagonism in field conditions (Jayaganesh and Venkatesan, 2006; Verma and Palani, 1997; Venkatesan, 2006). The higher soil availability of Mg observed in treatments supplied with magnesium nitrate, magnesium sulphate and kieserite could be due to the fact that all these sources are having water soluble form of magnesium unlike magnesite (Loganathan *et al.*, 2005). The available potassium content was

Table 1: Influence of different sources of magnesium fertiliser on physico chemical properties of soil

Treatment	pH	EC ($dS\ m^{-1}$)	OM (%)	P	K	Ammoniacal nitrogen	Urease activity	Mg	S
				------------------	------------------	($mg\ kg^{-1}$)	------------------	------------------	------------------
Control (No Mg fertiliser application)	3.90	0.19	2.60	17.3	390	10.9	55.70	38.00	11.90
Soil application of $MgNO_3$ @ 20 kg Mg ha^{-1} $year^{-1}$ in two splits	4.50	0.12	2.83	17.3	222	9.43	71.80	117.00	18.00
Soil application of magnesite @ 20 kg Mg ha^{-1} $year^{-1}$ in two splits	3.90	0.20	2.00	31.2	370	8.17	52.80	66.00	18.90
Standard practice (200 kg $MgSO_4$ ha^{-1} $year^{-1}$ in two splits)	4.10	0.17	2.87	3.7	243	9.07	60.17	76.00	12.80
Standard practice (200 kg $MgSO_4$ ha^{-1} $year^{-1}$ in two splits) with the reduction of 50% K_2O (4:1.5) with Mg	4.10	0.13	3.17	11.4	224	10.5	32.81	46.00	13.60
Kieserite (equivalent to 20 kg Mg ha^{-1} $year^{-1}$) in two splits	3.80	0.29	2.27	5.4	231	10.6	97.73	53.00	19.60
SEm±	0.13	0.008	1.16	24.0	75	4.92	52.00	12.35	9.076
CD at p = 0.05	0.28	0.016	2.41	49.0	156	10.2	108.00	25.62	18.82
CD at p = 0.01	0.38	0.023	3.28	67.0	212	13.9	146.00	34.82	25.58

SEm±: Standard error mean, CD: Critical difference, EC: Electrical conductivity, OM: Organic matter maximum in magnesite applied blocks. Similarly pH of the soil was highly influenced by magnesium nitrate followed by magnesium sulphate applications. The other parameters like phosphorus, electrical conductivity, organic matter, ammoniacal nitrogen and urease activity did not show any regular trend.

Leaf analysis: All forms of magnesium fertilizers significantly influenced Mg content of mature leaf. Presence of higher levels of potassium in control blocks further confirms the antagonism existing between K and Mg of tea leaves (Table 2). The results are inline with the findings of Venkatesan *et al.* (2005) and Venkatesan *et al.* (2006). Sulphur content of mature leaf was significantly influenced by magnesium sulphate and kieserite applications, while no trend was seen in flush shoots.

Green leaf yield: Soil application of 200 kg magnesium sulphate along with NK made a significant increase in yield ($p = 0.01$ level) compared to the control blocks (Table 2). The results on yield Vs Mg sources are in line with the observations made at Georgia by Dontsova *et al.* (2005), at Chinese condition by Ma *et al.* (2005) and at Sri Lankan conditions by Hettiarachchi and Sinclair (2002). The influence of various sources of Mg on tea through yield is very well recognized this study. The very important information coming out from this study is the synergistic effect of Mg and S which in turn boosted the yield significantly. It has been recently reported that sulphur also plays a vital role in nitrogen metabolism in addition to K (Ruan *et al.*, 1998; Ding *et al.*, 2006; Ruan *et al.*, 1999; Ma *et al.*, 2005; Venkatesan *et al.*, 2005, 2006). The application of Kieserite showed a significant increase in yield at $p = 0.05$ level compared to the control. A drastic reduction in yield was noticed when 50% of K was reduced from standard recommendation. The block tea samples were sent to professional tea tasters for evaluating briskness, colour of infusion and other related parameters. Considering the made tea yield and organoliptic evaluation, it was inferred that the source magnesite yielded better cost benefit ratio followed by magnesium sulphate (Table 2).

Table 2: Influence of different sources of magnesium fertiliser on nutrient content in leaf

	K(%)		Mg(%)		S(%)		Mean made tea yield		Tea teaster score Marks out
Treatments	3L+B	ML	3L+B	ML	3L+B	ML	(kg ha^{-1} year^{-1})	Ratio	of 50#
Control (No Mg fertiliser application)	1.99	1.66	0.51	0.15	0.38	0.21	3450	-	27
Soil application of $MgNO_3$ @ 20 kg Mg ha^{-1} year^{-1} in two splits	1.60	1.30	0.60	0.18	0.40	0.23	3493	1:1.2	29
Soil application of magnesite @ 20 kg Mg ha^{-1} year^{-1} in two splits	1.63	1.37	0.55	0.17	0.41	0.21	3566	1:3.4	29
Standard practice (200 kg $MgSO_4$ ha^{-1} year^{-1} in two splits)	1.60	1.38	0.59	0.17	0.44	0.36	3912**	1:3.2	34
Standard practice (200 kg $MgSO_4$ ha^{-1} year^{-1} in two splits) with the reduction of 50% K_2O (4:1.5) with Mg	1.72	1.33	0.60	0.16	0.44	0.36	3518		31
Kieserite (equivalent to 20 kg Mg ha^{-1} year^{-1}) in two splits	1.73	1.38	0.53	0.16	0.44	0.32	3717*	1:2.5	32
SEm±	0.10	0.12	0.12	0.01	0.04	0.02	125		
CD at p = 0.05	0.20	0.26	0.25	0.02	0.08	0.05	257		
CD at p = 0.01	0.27	0.35	0.34	0.02	0.11	0.10	346		

SEm±: Standard error-mean, CD: Critical difference; 3L + B: Three leaf and a bud; ML: Mature leaf; *p = 0.05, **p = 0.01, #: Based on organoleptic evaluation

Table 3: Influence of different sources of magnesium fertiliser on biochemical parameters of green leaves

Treatments	Amino acids ($g\ kg^{-1}$)	Polyphenols ($g\ kg^{-1}$)	Chlorophyll ($mg\ kg^{-1}$)	Carotenoids ($mg\ kg^{-1}$)	Catechins ($g\ kg^{-1}$)
Control (No Mg fertiliser application)	11.40	264.30	1450.00	180.00	185.00
Soil application of $MgNO_3$ @ 20 kg Mg ha^{-1} $year^{-1}$ in two splits	19.30	279.70	1500.00	200.00	190.00
Soil application of magnesite @ 20 kg Mg ha^{-1} $year^{-1}$ in two splits	18.00	273.50	1457.00	205.00	195.00
Standard practice (200 kg $MgSO_4$ ha^{-1} $year^{-1}$ in two splits)	19.70	277.50	1817.00	230.00	200.00
Standard practice (200 kg $MgSO_4$ ha^{-1} $year^{-1}$ in two splits) with the reduction of 50% K_2O (4:1.5) with Mg	18.40	268.90	1450.00	225.00	189.00
Kieserite (equivalent to 20 kg Mg ha^{-1} $year^{-1}$) in two splits	19.40	273.50	1750.00	228.00	200.00
SEm±	0.71	2.72	40.21	22.46	11.14
CD at p = 0.05	1.46	5.65	83.39	46.59	23.10
CD at p = 0.01	1.99	7.68	113.34	63.32	31.40

SEm± : Standard error-mean; CD: Critical difference

Table 4: Influence of different sources of magnesium fertilizer on quality parameters of black tea

Treatments	TF (%)	TR (%)	HPS (%)	TLC	Caffeine (%)	Amino acid (%)	FI
Control (No Mg fertilizer application)	0.49	6.10	6.53	2.90	3.46	1.20	1.59
Soil application of $MgNO_3$ @ 20 kg Mg ha^{-1} $year^{-1}$ in two splits	0.49	6.43	7.58	3.20	3.30	1.50	1.65
Soil application of magnesite @ 20 kg Mg ha^{-1} $year^{-1}$ in two splits	0.52	6.51	7.77	3.30	3.22	1.40	1.60
Standard practice (200 kg $MgSO_4$ ha^{-1} $year^{-1}$ in two splits)	0.86	8.33	8.13	3.90	3.33	1.60	1.85
Standard practice (200 kg $MgSO_4$ ha^{-1} $year^{-1}$ in two splits) with the reduction of 50% K_2O (4:1.5) with Mg	0.64	8.12	8.03	3.00	3.25	1.60	1.75
Kieserite (equivalent to 20 kg Mg ha^{-1} $year^{-1}$) in two splits	0.81	8.16	7.16	3.80	3.35	1.40	1.180
SEm±	0.04	0.47	0.40	0.21	0.08	0.02	0.003
CD at p = 0.05	0.08	0.97	0.83	0.44	0.16	0.04	0.006
CD at p = 0.01	0.10	1.32	1.13	0.59	0.22	0.06	0.009

SEm±: Standard error-mean, CD: Critical difference; TF: Theaflavins; TR: Thearubigins; TLC: Total liquor colour; HPS: Highly polymerised substances; FI: Flavour index

Biochemical constituents: The biochemical constituents like amino acids, chlorophylls, carotenoids, polyphenols and catechins were analysed in two immediate harvesting rounds after manuring and the mean values are furnished in Table 3.

It is not surprising to obtain lowest amino acid content in the control plot, where no magnesium was applied and in the plot where 50% potassium dose was reduced. They showed that K is required during the nitrate reduction, which is an important step in nitrogen metabolism. This could be the reason for obtaining decreased amino acid content due to the reduction of potassium dose. Since the other remaining treatments in this experiment were supplied with uniform quantum of nitrogen and potassium fertilizers, the increase in amino acid contents could be attributed to the role played by Mg. Ruan *et al.* (1999) and Ma *et al.* (2005) proved that externally added magnesium has biased the amino acid synthesis pathway. Similar kind of trend was observed in our study also. The reduction of potassium fertilizer reduced the carotenoids content. The chlorophyll content of green leaf was very much manifested by magnesium sulphate application followed by kieserite. It could be due to the promoting effect of K on chlorophyll (Venkatesan *et al.*, 2005; Wickremasinghe *et al.*, 1966; Senthurpandian *et al.*, 2008). The similar kind of trend was observed in polyphenols. Among all the treatments, magnesium sulphate application resulted in higher amount biochemical constituents, which could be because sulphur plays an important role in the production of biochemical parameters.

Quality constituents: Theaflavins, thearubigins, total liquor colour and highly polymerised substances were higher in magnesium sulphate and kieserite applied plots (Table 4). Soil application of kieserite has promoted the TF content, however the other important parameters like TR, TLC and HPS remained lower when compared to other sources of magnesium. Thearubigins content was higher in the case of magnesium sulphate applied blocks. HPS also higher in magnesium sulphate applied plots. The total liquor colour recorded in control blocks was less than 3, while all other treatments showed a slightly higher amount of TLC. In general, south Indian CTC black teas are reported to have a TLC value of greater than 3 (Ravichandran and Parthiban, 1997; Ravichandran and Parthiban, 1998; Venkatesan *et al*., 2006). The different sources of soil applied magnesium directly influenced the amino acid content of made tea and it was high in magnesium sulphate and magnesium nitrate applied blocks.

Flavour Index (FI) estimated in made tea was also increased due to soil application of magnesium. Tea aroma constituents consists of many groups of flavor compounds (Owuor, 1992; Ravichandran and Parthiban, 1998; Owuor *et al*., 1990). It was higher due to magnesium sulphate application and it directly reflected on the price of the made tea also. The amino acid content of made tea was positively correlated with flavor index of made tea at p = 0.05 level (Table 6).

PFA parameters: The influence of different sources of magnesium on CFC, total ash and WE is furnished in Table 5. Soil application of magnesium sulphate yielded lower amount of CFC when compared to all other treatments. However, the application of magnesium sulphate along with 50% reduction of potassium fertilizer yielded higher amount of CFC. Because the inadequate potassium leads to the accumulation of carbohydrates and cellulose, which results as crude fiber content. Similar kind of observation was reported earlier (Roberts, 1975; Venkatesan and Ganapathy, 2004; Venkatesan and Ebert, 2005). Water extract was higher in magnesium sulphate applied plots when compared to other sources of magnesium fertilizer and control blocks. According to PFA limits it must be always greater than 32%. The trend observed in WE was in contrast to that of the crude fiber content obtained. In our study the total ash content varied between 55 and 56 g kg^{-1}, which are well below the limit prescribed by PFA (40 to 80.0 g kg^{-1}).

Table 5: Influence of different sources of magnesium fertiliser on PFA parameters of made tea

Treatment details	CFC (g kg^{-1})	WE (g kg^{-1})	Total ash (g kg^{-1})
Control (No Mg fertiliser application)	150.80	400.30	56.10
Soil application of $MgNO_3$ @ 20 kg Mg ha^{-1} $year^{-1}$ in two splits	145.50	410.50	56.30
Soil application of magnesite @ 20 kg Mg ha^{-1} $year^{-1}$ in two splits	135.40	415.40	55.60
Standard practice (200 kg $MgSO_4$ ha^{-1} $year^{-1}$ in two splits)	130.30	426.10	55.20
`Standard practice (200 kg $MgSO_4$ ha^{-1} $year^{-1}$ in two splits) with the reduction of 50% K_2O (4:1.5) with Mg	149.10	420.70	56.40
Kieserite (equivalent to 20 kg Mg ha^{-1} $year^{-1}$) in two splits	132.20	418.30	56.60
SEm±	3.87	3.58	1.06
CD at p = 0.05	8.03	7.42	2.21
CD at p = 0.01	10.91	10.08	3.00

SEm±: standard error mean; CD: Critical difference; CFC: Crude fiber content; WE: Water extract

Table 6: Correlation coefficients among quality parameters, yield and nutrient content of green leaves

Parameters	AA	Caffeine	CFC	FI	HPS	K	Mg	P	Total ash	TF	TLC	TR	WE
Caffeine	-0.646												
CFC	-0.278	0.236											
FI	0.847*	-0.740	-0.646										
HPS	0.930**	-0.805	-0.371	0.846									
K	-0.115	0.060	0.155	0.043	-0.243								
Mg	0.470	-0.289	0.668	0.018	0.363	-0.207							
P	0.443	-0.664	-0.623	0.695	0.543	-0.419	-0.061						
Total ash	-0.198	0.135	0.468	-0.149	-0.428	0.711	0.170	-0.221					
TF	0.318	-0.020	-0.579	0.578	0.167	0.620	-0.472	0.085	0.243				
TLC	0.367	-0.066	-0.941*	0.645	0.337	-0.101	-0.569	0.518	-0.346	0.702			
TR	0.680	-0.214	-0.503	0.733	0.542	0.416	-0.131	0.081	-0.015	0.871*	0.647		
WE	0.850*	-0.577	-0.663	0.932	0.847*	0.066	-0.051	0.456	-0.320	0.646	0.693	0.871*	
Yield	0.451	0.037	-0.819	0.554	0.417	-0.184	-0.427	0.273	-0.543	0.613	0.916*	0.713	0.730

*: Significant at 5% level; **: Significant at 1% level; AA: Amino acid; WE: Water extract; TR: Thearubigins; TF: Theaflavins; TLC: Total liquor colour; HPS: Highly polymerised substances; FI: Flavour index; CFC: Crude fiber content; P: Phosphorus; K: Potassium, Mg: Magnesium

CONCLUSION

This study confirmed that soil application of different sources of magnesium fertiliser does not harm the quality of black tea. On the whole, magnesium sulphate is the most suitable source of Mg for application in tea gardens when compared to all other sources. It enhances the biochemical and quality constituents of black teas and fetches the economic probability.

ACKNOWLEDGMENTS

The authors thank Dr. N. Muraleedharan, Adviser, UPASI Tea Research Foundation for his constant encouragement throughout the study. Authors wish to express their sincere thanks to Dr. P. Mohan Kumar, Director for his help during study period. The financial assistance provided by the Tea Board, Government of India under X Five Year Plan project is gratefully acknowledged.

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