International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2018; 6(4): 1092-1097

Received: 20-05-2018
Accepted: 24-06-2018

V Venkatesh
Department of Soil Science and Agricultural Chemistry, College of Agriculture, Central Agricultural University, Imphal, Manipur, India

RK Kumarjit Singh
Department of Soil Science and Agricultural Chemistry, College of Agriculture, Central Agricultural University, Imphal, Manipur, India

N Surbala Devi
Department of Soil Science and Agricultural Chemistry, College of Agriculture, Central Agricultural University, Imphal, Manipur, India

Correspondence
V Venkatesh
N Surbala Devi
Department of Soil Science and Agricultural Chemistry, College of Agriculture, Central Agricultural University, Imphal, Manipur, India

Critical limit of available magnesium for green gram in soils of Imphal West district, Manipur, India

V Venkatesh, RK Kumarjit Singh and N Surbala Devi

Abstract
The critical limit of magnesium in soil and plant (green gram var. DGGS-4) was determined through a pot culture experiment with thirty soils of Imphal West district, Manipur, India for predicting the response of green gram to magnesium application. All the soil samples were acidic in reaction with pH value ranging from 4.01 to 6.42 with mean of 5.43, electrical conductivity from 0.04 to 0.27 dSm^{-1} with an average of 0.08 dSm^{-1}, organic carbon content from 2.62 to 1.05 % with mean value of 1.94%, cation exchange capacity of the soils from 20.40 to 11.50[cmol (p+) kg^{-1}] with mean value of 16.28[cmol (p+) kg^{-1}]. Most of the soils are clay in texture. Available magnesium content in soils varied from 72.9 to 352.35 ppm with an average value of 185.09 ppm. Available magnesium in the soils was positively and significantly correlated with plant magnesium concentration (r=434**) and its uptake (r=372*). The critical limit of available Mg was established at 164 ppm for soil and 0.12% (1200 ppm) for 45 days old green gram plants. Based on the critical limit, 46.66% of the soils studied were found to be magnesium deficient. Soil containing Mg below this critical limit may respond economically to Mg fertilization for growing Green gram.

Keywords: Critical limit, Magnesium, soil, Green gram, Bray's yield (percent)

Introduction

Pulses occupy a unique position in Indian farming as a sole crop, catch crop, cover crop, green manure and inter crop. The Indian people are predominantly vegetarian; the pulses are an indispensable part of the diet as it contains 23.1 % protein which is nearly two and half times more than the cereals, 0.5 to 4.33 per cent fats and 23.4 to 66.3 per cent carbohydrates (Sinha, 1977) [28]. It is also important in cropping system as it helps in improving soil fertility. It also gives palatable and nutritious fodder for cattle (Lal, 1976) [14]. Pulses recognized as a restorer of soil fertility by virtue of its ability to fix atmospheric nitrogen in the soil through root nodules.

Magnesium is a secondary nutrient and is as significant as primary nutrients in plants, but needed in smaller quantities. It is necessary for the augmentation of roots and cells (Mikkelsen, 2010) [17]. The element is an essential ingredient of chlorophyll and also has a role in the translocation of starch within the plants (Ding *et al.*, 2006) [9]. Magnesium deficiency is generally noticed in low pH soils which are highly weathered and coarse textured (Synder and Thompson, 2005 and Cakmaka and Kirkby, 2008) [29, 6]. A number of alluvial, red and lateritic soils in India are deficient in calcium, magnesium and sulphur (Naik and Das, 1964) [18]. The availability of magnesium is affected by soil pH, texture and clay content of the soil (Lombin and Payami, 1976, Ananthanarayana *et al.*, 1986 and Pasricha and Sarkar, 2009) [15, 122]. The availability of the nutrient to plants depends on various factors: the distribution and chemical properties of the source rock material and its grade of weathering, site specific climatic and anthropogenic factors and in agricultural systems, to a high degree on the agronomic management practices established at the specific production site including the cultivated crop species and crop rotation, cropping intensity and organic and mineral fertilization practice (Kanwar, 1976 and Mikkelsen, 2010) [12, 17].

Each essential nutrient has certain specific role to play in the plant and their presence in soil above critical limit is a must for a plant to complete its life cycle. Critical limit in plant refers to a level at or below which plant either develops deficiency symptoms or causes reduction in crop yield as compared to optimum yield.

Critical limits quite often employed for a wide variety of soils and crops, even though the limit may be different not only for soils, crop species but also for different varieties of a given crop (Nand, 1976, Tandon, 1992, Ganeshamurthy and Hegde, 1980, Singh and Agarwal, 2007, Kasinath, *et al.*, 2014) [19, 30, 10, 26, 13].

The response of crop plants to the insufficiency or sufficiency of specific nutrients has helped to generate information on the critical limits of each of the elements (Bates, 1971) [2]. Although, Mg is not widely used as a fertilizer but efficient and economical method to correct its deficiency on a long term basis and in a specific cropping system is desirable. In order to apply Magnesium fertilizers for better efficiency of yield it is important to know the critical limit of Mg in the soil. The information on Mg fertilizer use emanating from soil testing laboratories should be based on the critical limits of extractable Mg for different crops and soils. This also save numerous amount of fertilizers being wasted by the farmers while growing the crops.

In view of the above, an attempt was made to study the critical limit of Magnesium in soil and Green gram plant.

Material and Methods

Thirty bulky soil samples (0-20 cm depth) were collected from different fields of Imphal West district of Manipur, India randomly (Table 1). The soil samples were air dried in shade, ground and passed through 2 mm sieve. These samples were analyzed for soil reaction (pH) and electrical conductivity (EC) using standard procedures as described by Jackson (1973) [11]. Organic carbon was determined by wet oxidation method of Walkley and Black (1934) [31], soil texture by Hydrometer method (Buoyoucous 1962) [5], cation exchange capacity (CEC) by (Borah *et al.*, 1987) [3]. Available Magnesium content of soils was measured in versenate method after extracting the soils with EDTA (Ethylene di-amine tetra acetic acid) following the standard procedure (Jackson 1973) [11].

A pot experiment was conducted to evaluate the critical concentration of Magnesium in soils and Green gram plant. Four kg of air dried soils per pot was taken in a series of pots. Recommended doses of nitrogen, phosphorus and potassium @ 20, 40 and 20 kg/ha were given as basal through urea, single super phosphate and muriate of potash, respectively. Magnesium was applied as basal dosage @ 10, 20 and 30 kg Magnesium ha^{-1} as reagent grade of Magnesium sulphate ($MgSO_4.7H_2O$).Green gram var. DGGS-4 was sown in each pot. Each treatment was replicated thrice in completely randomized design. Watering with deionized water and intercultural operations were adopted uniformly in each pot as and when required. The plants were harvested at initial flowering stage (45 after sowing) and washed in acidified solution, rinsed with deionized water and dried at 65^0 C in a hot air oven for 24 hours. Dry-matter yield of the plant was recorded and ground in the stainless steel blender. The dry powdered plant samples were digested in tri-acid mixture (HNO_3:$HClO_4$:H_2SO_4:10:3:1) and filtered through Whatman No.42 for estimation of Mg with the help of versenate titration method (Jackson, 1973) [11].

$$\text{Bray's yield (percent)} = \left(\frac{\text{Yield without Magnesium}}{\text{Yield at optimum Magnesium}}\right) \times 100$$

The critical values of available Magnesium in soil and plant were determined by plotting the Bray's percent yield against soil Magnesium content and against plant tissue Magnesium concentration separately, following the graphical method of Cate and Nelson (1965) [7].

Results and Discussion

Initial Soil Properties

All the soil samples were acidic in nature with pH values ranging from 4.01 (stongly acidic) to 6.42 (moderately acidic) with mean value of 5.43 (Table 2). Similar acidic nature of the soils was also reported by Nayak *et al.* (1996) [21] and Sahoo *et al.* (2010) [25]. Electrical conductivity varied from 0.04 to 0.27 dSm^{-1} with mean value of 0.08 dSm^{-1} which may be due to leaching loss of soluble salts from soils under high rainfall (Brady and Weil, 1999 and Maji *et al.,* 2005) [4, 16]. Organic carbon content varied from 2.62 to 1.05 % with mean value of 1.94%. This is at par with the findings of Saha and Bala (1995) [24]. Cation exchange capacity (CEC) of the soils was in the range of 11.50 - 20.40 [cmol (p+) kg^{-1}] with mean value of 16.28[cmol (p+) kg^{-1}]. Higher CEC was perhaps due to higher organic carbon content in the soil. Similar observation on positive correlation between CEC and organic carbon content was reported by Maji *et al.* (2005) [16]. Clay content varied from 31.00 to 71.90 % with mean value of 49.73%. The silt and sand contents of the soils ranged from 19.20 to 50.40 % (mean 30.41%) and 1.20 to 37.10 % (mean 19.86%). The texture of the soils was mostly clay (80%), though some soils were clay loam, silt clay and silt clay loam. Similar texture was also reported earlier by Devi *et al*. (2018) [8]. Correlation study revealed that available Magnesium was positively correlated with clay, pH, CEC and organic carbon and negatively with EC (Table 5). Similar correlation was also given by Singh *et al.* (2017) [27].

Effect of magnesium on dry matter yield

The data on dry matter yield of green gram revealed that the yield in control pots varied in different soils and it ranged between 5.55 – 7.39 g pot^{-1} with a mean value of 6.56 g pot^{-1}. This may be due to variation in the available Magnesium status of the soils which ranged from 72.9 - 352.35 mg kg^{-1} with an average value of 185.09 mg kg^{-1}. Dry matter yield of green gram increased over control with increase in rates of Magnesium application. Highest value was recorded with 30 kg Mg ha^{-1}. Bray's percent yield varied from 64.26 - 85.39 percent with a mean value of 76.33 percent. Response of crops to Magnesium application in different soils have been reported by many workers Narwal *et al.* (1985) [20] and Reinbott and Blevins (1995) [23]. Plant magnesium concentration in control pots varied from 984.20 – 1518.80 mg kg^{-1} with an average of 1240.95 mg kg^{-1}. Magnesium uptake in control pots was in the range of 6.32 – 10.32 mg pot^{-1} with a mean value of 8.17 mg pot^{-1}.

Simple correlation study indicated that available Mg was positively and significantly correlated with plant magnesium content (r=464**) and plant uptake (r=0.372*) in control pots (Table 4).There was positive but non-significant correlation between available magnesium and control dry weight (r=0.053) and Bray's per cent yield (r = 0.190).

Critical limits of magnesium in soil and green gram plant

The computed data in respect of the delineation of critical limits of Mg in soil and green gram as presented in Table.3 and Fig. 1 and 2 using graphical procedure of Cate and Nelson (1965) [7], the plot of Bray's per cent yield against soil magnesium revealed that the critical limit of Magnesium was found to be 164 mg kg^{-1} in soil (Fig. 1) below which economic response to Magnesium application can be expected. Similarly a plant critical limit of 0.12% (1200 mg kg^{-1}) (Fig. 2) was established to separate deficient plants from those having sufficient Magnesium. The similar experiment on Critical limit of Magnesium was done in Tomato, Rice and Peanut (Nand, 1976 and Kasinath *et al*., 2014) [19, 13].

Table 1: GPS readings of the soil samples collected

Name of place	Latitude	Longitude
Potsangbam awang khullel	N24^{0}54.851'	E093^{0}54.161'
Leikinthabi	N24^{0}55.917'	E093^{0}53.601'
Sekmai	N24^{0}56.213'	E093^{0}52.628'
Pheidinga	N24^{0}54.010'	E093^{0}53.286'
Khonghampat	N24^{0}52.892'	E093^{0}54.100'
Leimakhong	N24^{0}55.597'	E093^{0}51.151'
Kanto	N24^{0}55.743'	E093^{0}51.519'
Khurkhul	N24^{0}54.582'	E093^{0}50.960'
Loitang	N24^{0}53.829'	E093^{0}51.277'
Phumlou	N24^{0}52.503'	E093^{0}51.492'
Lamdeng	N24^{0}49.534'	E093^{0}52.046'
Heibongpokpi	N24^{0}49.901'	E093^{0}51.133'
Lairenkabi	N24^{0}50.588'	E093^{0}49.857'
Phayeng	N24^{0}51.334'	E093^{0}48.925'
Haorang sabal	N24^{0}49.444'	E093^{0}51.149'
Kiyam	N24^{0}48.496'	E093^{0}50.452'
Patsoi yurang	N24^{0}47.993'	E093^{0}51.987'
Yurembam	N24^{0}47.692'	E093^{0}52.482'
Sagoltongba	N24^{0}47.065'	E093^{0}51.442'
Konthoujam	N24^{0}46.507'	E093^{0}50.707'
Khaidem	N24^{0}46.152'	E093^{0}50.024'
Khumbong	N24^{0}46.206'	E093^{0}49.473'
Moidangpok	N24^{0}46.051'	E093^{0}48.851'
Keithelmanbi	N24^{0}46.098'	E093^{0}48.191'
Langjing	N24^{0}47.820'	E093^{0}52.972'
Tabungkhok awang leikai	N24^{0}46.566'	E093^{0}53.192'
Irom meijrao	N24^{0}42.695'	E093^{0}53.074'
Thiyam leishangkhong	N24^{0}39.620'	E093^{0}53.693'
Langthanbal lep awang leikai	N24^{0}43.574'	E093^{0}54.442'
Awang khunou	N24^{0}46.944'	E093^{0}50.760'

Table 2: Initial soil properties

S. No	Name of place	pH	EC (dSm^{-1})	CEC [cmol (p+) kg^{-1}]	OC (%)	Sand (%)	Silt (%)	Clay (%)	Texture
1.	Potsangbam awang khullel	5.71	0.07	17.00	1.45	36.00	22.70	41.30	clay
2.	Leikinthabi	5.74	0.04	15.40	2.34	24.70	23.40	51.90	clay
3.	Sekmai	5.13	0.11	13.00	1.82	28.50	27.60	43.90	clay
4.	Pheidinga	5.73	0.06	19.60	1.62	15.20	44.50	40.30	silt clay
5.	Khonghampat	5.63	0.05	19.20	2.41	12.70	50.40	36.90	silt clay loam
6.	Leimakhong	5.12	0.08	15.00	2.21	15.20	33.50	51.30	clay
7.	Kanto	5.49	0.15	13.60	1.94	20.20	44.50	35.30	clay loam
8.	Khurkhul	6.42	0.06	20.20	2.38	22.70	37.00	40.30	clay loam
9.	Loitang	4.73	0.07	19.40	1.96	26.80	27.90	45.30	clay
10.	Phumlou	5.64	0.06	18.40	1.98	15.40	20.20	64.40	clay
11.	Lamdeng	5.93	0.07	16.40	1.05	27.00	30.20	42.80	clay
12.	Heibongpokpi	4.01	0.09	20.40	2.24	25.20	30.40	44.40	clay
13.	Lairenkabi	5.58	0.07	15.80	1.94	6.20	24.40	69.40	clay
14.	Phayeng	6.23	0.15	14.20	1.21	21.10	36.70	42.20	clay
15.	Haorang sabal	5.07	0.27	13.80	2.03	23.70	32.80	43.50	clay
16.	Kiyam	5.93	0.06	12.20	2.46	13.70	28.50	57.80	clay
17.	Patsoi yurang	5.55	0.05	19.40	2.13	29.60	31.00	39.40	clay
18.	Yurembam	5.61	0.09	17.20	1.86	7.10	21.90	71.00	clay
19.	Sagoltongba	5.55	0.07	15.00	2.39	1.20	26.90	71.90	clay
20.	Konthoujam	5.85	0.08	12.60	1.84	11.20	25.30	63.50	clay
21.	Khaidem	5.74	0.11	16.80	1.41	33.00	19.20	47.80	clay
22.	Khumbong	4.84	0.04	19.00	2.31	15.50	24.20	60.30	clay
23.	Moidangpok	5.14	0.08	16.80	2.26	3.70	32.80	63.50	clay
24.	Keithelmanbi	4.96	0.06	12.40	1.29	13.00	22.60	64.40	clay
25.	Langjing	5.04	0.07	14.80	2.43	17.10	31.00	51.90	clay
26.	Tabungkhok awang leikai	5.45	0.07	13.70	1.53	23.60	36.90	39.50	Clay loam
27.	Irom meijrao	5.27	0.06	18.70	2.62	16.20	31.00	52.80	clay
28.	Thiyam leishangkhong	5.79	0.06	17.60	1.41	19.50	33.60	46.90	clay

29.	Langthanbal lep awang leikai	5.21	0.09	19.20	2.34	37.10	26.00	36.90	clay
30.	Awang khunou	4.95	0.07	11.50	1.38	33.70	35.30	31.00	clay loam

Table 3: Effect of Mg application on dry matter yield and plant magnesium concentration and its uptake in no magnesium pots

S. No	Name of place	Available Mg in soil (mg kg^{-1})	Dry matter yield (g pot^{-1}) Magnesium levels(kg ha^{-1})				Plant Mg concentration in no Mg pots (mg kg^{-1})	Mg uptake in no Mg pots (mg kg^{-1})	Bray's yield (%)
			0	10	20	30			
1.	Potsangbam awang khullel	133.65	6.37	7.69	8.68	9.20	1130.00	7.20	69.23
2.	Leikinthabi	255.15	6.50	7.20	7.44	7.77	1518.80	9.87	83.70
3.	Sekmai	194.40	6.63	7.73	8.64	9.17	1178.60	7.81	72.24
4.	Pheidinga	145.80	5.93	7.70	8.18	9.15	1081.40	6.41	64.87
5.	Khonghampat	145.80	6.55	7.72	8.98	9.58	1057.10	6.92	68.31
6.	Leimakhong	218.70	6.20	6.13	7.34	8.58	1324.40	8.21	72.22
7.	Kanto	157.95	6.24	7.96	8.97	9.15	1154.30	7.20	68.20
8.	Khurkhul	243.00	7.39	7.80	8.58	9.17	1300.10	9.61	80.60
9.	Loitang	121.50	6.83	8.24	8.72	9.30	1251.50	8.55	73.50
10.	Phumlou	230.85	6.99	8.33	7.10	8.09	1385.10	9.68	83.92
11.	Lamdeng	352.35	6.86	7.02	8.24	7.64	1445.90	9.92	83.33
12.	Heibongpokpi	218.70	6.15	6.66	7.01	8.31	1300.10	8.00	73.97
13.	Lairenkabi	206.55	7.21	8.20	8.82	9.13	1227.20	8.85	78.97
14.	Phayeng	133.65	7.17	7.58	8.05	8.46	1312.20	9.41	84.82
15.	Haorang sabal	133.65	6.12	7.16	8.06	9.36	1032.80	6.32	65.33
16.	Kiyam	255.15	5.55	6.73	7.00	8.64	1142.10	6.34	64.26
17.	Patsoi yurang	230.85	6.70	7.51	8.43	8.68	1494.50	10.01	77.15
18.	Yurembam	206.55	6.47	7.28	8.16	9.00	1044.90	6.76	71.90
19.	Sagoltongba	182.25	6.39	6.80	7.34	7.78	1494.50	9.55	82.14
20.	Konthoujam	157.95	6.56	7.35	8.12	8.36	1385.10	9.09	78.50
21.	Khaidem	133.65	7.34	7.55	7.82	8.60	1360.80	9.99	85.39
22.	Khumbong	194.40	6.25	6.85	7.85	8.14	1020.60	6.38	76.75
23.	Moidangpok	218.70	6.90	6.96	7.44	8.22	1445.90	9.98	83.90
24.	Keithelmanbi	121.50	7.08	7.34	8.05	8.35	1458.00	10.32	84.80
25.	Langjing	145.80	6.43	7.20	7.94	8.66	984.20	6.33	74.21
26.	Tabungkhok awang leikai	145.80	6.36	7.03	8.12	8.16	1142.10	7.26	77.87
27.	Irom meijrao	255.15	6.50	7.04	8.16	8.37	1227.20	7.98	77.63
28.	Thiyam leishangkhong	109.35	6.17	6.36	8.05	8.30	1069.20	6.60	74.38
29.	Langthanbal lep awang leikai	230.85	6.48	7.36	8.05	8.22	1275.80	8.27	78.79
30.	Awang khunou	72.90	6.43	6.52	7.19	8.12	984.20	6.33	79.15
	Mean	185.09	6.56	7.30	8.02	8.59	1240.95	8.17	76.33

Table 4: Correlation coefficient (r-values) between available magnesium and dry matter yield, plant magnesium concentration and its uptake in no magnesium pots and Bray's yield

Parameters	Plant magnesium uptake	Plant magnesium concentration	dry matter yield	Bray's yield
Soil magnesium	0.372*	0.464**	0.053	0.190

**. Correlation is significant at the 1% level

*. Correlation is significant at the 5% level

Table 5: Correlation coefficient (r-values) between available magnesium and soil properties

Parameters	Available Mg
Clay	0.208
pH	0.182
EC	-0.251
CEC	0.282
OC	0.359*

*. Correlation is significant at the 5% level

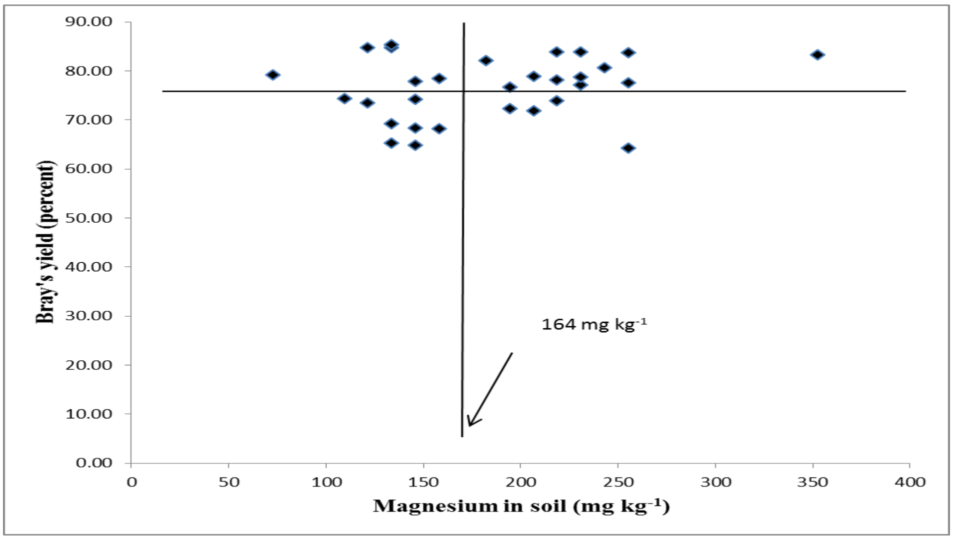

Fig 1: Scatter diagram of available magnesium in soil versus Bray's yield (percent) for determining soil critical magnesium

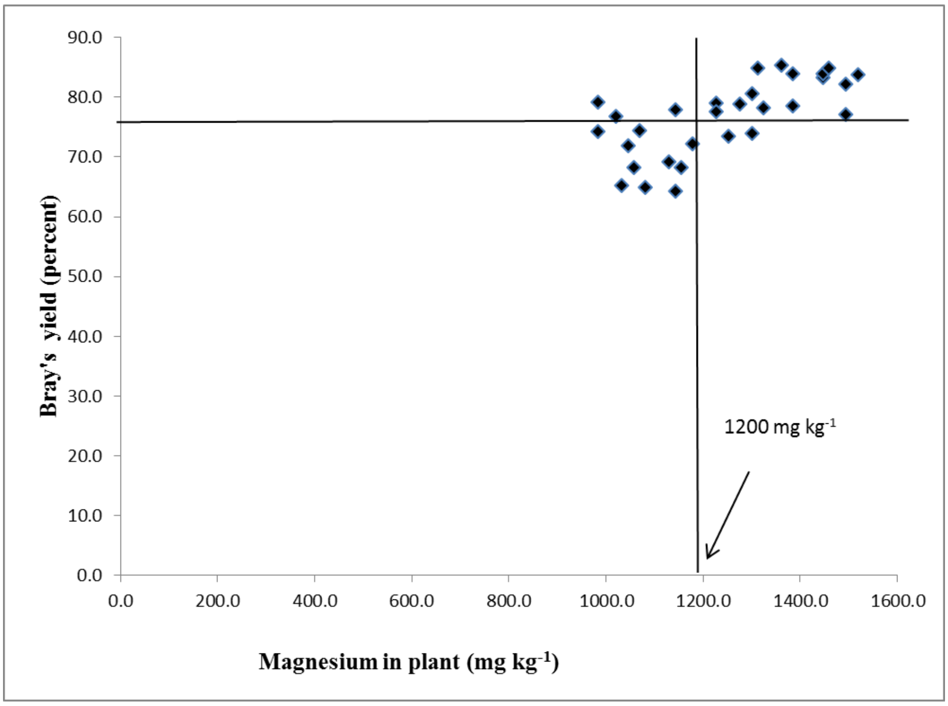

Fig 2: Scatter diagram of magnesium in plant versus Bray's yield (percent) for determining plant critical magnesium

Conclusion

The results indicate that the critical limit values of available Mg in soils of Imphal West district, Manipur was164 ppm. The soils will likely respond to Mg application effectively when it contains less than 164 ppm available Magnesium. On the basis of the response of green gram to Magnesium, a critical level of 0.12% (1200ppm) Magnesium was obtained in green gram plant at initial flowering stage (45 days after sowing). Based on the critical limit, 46.66% of the soils studied were found to be magnesium deficient.

References

1. Ananthanarayana R, Reddy MN, Mithyanatha MS, Perur NG. Status of available secondary nutrients in acid soils of Karnataka Journal of the Indian Society of Soil Science. 1986; 34:614-616.
2. Bates TE. Factors affecting critical nutrient concentrations in plants and their evaluation: A review. Soil Science. 1971; 112:116-126.
3. Borah DK, Bordolo PK, Karmakar PM, Barauah NG, Das M. Practical manual for fundamental soil science (Part-II), Jorhat I, 1987.
4. Brady NC, Weil RR. The Nature and Properties of Soil. Edn 12, Prentice Hall, New Jersey, USA, 1999.
5. Buoyoucous GJ. Hydrometer method improved for making analysis of soils. Agronomy Journal. 1962; 54:464-465.
6. Cakmaka I, Kirkby EA. Role of magnesium in carbon partitioning and alleviating photooxidative damage. Physiologia Plantarum. 2008; 133:692-704.
7. Cate RB, Nelson LA. Graphical procedure for critical limits of nutrients. Proceedings of the Soil Science Society of America. 1965; 89:658.
8. Devi NS, Singh RKK, Sarangthem I, Devi TS. Status of DTPA-extractable micronutrients in Valley Districts of Manipur. International Journal of Current Microbiology and Applied Science. 2018; 7(03):3422-3433.

9. Ding Y, Luo W, Xu G. Characterization of magnesium nutrition and interaction of magnesium and potassium in rice. Annals of Applied Biology. 2006; 149:111-123.
10. Ganeshamurthy AN, Hegde DM. Soil health and nutritional security secondary nutrients, Proceedings of Indian Society of Soil Science, Platinum Jubilee Symposium, 1980, 1-20.
11. Jackson ML. Soil Chemical Analysis, Prentice Hall of India Private Limited, New Delhi, 1973.
12. Kanwar JS. Calcium, Magnesium and Sulphur. In: Soil Fertility - Theory and Practice, Kanwar, ed: Journal of Indian Council of Agricultural Research, New Delhi, 1976, 202-212.
13. Kasinath BL, Ganeshmurthy AN, Nagegowda NS. Critical limit of soil and plant magnesium in tomato-growing soils of South Karnataka. Journal of Horticultural Sciences. 2014; 9(2):209-212.
14. Lal S. Relationship between grain and biological yields in chickpea (*Cicer arietinum* L.). Tropical Grain legume Bulletin. 1976; 6:29-31.
15. Lombin G, Payami AAA. Magnesium status and availability in soils of Western Nigeria. Journal of the Indian Society of Soil Science. 1976; 122:91-99.
16. Maji AK, Reddy GPO, Thailand S, Walke NG. Characterization and classifications of land forms and soil over Basaltic terrain in sub-humid tropics in Central India. Indian Journal of Agricultural Science. 2005; 53(2):151-162.
17. Mikkelsen R. Soil and fertilizer magnesium. Better Crops 2010; 94:26-28.
18. Naik MS, Das NB. Available sulphur status of Indian soils by the Aspergillus niger method. Journal of the Indian Society of Soil Science. 1964; 12:151-155.
19. Nand KF, Critical PK, Ca. Mg contents in the tops of Rice and Peanut plants. Plant and Soil. 1976; 45:421-431.
20. Narwal RP, Vinod K, Singh J. Potassium and magnesium relationship in cowpea (*Vigna unguiculata* (L.). Plant Soil. 1985; 86:129-134.
21. Nayak DC, Sen TK, Chamuah GS, Sehgal JL. Nature of soil acidity in some soils of Manipur. Journal of the Indian Society of Soil Science. 1996; 44:209-214.
22. Pasricha NS, Sarkar AK. Secondary nutrients, Fundamentals of Soil Science, Indian Society of Soil Science, Dev Prakash Sastri Marg, Pusa New Delhi, 2009.
23. Reinbott TM, Blevins DG. Response of soybean to foliar-applied boron and magnesium and soil-applied boron. Journal of Plant Nutrition 1995; 18:179-200.
24. Saha GC, Bala N. Characterisation and classification of soils on valley plains of middle Andaman Islands. Journal of the Indian Society of Soil Science. 1995; 43(1):99-103.
25. Sahoo AK, Sarkar D, Baruah U, Butte PS. Characterization and classification and evaluation of soils in Langol hill, Manipur for Rational land use planning. Journal of the Indian Society of Soil Science. 2010; 58(4):355-362.
26. Singh VK, Agarawal HP. Development of DRIS norms for evaluating, nitrogen, phosphorus potassium and sulphur requirements of rice crop. Journal of the Indian Society of Soil Science. 2007; 55:294-303.
27. Singh YV, Kant S, Singh SK, Sharma PK, Jat LK, Kumar M et al. Assessment of physico-chemical characteristics of the soil of Lahar Block in Bhind District of Madhya Pradesh (India). International Journal of Current Microbiology and Applied Science. 2017; 6(2):511-519.
28. Sinha SK. Food Legumes: Distribution, Adaptability and Biology of Yield. FAO plant production and protection pap.3, Rome, 1977.
29. Synder C, Thompson B. Efficient Fertilizer use-Secondary Nutrients: Section, Secondary Nutrients (Calcium, Magnesium, Sulfur) Research Section. PDA, Info. Org. UK. Potash Development Association, 2005.
30. Tandon HLS. Management of Nutrient Interaction in Agriculture. FDCO, New Delhi, 1992.
31. Walkley A, Black IA. An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Science. 1934; 37:29-38.