Variation in soil chemical properties and yield of cowpea under graded doses of magnesium application in Ultisol of Kerala

ABSTRACT

Aim: A pot culture study was conducted to determine the effect of varying magnesium levels on soil chemical properties and yield of cowpea in Ultisols of Kerala.

Study design: Completely randomized design

Place and duration of study: Radiotracer Laboratory, College of Agriculture, Vellanikkara, Kerala Agricultural University, from January-April 2019.

Methodology: Varying magnesium levels ranging from 5 mg kg^{-1} to 80 mg kg^{-1} were provided as magnesium carbonate along with recommended doses of fertilizers for cowpea maintained in pots. Rhizosphere samples were analyzed during flowering and at harvest of the crop following standard procedures. Yield and yield attributes are recorded at the time of harvest.

Results: Graded doses of magnesium could introduce significant variations in the soil available nutrient status and yield of cowpea. Soil pH and available magnesium in rhizosphere soil during flowering and after crop harvest increased with the increasing levels of magnesium carbonate, and the treatment supplied with 80 mg kg^{-1} of magnesium recorded the highest pH, available phosphorus, potassium and magnesium. In contrast, the gradation of magnesium could not produce significant variation in yield. The highest yield was recorded in treatment supplied with 10 mg kg^{-1} of magnesium and was on par with those of higher levels of magnesium supplement.

Conclusion: Graded doses of magnesium could introduce variation in available nutrient status but a better yield response in cowpea was obtained magnesium at 10 mg kg^{-1} of soil.

Keywords: magnesium, Ultisol, available nutrients, yield

INTRODUCTION

Lateritic soils occupy more than fifty per cent of the total geographical area of Kerala. The soils are characterized by low pH, and low cation exchange capacity leading to low nutrient retention due to the dominance of kaolinite, and oxides and hydrous oxides of iron and aluminium (Chandran*et al*., 2005). Magnesium saturation constitutes 4-20 % of the cation exchange capacity of the soil (Fageria, 2010). Even though magnesium is one of the major exchangeable cations on the exchange complex of soil, magnesium deficiency is a major constraint to crop productivity. About 90–98 per cent of the soil Mg is incorporated in the crystal lattice structure of minerals, thus not directly available for plant uptake. Crop loss due to magnesium deficiency can be alleviated with appropriate fertilization practices. Wilkinson (2000) reported a positive correlation and interactions between phosphorus and magnesium in the soil. Generally, Mg has an effect on potassium translocation in soil. The low magnesium status in soil decreases potassium availability (Hanaway, etal 1982). Barber (1995) reported the existence of negative interaction between calcium and magnesium in the soil. Kene et al. (1990) observed a reduced calcium uptake by plants in high magnesium-containing soil, and the plants grown under such conditions showed calcium deficiency. Studies on interactions between calcium, magnesium and potassium showed a suppressive effect of calcium and potassium on magnesium uptake, which also depends on ionic concentration and soil properties (Camberato and Pan, 2000). Studying nutrient interaction at root–soil interface is an important aspect in mineral nutrition. Hence present investigation was undertaken to study the influence of applied magnesium on soil chemical properties and corresponding variation in cowpea yield.

MATERIALS AND METHODS

The pot culture experiment was laid out as a completely randomized design with twelve treatments and four replication in January-april 2019. Top soil (0-15cm) representing Ultisol was collected from Water Management Research Unit ($13^0$32N and $76^0$26E), Kerala Agricultural University. The soil sample was air dried, ground, sieved through a 2 mm sieve and characterized for physico-chemical properties. The soil was sandy clay in texture with an initial pH of 4.7. Organic carbon (1.32%), available nitrogen (476.67 kg ha^{-1}) and potassium (240.18 kg ha^{-1}) were medium in status, while phosphorus (98.04 kg ha^{-1}) was high. The secondary and micronutrients except magnesium (64.53 mg kg^{-1}) and boron (0.22 mg kg^{-1}) were sufficient (Table 1).

Five kilogram of soil was filled in earthen pots. Treatments included were absolute control (T_1), recommended dose of fertilizers (RDF) (T_2), RDF + magnesium @ 5 mg kg^{-1} of soil (T_3), RDF+ magnesium @ 10 mg kg^{-1} of soil (T_4), RDF+ magnesium @ 15 mg kg^{-1} of soil (T_5), RDF+ magnesium @ 20 mg kg^{-1} of soil (T_6), RDF + magnesium @ 30 mg kg^{-1} of soil (T_7), RDF+ magnesium @ 40 mg kg^{-1} of soil (T_8), RDF+ magnesium @ 50 mg kg^{-1} of soil (T_9), RDF + magnesium @ 60 mg $kg^{-1}$of soil (T_{10}) and RDF + magnesium @ 80 mg kg^{-1} of soil (T_{11}).

The recommended dose of fertilizers for cowpea includes the application of 20 t ha^{-1} of vermicompost, 250 kg ha^{-1} calcium carbonate and 20:30:10 kg ha^{-1} of N, P_2O_5 and K_2O and was modified based on initial soil test result (KAU, 2016). After applying calcium carbonate, a one-week interval was given for applying organic manure. Two weeks after the application of organic manure, varying levels of magnesium carbonate were added in accordance with the treatments.

Three seeds of bhagyalakshmi, a bush cowpea variety, were sown in each pot, and one healthy seedling was maintained after one week of emergence. Half dose of nitrogen and complete doses of phosphorus and potassium were applied after thinning the population. The remaining dose of nitrogen was supplied two weeks after the first application. Foliar application of boron (0.05%) was done twice to combat boron deficiency. The nutrients were supplied through water-soluble sources. Organic manure used for the study was characterized and was found having a pH of 7.10. The nitrogen, phosphorus, potassium, calcium and magnesium in the vermi compost were 1.71, 0.30, 0.61, 1.27 and 0.28% respectively (table 2). Irrigation with de-ionized water, weed control and plant protection measures were adopted uniformly in each pot.

RESULTS AND DISCUSSION

Soil analysis was carried out during flowering and at harvest of the crop. At flowering, soil samples were collected by a destructive sampling of two replications. A composite sample from five pots maintained under each replication was used for analyzing various chemical properties. Soil pH, EC, K, Ca and Mg were determined by following the procedure of Jackson (1958). The organic carbon was analysed by the wet oxidation method of Walkley and Black (1934), available N by Subbiah and Asija (1956) method, P by Bray and Kurtz (1945) method and Fe, Mn, Zn and Cu was determined by following the procedure of Sims and Johnson (1991). The data was analysed statistically using OPSTAT software package (Sheoran *et al*., 1998) and Duncan's multiple range test was employed to test the significance of the difference between means of treatments.

Soil pH measured during flowering and after harvest differed significantly between treatments with the highest increment obtained in soil treated with 80 mg kg^{-1} of magnesium (Table 3). Applying magnesium carbonate with a neutralizing value of 118.61% resulted in an increased soil pH. The increased soil pH observed after crop harvest compared to the flowering stage in all treatments except absolute control might be due to the slow solubility of magnesium carbonate. The solubility of dolomite/ magnesite was 87% less than kieserite three weeks after application (Senbayram*et al.,* 2015).

The organic carbon content in the soil increased from the initial value of 1.32 % in all treatments except absolute control during flowering and harvest, which can be attributed to the addition of vermicompost at 20 t ha^{-1}(Table 3). Available nitrogen status in soil varied between 347.72 – 534.46 mg kg^{-1} during flowering and 286.12 – 501.72 mg^{-} kg $^{-1}$at harvest. Available nitrogen in the soil was significantly higher in treatment supplied with a recommended dose of fertilizers during flowering and after harvest of crop, which can be attributed to the higher organic carbon status of soil in this treatment (Table 1). Organic carbon content of the soil is taken as the index of nitrogen supplying power as the C:N ratio is usually stabilized at 10:1 to 12:1 under tropical humid climate (Sureshkumar*et al*., 2018; John, 2014).

Soil analysis for available phosphorus during flowering and harvest showed significantly higher status in treatment supplied with 80 mg kg^{-1} magnesium, which might be due to the increase in soil pH (table 3). The pH of soil recorded during flowering and harvest was 5.20. Hence result was in accordance with the finding of Fageria *et al.* (2008), who reported an increase in available phosphorus as pH increased to above 5.0, due to the release of P ions from Al and Fe oxides. Adams (1980) also reported the occurrence of positive correlation and interactions between phosphorus and magnesium in soil and that Mg helps in greater solubilisation of phosphorus in soil.

Available potassium was significantly higher in soil received 80 mg kg^{-1}magnesium both flowering and after harvest (Table 4). This might be due to release of potassium from the exchange sites to maintain the equilibrium between the soil solid phase and solution phase. According to Schofield's ratio law the ratio of cations held by the soil and the ratio in equilibrium solution is constant (Sanyal*et al*., 2009). Hannaway*et al*. (1982) studied the effect of Mg on K translocation in soil and reported that low magnesium status in soil decreases the available K.

Available calcium levels ranged between 390.67- 538.25 mg kg^{-1} during flowering and 467.35 - 627.25 mg kg^{-1} during harvest. Available calcium level increased from the initial level in all treatments except absolute control due to the calcium release from calcium carbonate/ organic manure (Table 4). A further increase in available calcium in soil was observed after the crop harvest, which might indicate the release of calcium from calcium carbonate and/or organic manure (1.27% calcium). Though there is conflicting information concerning the reaction time of limestone in acid soils, Jones and Mallarino (2018) reported a significant influence of reagent-grade calcium carbonate in the soil after 200 days of incubation though a significant increase in pH was realized within 10 days.

The variations in available Mg content in soil at both stages of analysis corresponded to the gradation in magnesium through added sources with the highest content in treatment supplied with 80mg $kg^{-1}$of magnesium (Table 4). An increase in available magnesium status at crop harvest when compared to the flowering stage indicates the release of magnesium from magnesium carbonate. Further, an increase in the available pool of nutrients in maintaining sufficient soil humidity and temperature was reported by Fageria (2010).

Yield and related biometric attributes were significantly influenced by the varying levels of magnesium added (Table 5). Significantly higher plant height was obtained in treatment supplied with 10 mg $kg^{-1}$of magnesium with a mean value of 61.65cm and followed by plants treated with 30 and 15 mg $kg^{-1}$of magnesium. The treatments differed significantly with respect to number of pods per plant. A significantly higher number of pods per plant was obtained in plants received 50 mg $kg^{-1}$of magnesium and was on par with that of 5, 10, 15, 20 and 80 mg $kg^{-1}$of magnesium. A significantly long pods were observed in plants supplied with 5, 30, and 60 mg $kg^{-1}$of magnesium. The treatments differed significantly with respect to the yield per plant. Plants treated with 10 mg $kg^{-1}$of magnesium recorded significantly higher yield but were on par with that of 50, 20, 30, 60 and 80 mg kg^{-1} magnesium received plants. The absolute control treatment recorded the lowest yield. The lack of growth response to the higher dose of magnesium addition indicated that moderate level of magnesium *ie* 10 mg kg^{-1} would be sufficient to meet the magnesium requirements of cowpea.

CONCLUSION

On a final note, concurrent increases in soil pH and available magnesium were recorded during flowering and harvest stage of cowpea with graded dose of magnesium added. A better amelioration of soil pH and highest available magnesium, potassium and phosphorus were recorded in soil that received 80 mg kg^{-1} of magnesium. But the response of cowpea yield was not in accordance with the varying levels of magnesium supplied. A better yield response in cowpea was obtained magnesium at 10 mg kg^{-1} of soil, suggesting to be the optimum dose for yield maximization.

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Table 1. Initial soil properties of the experimental site

Soil parameters	**Value**
Sand (%)	46.90
Silt (%)	11.60
Clay (%)	40.30
Texture	Sandy clay
pH	4.70
Electrical Conductivity (EC) (dS m^{-1})	0.07
Organic carbon (OC) (%)	1.32
Available nitrogen (Av. N) (kg ha^{-1})	476.67
Available phosphorus (Av. P) (kg ha^{-1})	98.04
Available potassium (Av. K) (kg ha^{-1})	240.18
Available calcium (Av. Ca) (mg kg^{-1})	429.30
Available magnesium (Av. Mg) (mg kg^{-1})	64.53
Available sulphur (Av. S) (mg kg^{-1})	5.00
Available iron (Av. Fe) (mg kg^{-1})	12.41
Available manganese (Av. Mn) (mg kg^{-1})	16.26
Available zinc (Av. Zn) (mg kg^{-1})	3.81

Available copper (Av. Cu) (mg kg^{-1})	8.08
Available boron (Av. B) (mg kg^{-1})	0.24
Effective cation exchange capacity (cmol(+) kg^{-1})	5.63

Table 2 Characteristics of organic manure

Parameters	**Content**
pH	7.10
EC (dS m^{-1})	0.81
Nitrogen (%)	1.79
Phosphorus (%)	0.30
Potassium (%)	0.61
Calcium (%)	1.97
Magnesium (%)	0.28
Sulphur (%)	0.25
Iron (mg kg^{-1})	1000.00
Manganese (mg kg^{-1})	290.60
Zinc (mg kg^{-1})	80.50

Copper (mg kg^{-1})	24.00
Boron (mg kg^{-1})	64.40

Table 3. Effect of treatments on soil pH, organic carbon, available N and available P content of soil

Treatments		pH		Organic carbon (%)		Available Nitrogen(kg ha^{-1})		Available P (kg ha^{-1})	
		Flowering	Harvest	Flowering	Harvest	Flowering	Harvest	Flowering	Harvest
T_1	Absolute control	4.75^{g}	4.72^{g}	1.27^{g}	1.08^{f}	347.72^{g}	286.12^{c}	82.89^{g}	72.23^{h}
T_2	Recommended dose of fertilizers (RDF)	4.88^{f}	4.92^{e}	2.54^{a}	2.12^{a}	534.55^{a}	501.72^{a}	122.55^{bc}	137.24^{a}
T_3	RDF + magnesium @ 5 mg kg^{-1} of soil	4.94^{d}	4.96^{de}	2.02^{c}	1.90^{abc}	502.46^{bc}	489.21^{a}	116.89^{d}	98.28^{e}
T_4	RDF + magnesium @10 mg kg^{-1} of soil	4.96^{d}	4.97^{de}	1.43^{f}	1.72^{bcd}	512.37^{b}	345.18^{b}	107.14^{f}	98.79^{e}
T_5	RDF + magnesium @ 15 mg kg^{-1} of soil	4.88^{ef}	4.91^{e}	2.54^{a}	1.70^{cde}	503.52^{bc}	332.41^{bc}	121.50^{c}	125.1^{c}
T_6	RDF + magnesium @ 20 mg kg^{-1} of soil	4.94^{d}	4.98^{cd}	1.51^{f}	1.67^{cde}	371.02^{f}	482.94^{a}	113.3^{e}	88.1^{g}
T_7	RDF + magnesium @ 30 mg kg^{-1} of soil	5.01^{c}	5.02^{c}	1.48^{f}	1.525^{de}	506.38^{b}	502.94^{a}	108.35^{f}	94.48^{f}

T_8	RDF + magnesium @ 40 mg kg^{-1} of soil	5.04^{c}	5.14^{b}	1.87^{d}	1.50^{de}	509.52^{b}	348.45^{b}	107.69^{f}	98.29^{e}
T_9	RDF + magnesium @ 50 mg kg^{-1} of soil	4.92^{de}	4.95^{de}	2.23^{b}	1.47^{e}	429.98^{e}	495.48^{a}	123.83^{b}	125.20^{c}
T_{10}	RDF + magnesium @ 60 mg kg^{-1} of soil	5.10^{b}	5.14^{b}	1.77^{de}	1.95^{ab}	512.09^{b}	470.39^{a}	106.7^{f}	109.73^{d}
T_{11}	RDF + magnesium @ 80 mg kg^{-1} of soil	5.20^{a}	5.20^{a}	1.74^{e}	1.99^{a}	491.40^{c}	472.39^{a}	131.76^{a}	129.88^{b}

Treatment means with common superscript do not differ significantly

Table 4. Effect of treatments on available potassium, calcium and magnesium

Treatments		Potassium (kg ha^{-1})		Calcium (mg kg^{-1})		Magnesium (mg kg^{-1})	
		Flowering	Harvest	Flowering	Harvest	Flowering	Harvest
T_1	Absolute control	139.38^{f}	191.99^{h}	390.67^{c}	467.35^{f}	55.57^{i}	63.10^{g}
T_2	Recommended dose of fertilizers (RDF)	183.29^{b}	268.24^{bc}	511.75^{b}	575.02^{d}	73.77^{g}	80.90^{e}
T_3	RDF + magnesium @ 5 mg kg^{-1} of soil	149.01^{e}	234.24^{fg}	502.00^{b}	580.50^{d}	67.72^{h}	70.52^{f}
T_4	RDF + magnesium @10 mg kg^{-1} of soil	150.02^{e}	244.49^{e}	510.75^{b}	624.00^{a}	75.90^{f}	79.49^{b}
T_5	RDF + magnesium @ 15 mg kg^{-1} of soil	148.06^{e}	259.56^{cd}	502.40^{b}	627.25^{a}	76.90^{fg}	93.10^{d}
T_6	RDF + magnesium @ 20 mg kg^{-1} of soil	156.96^{d}	229.60^{g}	504.75^{b}	598.25^{c}	77.85^{f}	82.55^{e}
T_7	RDF + magnesium @ 30 mg kg^{-1} of soil	157.86^{d}	242.42^{ef}	502.07^{b}	616.50^{ab}	81.77^{e}	89.42^{d}
T_8	RDF + magnesium @ 40 mg kg^{-1} of soil	165.20^{c}	256.92^{d}	538.25^{a}	605.30^{bc}	93.05^{d}	100.80^{c}
T_9	RDF + magnesium @ 50 mg kg^{-1} of soil	179.42^{b}	250.82^{de}	520.00^{ab}	597.50^{c}	105.25^{b}	110.40^{b}
T_{10}	RDF + magnesium @ 60 mg kg^{-1} of soil	166.65^{c}	276.92^{b}	499.92^{b}	614.00^{abc}	101.10^{c}	126.82^{a}
T_{11}	RDF + magnesium @ 80 mg kg^{-1} of soil	198.74^{a}	290.64^{a}	507.25^{b}	557.25^{e}	123.47^{a}	130.95^{a}
Treatment means with common superscript do not differ significantly							

Table 5. Effect of treatments on biometric parameters of cowpea

Treatments		Plant height (cm)	Pods per plant	Length of pods (cm)	Yield (g $plant^{-1}$)
T_1	Absolute control	37.90^{f}	8.25^{f}	9.60^{g}	33.04^{e}
T_2	RDF + magnesium @ 5 mg kg^{-1} of soil	52.80^{c}	19.5^{abc}	17.70^{a}	70.39^{c}
T_3	RDF + magnesium @10 mg kg^{-1} of soil	61.65^{a}	19.50^{abc}	15.80^{bc}	79.33^{a}
T_4	RDF + magnesium @ 15 mg kg^{-1} of soil	56.95^{b}	18.75^{abc}	15.95^{bc}	73.33^{bc}
T_5	RDF + magnesium @ 20 mg kg^{-1} of soil	49.65^{d}	20.25^{ab}	15.05^{cd}	76.57^{ab}
T_6	RDF + magnesium @ 30 mg kg^{-1} of soil	58.95^{b}	17.25^{bc}	17.00^{ab}	75.28^{abc}
T_7	RDF + magnesium @ 40 mg kg^{-1} of soil	48.40^{d}	18.00^{bc}	15.50^{c}	73.30^{bc}
T_8	RDF + magnesium @ 50 mg kg^{-1} of soil	49.80^{d}	21.75^{a}	16.35^{abc}	76.12^{abc}
T_9	RDF + magnesium @ 60 mg kg^{-1} of soil	48.25^{d}	16.50^{cd}	17.70^{a}	74.64^{abc}
T_{10}	RDF + magnesium @ 80 mg kg^{-1} of soil	49.55^{d}	18.75^{abc}	13.95^{de}	74.19^{abc}
Treatment means with common superscript do not differ significantly					