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Magnesium Supplementation Concerning Soil Chemical Properties and Cowpea Yield in Ultisol of Kerala, India

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Ultisol of Kerala faces high magnesium deficiency due to poor retention of magnesium to soil exchange surfaces under high rainfall conditions. Hence magnesium nutrition management is an important aspect of fertility improvement in these soils. We conducted a pot culture study to determine the influence of varying magnesium levels on soil chemical properties and yield of cowpea in Ultisols of Kerala. We used a completely randomized design. The study was carried out in the Radiotracer Laboratory, College of Agriculture, Vellanikkara, Kerala Agricultural University, in January-April 2019. Magnesium carbonate at levels 5 to 80 $mg.kg^{-1}$ was provided 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. Graded doses of magnesium introduced significant

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($P< 0.05$) variations in the soil available nutrients and yield of cowpea. Soil pH and available magnesium in rhizosphere soil during flowering and post-harvest increased with the increasing levels of magnesium carbonate, and using 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. Graded doses of magnesium introduced variation in available nutrients but a better yield response in cowpea was obtained from magnesium at 10 $mg.kg^{-1}$.

Keywords: Available nutrients; magnesium; ultisol; yield.

1. INTRODUCTION

Ultisol occupy more than 50% 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, oxides, and hydrous oxides of iron and aluminium [1]. Magnesium saturation constitutes 4-20% of the cation exchange capacity of the soil [2]. 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% 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 [3] reported a positive correlation between phosphorus and magnesium in the soil. Generally, Mg has an effect on potassium translocation in soil. Gransee and Führs [4], noted that continuous excessive potassium fertilization increases the risk of induced magnesium deficiency in soil due to interference in magnesium uptake. Barber [5] reported the existence of negative interaction between calcium and magnesium in the soil. Kene et al. [6] 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 [7]. Studying nutrient interaction at root–soil interface is an important aspect of mineral nutrition. Hence, We aimed to study the influence of applied magnesium on soil chemical properties and corresponding variation in cowpea yield.

2. MATERIALS AND METHODS

The pot culture experiment was laid out as a completely randomized design with 11 treatments and four replication in January-April 2019. Topsoil (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 physicochemical properties.

Five kilograms of soil were filled in earthen pots. Treatments included were control (T_1), recommended dose of fertilizers (RDF; T_2), RDF + magnesium (5 $mg.kg^{-1}$; T_3), RDF+ magnesium (10 $mg.kg^{-1}$; T_4), RDF+ magnesium (15 $mg.kg^{-1}$; T_5), RDF+ magnesium (20 $mg.kg^{-1}$; T_6), RDF + magnesium (30 $mg.kg^{-1}$; T_7), RDF+ magnesium (40 $mg.kg^{-1}$; T_8), RDF+ magnesium (50 $mg.kg^{-1}$; T_9), RDF + magnesium (60 $mg.kg^{-1}$; T_{10}) and RDF + magnesium (80 $mg.kg^{-1}$; T_{11}). Four replications of each treatments were maintained and two replications were used for destructive sampling during flowering of the crop.

The recommended dose of fertilizers for cowpea includes the application of 20 $t.ha^{-1}$ of vermicompost (VC), 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 [8]. After applying calcium carbonate, a one-week interval was given for applying organic manure. Two weeks post-application of organic manure, varying levels of magnesium carbonate were added following 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 a 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 to have a pH of 7.10. The nitrogen, phosphorus, potassium, calcium, and magnesium in the VC 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.

Soil analysis was carried out during flowering and at the harvest of the crop. At flowering, soil samples were collected by 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 [9]. The organic carbon was analyzed by the wet oxidation method of Walkley and Black [10], available N by Subbiah and Asija [11] method, P by Bray and Kurtz [12] method and Fe, Mn, Zn, and Cu was determined by following the procedure of Sims and Johnson [13]. The data were analyzed statistically using the OPSTAT software package [14] and Duncan's multiple range test was employed to test the significance of the difference between means of treatments.

3. RESULTS AND DISCUSSION

The soil was sandy clay in texture with an initial pH of 4.7. Organic carbon, available nitrogen, and potassium were medium in status, while phosphorus was high. The secondary and micronutrients except magnesium and boron were sufficient (Table 1).

3.1 Effect of Magnesium Supplementation on Soil pH

Soil pH measured during flowering and after harvest differed significantly ($P<0.05$) between treatments with the highest increment obtained in soil treated with 80 $mg.kg^{-1}$ (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 [15].

3.2 Effect of Magnesium Supplementation on Organic Carbon Status of Soil

The organic carbon content in the soil increased in all treatments except absolute control during flowering and harvest, which can be attributed to the addition of VC (Table 3). Available nitrogen in the soil was significantly ($P<0.05$) higher in treatment supplied with a recommended dose of fertilizers during flowering and post-harvest, which can be attributed to the higher organic carbon status of soil in this treatment (Table 1). The 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 in tropical humid climates [16,17].

3.3 Effect of Magnesium Supplementation on Primary Nutrient Status of Soil

Soil analysis for available phosphorus during flowering and harvest showed a significantly ($P<0.05$) higher status in treatment supplied with 80 $mg.kg^{-1}$ magnesium, which might be due to the increase in soil pH (Table 3). Hence result was following the finding of Fageria et al. [18], 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 [19] also reported the occurrence of positive correlation and interactions between phosphorus and magnesium in soil and that Mg helps in greater solubilization of phosphorus in soil.

Available potassium was significantly ($P<0.05$) higher in soil received 80 $mg.kg^{-1}$magnesium both flowering and after harvest (Table 4). This might be due to the 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 an equilibrium solution is constant [20]. Hannaway [21] studied the effect of Mg on K translocation in soil and reported that low magnesium status in soil decreases the available K.

3.4 Effect of Magnesium Supplementation on Secondary Nutrient Status in Soil

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 the soil was observed post-harvest, which might indicate the release of calcium from calcium carbonate and/or organic manure. Though there is conflicting information concerning the reaction time of limestone in acid soils, Jones and Mallarino [22] 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 80 mg.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 [2].

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 vermicompost (VC)

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
Sulfur (%)	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 Mg supplementation on soil pH, organic carbon, available N, and available P content of the 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	The 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})	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})	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})	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})	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})	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})	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})	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})	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})	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 superscripts do not differ significantly

Table 4. Effect of supplementation 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	The 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})	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})	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})	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})	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})	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})	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})	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})	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})	198.74^{a}	290.64^{a}	507.25^{b}	557.25^{e}	123.47^{a}	130.95^{a}

Treatment means with common superscripts do not differ significantly

Table 5. Effect of supplementation on yield and biometric characteristics 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})	52.80^{c}	19.5^{abc}	17.70^{a}	70.39^{c}
T_3	RDF + magnesium (10 mg kg^{-1})	61.65^{a}	19.50^{abc}	15.80^{bc}	79.33^{a}
T_4	RDF + magnesium (15 mg kg^{-1})	56.95^{b}	18.75^{abc}	15.95^{bc}	73.33^{bc}
T_5	RDF + magnesium (20 mg kg^{-1})	49.65^{d}	20.25^{ab}	15.05^{cd}	76.57^{ab}
T_6	RDF + magnesium (30 mg kg^{-1})	58.95^{b}	17.25^{bc}	17.00^{ab}	75.28^{abc}
T_7	RDF + magnesium (40 mg kg^{-1})	48.40^{d}	18.00^{bc}	15.50^{c}	73.30^{bc}
T_8	RDF + magnesium (50 mg kg^{-1})	49.80^{d}	21.75^{a}	16.35^{abc}	76.12^{abc}
T_9	RDF + magnesium (60 mg kg^{-1})	48.25^{d}	16.50^{cd}	17.70^{a}	74.64^{abc}
T_{10}	RDF + magnesium (80 mg kg^{-1})	49.55^{d}	18.75^{abc}	13.95^{de}	74.19^{abc}

Treatment means with common superscripts do not differ significantly

3.5 Effect of Magnesium Supplementation on Yield of Cowpea

Yield and related biometric attributes were significantly (P<0.05) influenced by the varying levels of magnesium added (Table 5). Significantly (P<0.05) higher plant height was obtained in treatment supplied with 10 $mg.kg^{-1}$ of magnesium followed by 30 and 15 $mg.kg^{-1}$ of magnesium. The treatments differed significantly (P<0.05) concerning the number of pods per plant. A significantly (P<0.05) higher number of pods per plant was obtained in plants that received 50 $mg.kg^{-1}$ of magnesium and were on par with that of 5, 10, 15, 20, and 80 $mg.kg^{-1}$ of magnesium. Significantly (P<0.05) 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 (P<0.05) higher yields 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 [23-24].

4. CONCLUSION

On a final note, concurrent increases in soil pH and available magnesium were recorded during the flowering and harvest stage of cowpea with a graded dose of magnesium added. A better amelioration of soil pH and the 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 following the varying levels of magnesium. A better yield in cowpea was obtained from magnesium at 10 $mg.kg^{-1}$, suggesting to be the optimum dose for yield maximization.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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