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Impact of mine waste dumps on growth and biomass of economically important crops

Author Details

Narayanan Mathiyazhagan Department of Biotechnology, Periyar University, Salem- 636 011, India

Devarajan Natarajan (*Corresponding author*) Department of Biotechnology, Periyar University, Salem-636 011, India
e-mail: mdnataraj@rediffmail.com

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Abstract

The present study aimed to investigate the effect of magnesite and bauxite waste dumps on growth and biochemical parameters of some edible and economically important plants such as *Vigna radiata, V. mungo, V. unguiculata, Eleusine coracana, Cajanus cajan, Pennisetum glaucum, Macrotyloma uniflorum, Oryza sativa, Sorghum bicolour, Sesamum indicum, Ricinus communis, Brassica juncea, Gossypium hirsutum* and *Jatropha curcas*. The growth rate of all the crops was observed in the range of 75 to 100% in magnesite and 15 to 100% in bauxite mine soil. The moisture content of roots and shoots of all the crops were in the range of 24 to 77, 20 to 88 % and 42 to 87, 59 to 88% respectively. The height of the crops was in the range of 2.6 to 48 cm in magnesite soil and 3 to 33 cm in bauxite soil. Thus the study shows that both mine soils reflects some physical and biomolecule impact on selected crops.

Key words

Mine waste, Heavy metals, Edible crops

Introduction

The edible and economically valuable crops are essential for the survival of healthy life and economic growth of the country. The continued industrialization of every country has faced extensive environmental problems. Heavy metals (As, Cd, Co, Cu, Ni, Zn, and Cr) pose a critical concern to human health and the environment due to their occurrence of contaminant (Diels *et al.,* 2002). Now-a-days, the phytoremediation technologies are improved for the reclamation on contaminated soils. Some crops are also used for reclamation purpose on metal contaminated sites (Reda Abou-Shanab, 2007). These technologies have attracted more attention in recent years for the low cost of implementation and environmental benefits. Moreover, the phytoremediation technology is likely to be more acceptable than other methods (Mukhopadhyay and Maiti, 2010; Baker *et al*., 1994). Earlier studies have reported that certain plant species are able to survive and reproduce on soils heavily contaminated with Zn, Cu, Pb, Cd, Ni, Cr, and As (Vassilev, *et al.,* 2002). The organic amendments of soil are very important to increase soil fertility and intensifying the crop yield and also for changing the microbial make up in the region of the plant (Oberson and Joner, 2005). The major effects of mine dusts on plants showed over dust deposition on vegetation (Walker and Everett, 1987) photosynthesis, respiration, transpiration and secondary stresses such as drought, penetration of toxic metals (or) phytotoxic gaseous pollutants into plant tissue (Vardaka *et al.,* 1995). The major phytochemicals like chlorophyll is the principal pigment in plants, converting light energy to chemical energy; it allows photosynthesis (Jeffrey and Mantoura, 1997) for effective growth of plants. The leaf, shoot size (Ferrini *et al.,* 2005) and yield of the plants which is grown in the normal soil is lower than compost (organic and also trace in inorganic) containing soils. In view of the above, the aim of the investigation was to study the impact of magnesite and bauxite mine soil on the growth and biochemical parameter of some edible and economically important crops.

Materials and Methods

Sample collection: The waste dumps of magnesite (+11° 432 29. 48" N latitude, +78° 62 26. 28" E longitude) and bauxite (+11° 492 58. 63" N latitude, +78° 132 48. 60" E longitude) mining soils from Salem district, were collected in a large container and one part of the each sample was air dried and packed into the polyethylene

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bags for cultivating the crops under green house. The seeds of selected crops were obtained from the Danispet Nursery Garden, Salem, Tamil Nadu, India.

Metal analysis of soil: The moisture free control and mine soil samples (0.5g) were digested by acid digestion (HCl: HNO_3 in the ratio of 3:1). The obtained solutions were filtered through Whatman filter paper (No.0.5) and analyzed for heavy metal content (such as Cd, Cr, Mn, Mg, Cu, Ca, Fe, Zn, Pb and Hg) by inductively coupled plasma-optical emission spectrometry (ICP-OES, Perkin-Elmer (ICP-OES).

Germination and monitoring of seedlings: The seeds (*V. radiata, V. mungo, V. ungiculata, E. coracana, C. cajan, P. glaucum, M. uniflorum, O. sativa, S. bicolour, S. indium, R. communis, B. juncea, G.hirsutum* and *J. curcas*) were sown on polyethylene bags (18 cm in diameter and 13 cm in length) containing mine soils and agricultural soil as a control (each 2.5 kg per bag). All the experiments were carried out in greenhouse with natural light. The moisture content of each pot was maintained at 75% water holding capacity by weighing the pots two times per week (Reda Abou *et al.,* 2007) and monitoring the plant growth at regular interval.

Measurement of plant growth: The growth parameters (such as the seed germination rate (%), plant height (cm), number and size of leaves (cm) and width of the stem (mm)) of each plant were measured by weighing gauge (mm and cm) at an interval of 10 days upto 3 months and finally the biomass value of each plant was recorded (Etham *et al.,* 2009). The metal tolerance index of treated plants was calculated as per Wilkins (1978). The moisture content as a percentage by weight (fresh weight basis) was calculated as per formula of Kenneth and Hellevang (1995).

Biochemical analyses : The total chlorophyll content in the leaves of plants were determined as per modified protocol of Porra *et al.* (1989) and Doong *et al.* (1993) was recorded. The leaf samples (0.2 g) taken from the mid shoots of each plant were analyzed for protein (Jones *et al*., 1991) and carbohydrate content (Ahmed *et al*., 1985).

Statistical analyses: The each parameter of the crops (plant shoot growth number of leaves, size of leaf, width of stem, height of the plant, wet and dry biomass and moisture (%) was done in replicates for statistical analysis (standard deviation) through Microsoft Excel.

Results and Discussion

The physico-chemical parameters of the bauxite and magnesite soil is given in Table 1. The pH of bauxite soil was acidic (5.20-5.80) while magnesite soil was alkaline (8.10-8.50) in nature. The low pH of the tailings may be due to the weathering of the sulphide minerals and the alkaline values may be due to the reaction with carbonates. The parent material of each site has an important influence on the pH of the soil-mine waste materials (Osakwe and Otuya, 2008). Yang *et al.* (2011) reported that high pH can result in significant loss of nitrogen by volatilization, since NH tends to convert to NH_3 gas, it diffuses from alkaline soil to the atmosphere. As shown in table 1, the soil contained high concentrations of Cd, Zn, Mn and Pb collected from waste dump of magnesite and bauxite mine, while Hg was found only in bauxite soil. The concentration of heavy metals were above permissible limits as reported by Ramamurthy and Kannan (2009) (Table 1). The results are in concentration with the earlier findings of Giller *et al.,* 1998; Muller *et al.,* 2001 and Giller *et al.* 2009, Lokeshwary and Chandrappa (2006) and Xenidis *et al.,* (2003) where high concentration of Pb, Zn, and Cd was reported in mine waste dumps and mine tailing sites. In addition, Ang and Ang (2000) reported high concentration of four potentially toxic elements (Pb, Cd, As and Hg) from ex-mines. The concentration of Ca, Cu, Fe, Mg and Cr were found within the permissible limits as per environmental quality standard.

The results of different growth parameters (germination rate, shoot length/ height of plant, root length, number of leaves, size of leaves and width of stem) in most of crops grown in magnesite and bauxite soils (Table 2 and 3) showed almost similar values as compared to control soil (Table 4). The growth of the crops (*V. radiata, V. mungo, V. ungiculata, E. coracana, C. cajan, P. glaucum, M. uniflorum, O. sativa, S. bicolour, S. indium, R. communis, B. juncea, G. hirsutum* and *J. curcas*) in magnesite and bauxite soil after 10 days significantly increased the height of stem. It indicates that these crops have metal tolerance capacity on mine soil, it may also possible by the presence of sufficient quantity of other elements also enhanced the growth rate of plants. The biomass and moisture content (%) of most of the crops from both soils was almost parallel to the control plants. In magnesite soil, *J. curcas* and *R. communis* showed high moisture content than other crops, and contained 63.09% and 86.48%; 77.77% and 84.10% moisture in shoots and roots respectively. Among all crops, the roots (24.13%) of and shoots (25%) of *O. sativa* contained lowest moisture content (Table 5). The crop *S. bicolor, J. curcas* and *R. communis* contained high moisture content bauxite soil (74.35, 84.61 and 88.1 %) than other

Table- 1: Heavy metal content of magnesite and bauxite mine soil

Heavy metals (mg kg^{-1})	Magnesite mine soil	Bauxite mine soil	Permissible limit
pH	8.10-8.50	5.20-5.80	6-8
Cd	2070 ±2 .43	1060 ±1.31	2-6
Cu	65.96 ±.12	105.9 ±.18	100
Fe	2222 ±1.07	2222 ±1.01	12900
Ca	4907 ±2.57	85.95 ±1.20	52000
Mg	5330 ±3.26	2610 ±1.75	9000
Zn	1141±1.79	827.5 ±.64	300-600
Cr	69.96 ±.27	553.7±1.73	1000
Mn	3173 ±2.81	6674 ±3.70	1000
Pb	443 ±.96	742.6 ±.07	200
Hg	BDL	15 ±.12	NA

BDL: Below detectable limit; values are mean of replicate ± SD. The permissible limit data (in mg) by BIS was adopted from Ramamurthy and Kannan (2009)

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crops. The results of present study was in correlation with the study of Reda Abou-Shanab *et al.* (2007) who reported the growth of several crops in metal contaminated soils. Likewise, Etham *et al.* (2009) reported good physiological and morphological appearance on plant guard crops from heavy metal containing soils. The similar kind of results were reported by Ozbay and Newman (2004), Sylvia (2004) and Stino *et al.* (2009) on the effects of additional growth supplements (compost and organic with inorganic substance) used for plant (plant guard) growth. The metal tolerant index value of all crops from magnesite mine *viz.* 104.0, 110.3, 152.3, 104, 108.5, 85.71, 51.16, 90.32, 90.90, 127.7, 116.0, 110.5 and 113.4 except *O. sativa* and the bauxite soils showed the following metal tolerant index values of the selected crops *i.e.* 102.0, 117.2, 104.7, 120, 87.23, 78.57, 89.01, 94.23, 72.09, 93.54, 116.6, 113.9, 96.31 and 103.65 respectively. Kumar *et al.* (2008) reported that the significant metal tolerant index of the crop (*J. curcus*) was obtained from the metal contaminated soils.

The total chlorophyll content of all crops grown in magnesite and bauxite soils is shown in Fig. 1a. The total cholorphyll content of *V. radiata, C. cajan, S. bicolor, S. indicum* and *R.communis* grown in both soils was found to be less than crops grown in control soil. However, plants of *M. uniflorum* growth in magnesite and bauxite possessed high amount of total Chl as compared to control plants (4 mg g^{-1}). The plants of *V. radiata, V. mungo* and *V. ungiculata,* (100 to 30, 50 to 40, 60 to 35 mg g^{-1}) contained lower amount of carbohydrate than control plants (Fig. 1b). In support of the present study, Oncel *et al.* (2000) reported that 500 mg l^{-1} Pb did not have any toxic effect on plants in soil, whereas Cd showed toxic effect even at a low concentrations as 50 mg l^{-1}. The plants of *E.*

Table- 2: Growth parameters of crops grown in bauxite mine soil for 30 days

Crops	10th day				20th day				30th day				
	NL	SL (cm)	WS (cm)	HP (cm)	NL	SL (cm)	WS (cm)	HP (cm)	GR (%)	NL	SL (cm)	WS (cm)	HP (cm)
V. radiata	2	4±.2	.90±.3	10±1	5±.1	6±1	.15±.3	25±2.8	85	5±.1	5±1.7	.1±.0	25±.2.1
V. mungo	2	3.8±.3	.85±.2	10±.9	2±.1	4.4±1	.1±.08	22±1.	60	8±.2	6.8±2.	.2±.2	34±3.7
V. unguiculata	2	4.5±.7	1.6±.1	12.5±1	5±.1	6±1.6	.22±.1	26±1	75	8±.2	6.5±1	.2±.2	33±2.8
E. coracana	1	1.8±.1	.85±.9	1.5±.7	2±.1	2.2±.9	.1±.02	2.8±.1	50	3±.1	4.4±.8	.1±.4	3±.38
C. cajan	2	5.2±. 4	.90±.7	6.5±1	5±.2	7.5±1	.1±.06	20±2	90	8±.2	7.5±1	.1±.1	20.5±2
P. glaucum	_	_	.50±.6	3.5±.8	3±.1	11.5±3	90±.65	5.5±1	100	4±.1	22.4±1	.1±.2	5.5±1
M. uniflorum	2	1.8±.9	.90±.2	8.2±1	5±.1	2.7±.3	.11±.4	18.2±2	100	8±.1	4.3±1	.1±.8	31±3.2
O. sativa	_	-	.70±. 5	1±.7	2	10.5±3	.1±.3	5.3±.9	100	4±.1	19.5±2	.1±.2	8±1.4
S. bicolor	2	2±.6	.10±. 8	3±.8	3±.1	16±1.7	.12±.1	9±1.3	75	5±.2	25±2	.17±.3	14.5±2
S. indicum	2	8±.5	.70±. 2	2.5±.2	4±.1	1±.56	.90±.7	9.5±2	50	4±.1	1.8±.7	1±.5	10.5±1
R. communis	=	=	=	=	2	2.4±.8	.3±.41	9±1	15	4±.1	4.7±1	.3±.8	10.5±1
B. juncea	2	8±.4	.60±. 7	3.5±.3	2±.1	1±.27	.80±.3	5.5±1	92	5±.2	1.8±.9	.1±.1	7.5±1
G. hirsutum	=	=	=	=	2±.1	2.8±. 7	.11±.3	12.5±1	70	4±.1	5.2±1.	.2±.3	18.3±2
J. curcas	2	12±.8	2±.2	7.2±1	3±.1	12.6±1	2.7±.5	8.4±1	100	6±.2	12.6±1	2.8±.9	8.8±1

Table- 3: Growth parameters of crops grown in magnesite mine soil for 30 days

Crops	10th day				20th day				30th day				
	NL	SL (cm)	WS (cm)	HP (cm)	NL	SL (cm)	WS (cm)	HP (cm)	GR (%)	NL	SL (cm)	WS (cm)	HP (cm)
V. radiata	2	4±1	.75±.1	11.7±1	4±.1	6±1.8	.1±.21	21.3±2.4	75	5±.1	5.4±1	.2±.2	25.5±3
V. mungo	2	3.5±.1	.80±.2	11.5±1	5±.1	4.8±1	.12±.5	25±2.1	80	5±.1	5.8±1	.2±.24	32±4.2
V. unguiculata	2	4.6±1	1.2±.7	17.5±2	5±.1	6.5±1.	.23±.4	29±3.7	100	8±.2	7±1.3	.3±.34	48±3.5
E. coracana	1	1±.74	.50±.4	2.4±.9	2	1.5±.5	.1±.61	4.5±1.5	70	4±.1	4.7±1	.1±.45	2. ±.3
C. cajan	2	5.4±1.8	.79±.5	7±1	5±.1	7.5±1	.1±.32	22±1.2	90	8±.2	8±1.5	.1±.52	25.5±2
P. glaucum	1	5.8±1.6	.40±.2	3.5±.8	3	12.5±1	.1±.65	5±1.4	93	4±.1	13.5±1	.1±.54	6±1.5
M. uniflorum	2	2.3±.34	.80±.1	7.5±1	5±.1	2.8±.9	.1.1±.6	16.8±1.6	90	8±.1	4.6±.2	.1±.35	22±1.5
O. sativa	-	-	.90±.3	1±.7	2	8±1.6	.1±.35	4.2±1.4	90	3	7±1.35	.1±.54	4.7±.9
S. bicolor	1	2.2±.45	.87±.2	4±.5	3±.1	13±2.4	.1.2±.9	6±1.4	65.	5±.1	18±2.7	.1.±.6	14±2.3
S. indicum	2	.75±.56	.70±.1	2.5±.7	4±.1	1±.65	.90±.3	8.8±2.1	95.	4±.1	1.5±.9	.1±.35	10±1.7
R. communis	=	=	=	=	2	2.8±.8	.3±.65	10±1.5	75	4±.1	5.2±.9	.2±.45	11.5±2.
B. juncea	2	.30±.07	.80±.2	4.3±1	4±.1	.5±.23	.1±.61	6.5±1.1	96	5±.1	1.7±.2	.2±.35	6.5±1
G. hirsutum	-	-	1±.1	2±.3	3±.1	2.8±.8	.2±.61	14.5±2.7	70	5±.2	4.5±1.	.2±.54	21±2.4
J. curcas	2	13±1.2	2±.1	7.6±1	3±.1	13.8±2	29±.95	8.6±1.4	100	6±.1	12.7±2	2.9±.4	9.3±1

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Table- 4: Growth parameters of crops grown in control soil for 30 days

Crops	10th day				20th day				30th day				
	NL	SL (cm)	WS (cm)	HP (cm)	NL	SL (cm)	WS (cm)	HP (cm)	GR (%)	NL	SL (cm)	WS (cm)	HP (cm)
V. radiata	2	3.5±.2	.90±.3	9±1.8	2	6±1.6	.1.5±.2	24±2.6	75	5±.1	4.4±.7	.1±.31	24.5±2
V. mungo	2	4±1	.90±.4	10±2.5	5±.1	5.5±1	.1±.24	22±1.6	85	8±.2	7±1	.2±.61	29±3.4
V. unguiculata	2	3.5±1	1±.2	14±1.3	5±.1	4.5±.8	.2±.21	25±2.9	100	8±.3	6.6±1	.3±.04	31.5±2.6
E. coracana	1	1.2±.7	.80±.2	1±.31	2±.1	3.3±.9	.1±.31	2±.65	98	3±.1	4.5±.3	.1±.14	2.5±.75
C. cajan	_	_	.85±.3	5.5±1	5±.2	8.1±1	.1±.32	18±2.9	80	8±.2	5.6±.9	.1±.20	23.5±2.4
P. glaucum	1	6±.4	1±.2	3±.46	3±.1	14±2.6	.1±.65	6±1.6	100	3±.1	25±2.8	.2±.76	7±1.4
M. uniflorum	2	3.8±.4	.90±.3	5±.75	5±.2	2.7±1	.1±.05	15±2.7	95	8±.2	3.4±.2	.1±.24	43±3
O. sativa	_	_	.40±.1	1±.52	2±.1	8±1.8	.9±.45	3±.65	80	**	**	**	**
S. bicolor	2	2±.32	.90±.7	3.2±.7	4±.1	15.5±3	.1±.70	10±1.3	80	5±.2	22.5±2	.2±.35	15.5±2.4
S. indicum	2	.9±.21	.82±.4	3±.56	4±.2	1.1±.9	.1±.18	9±1.2	98	6±.2	1.6±.2	.1±.12	11±1.3
R. communis	=	=	=	=	_	_	_	_	80	4±.1	4.1±1	.2±.65	9±1.7
B. juncea	2	.30±.4	.70±.5	3.4±1	2±0	40±3.7	.80±.5	5.2±.8	95	4±.1	.50±.2	.1±.50	5.6±1.6
G. hirsutum	=	=	=	=	_	_	_	_	90	2±.1	5±1	1±.5	19±2.4
J. curcas	2	16±2	2±.2	6.7±1	3±.1	11.3±1	2.3±.5	7.9±1	100	7±.2	11.3±2	24±.5	8.2±1.8

GR: Germination rate; **NL:** Number of leaf; **SL:** Size of leaf; **WS:** Width of stem; **HP:** Height of the plant; **= :** No growth; **_:** Germination started; ****:** Infected by disease

Table- 5: Biomass value of the crops grown in magnesite and bauxite mine soil

Crops	Magnesite soil						Bauxite soil						Control soil					
	Wet mass (g)		Dry mass (g)		Moisture (%)		Wet mass (g)		Dry mass (g)		Moisture (%)		Wet mass (g)		Dry mass (g)		Moisture (%)	
	Rt	St	Rt	St	Rt	St	Rt	St	Rt	St	Rt	St	Rt	St	Rt	St	Rt	St
V. radiata	0.23	2.08	0.17	0.77	26.08	62.98	0.26	3.06	0.14	0.92	46.15	69.93	0.47	4.45	0.29	1.59	38.29	64.26
V. mungo	0.29	4.90	0.22	1.65	24.13	66.32	0.40	6.02	0.23	1.94	42.5	67.77	0.41	4.11	0.20	1.27	51.21	69.09
V. ungiculata	0.97	10.55	0.40	2.69	58.76	74.50	1.00	10.0	0.42	2.91	58	71.13	0.83	8.80	0.33	2.38	60.24	72.95
E. coracana	0.09	0.17	0.04	0.05	55.55	70.58	0.14	0.77	0.04	0.16	71.42	79.22	0.19	0.98	0.07	0.26	63.15	73.46
C. cajan	0.65	4.50	0.34	2.11	47.69	53.11	0.86	7.19	0.45	2.87	47.67	60.08	0.72	6.56	0.41	3.01	43.05	54.11
P. glaucum	0.37	1.22	0.11	0.33	70.27	72.95	0.30	1.35	0.09	0.34	70	74.81	0.32	1.70	0.15	0.49	53.12	71.17
M. uniflorum	0.16	4.33	0.05	0.87	68.75	79.90	0.17	3.07	0.05	0.74	70.58	75.89	0.14	5.10	0.11	1.15	21.42	77.45
O. sativa	0.10	0.20	0.05	0.15	50	25	0.50	2.61	0.20	1.05	60	59.77	0.37	2.01	0.18	0.96	51.35	52.23
S. bicolor	0.24	1.37	0.11	0.40	54.16	70.80	0.08	0.39	0.11	1.00	87.5	74.35	0.34	1.86	0.18	0.72	47.05	61.29
S. indium	0.04	0.27	0.02	0.21	50	20.22	0.25	2.88	0.11	0.40	56	86.11	0.17	3.06	0.07	0.52	58.82	83
R. communis	0.27	1.51	0.06	0.24	77.77	84.10	0.17	0.78	0.06	0.12	64.70	84.61	0.41	2.70	0.15	0.53	63.41	80.37
B. juncea	0.06	1.02	0.06	0.12	33.33	88.23	0.09	1.10	0.05	0.32	44.44	70.90	0.76	1.49	0.17	0.56	77.63	62.41
G. hirsutum	0.80	7.55	0.51	1.35	36.25	82.11	1.00	7.20	0.43	1.41	57	80.41	0.72	7.23	0.45	1.52	27	78.97
J. curcas	1.68	29.12	0.32	2.15	63.09	86.48	1.47	24.9	0.30	2.03	64.6	88.1	1.42	25.1	0.29	2.00	75.8	92.05

Rt: Root, **St**: Shoot

coracana, C. cajan, O. sativa, S. bicolour, S. indium, R. communis, B. juncea and *P. glaucum* showed similar amount of carbohydrate in both the mine soil as compared to control plants (Fig. 1b). The plants of *M. uniflorum* and *J. curcas* from both soils contained (150 and 180 mg g^{-1} and 175 and 98 mg g^{-1}) higher amount of carbohydrate than control plants. It may be due to the presence of essential elements present in the soil and metal tolerance nature of the crops. The plants of *G. hirsutum, M. uniflorum, V. ungiculata* and *J. curcas* from the magnesite mine soil possesed high amount of protein (362 and 396 mg g^{-1}) (Fig. 1c). While in bauxite soil, *C. cajan, P. glaucum, S. bicolour, S. indium, R. communis, B. juncea, G. hirsutum* and *J. curcas* showed lower to equal amount of protein (84 and 352 mg g^{-1}) than control and these variations may be pH and moisture holding nature and heavy metal stress of mine soil. These results are in conformation with the earlier reports of Azmat *et al.* (2005) and Jones (1991) where high concentration of Cd decreased the nutritive value of bean. The overall results indicate that some physical and biomolecule impacts on selected crops. Among these crops *Cajanus cajan* was found to have remarkable growth impacts on both mine soils.

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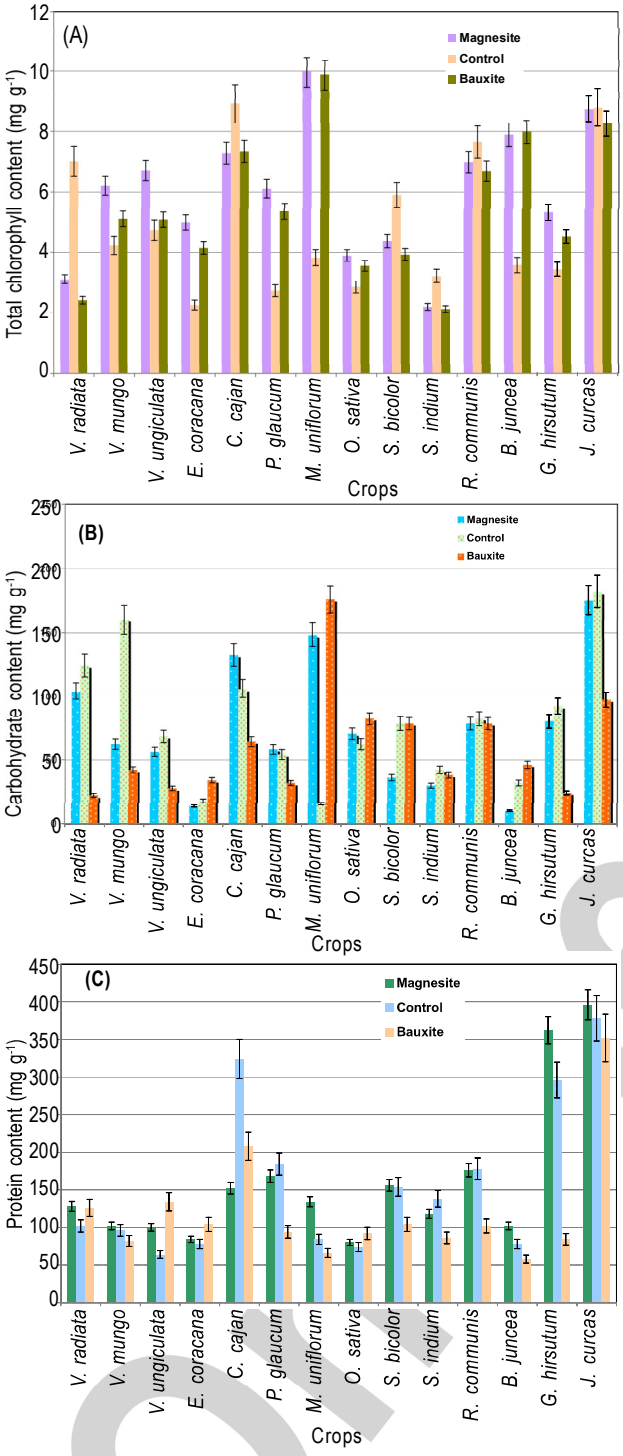

Fig.1 : (A) Total chlorophyll, (B) Carbohydrate and (C) Protein in selected crop grown in magnesite and bauxite mine soil. The error bars in all the figures indicates that the mean values of standard error

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