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Research Article

Effect of Direct Application of Mussoorie Rock Phosphate on Soil Chemical Properties and Spinach (Spinacia *Oleracia*) Productivity in Alluvial Soil

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Abstract

A field experiment was carried out in rabi season of 2009-10 and 2010-11 at Crop Research Farm of the Department of Soil Science, Sam Higginbottom Institute of Agriculture, Technology and Sciences, Allahabad (U.P.) India, to study the effect of direct application of mussoorie rock phosphate (0, 100, 150 & 200kg/ha) on soil chemical properties, productivity, soil and plant content of micronutrients and heavy metals in spinach (Spinacia *oleracia*) on an alluvial soil. The experiment was laid out in randomized block design with three replications. Results of two year's average data revealed that increasing levels of mussoori rock phosphate significantly improve the chemical properties of soil, build up of available nutrients and CEC. Higher organic carbon content (0.58%), available nitrogen (192.74kg/ha), available phosphorus (28.36 kg/ha), available potassium (249.02 kg/ha), exchangeable calcium (4.79 Meq/100g), exchangeable magnesium (3.79 Meq/100g) and cation exchange capacity (15.70 cmol/kg) were recorded in the treatment where 200 kg/ha MRP was applied, which were over their respective controls. Increasing levels of mussoori rock phosphate significantly increase the fresh weight and dry weight of spinach and reduce the soil and plant content of micronutrients and heavy metals as compared to their respective control. Highest fresh weight (171.14q/ha) and dry weight (27.88q/ha) of spinach and lower metal content (Cd-0.14 ppm, Pb-0.14 ppm, Cr-0.22 ppm and Zn- 0.33 ppm) were recorded in the treatment receiving MRP, 200 kg/ha which were below the critical level of toxicity.

Keywords: Mussoorie rock phosphate; soil chemical properties; productivity; micronutrients; heavy metals; spinach yield

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Introduction

Phosphorus is the primary constituents of plants and animals life, playing a vital role in many metabolic processes and phenology of crops and vegetables. Phosphorus has functions of a structural nature in macromolecules such as nucleic acids and of energy transformation as Adenosine Tri-phosphate (ATP) in metabolic pathways of biosynthesis and degradation. Soil type, crops, water, P fertilizer, management practices and climatic conditions of an area are important factors to be considered when attempting to formulate sound P-fertilizer source and application for adequate crops yield response. Most of annual plants especially leafy vegetable such as spinach well respond to phosphorus application. From soil most of the plants often absorb phosphorus in the form of $H_2PO_4^-$ and HPO_4^{2-} ions. It is readily available to plants between a pH of 6.0-7.5 (unavailable in very acid or alkaline soils). The challenges in soil and plant sciences are to provide the proper amount of phosphorus, in the proper form, at proper time to the plants where the plant roots will absorb it properly. A drawback is so far concern to possibility of heavy metals accumulation in soil and plants structure due to indiscriminate and continuous direct use of rock phosphate in soil for crop production [1]. Considerable research has been conducted in the past years on the characteristics and agronomic effectiveness of rock phosphate rock (RP) for direct application. In some locations, the use of rock phosphate is an attractive alternative to the use of more expensive water-soluble P fertilizers (e.g. Super Phosphate (SSP), Triple Super Phosphate (TSP) because of the low cost involved. The main factors affecting the agronomic effectiveness of rock phosphate are source (reactivity) of RP, soil properties and crop species. Owing to the facts this study was carried out to evaluate the effect of direct application of mussoorie rock phosphate on soil chemical properties, productivity, soil and plant content of micronutrients and heavy metals in spinach (Spinacia *oleracea*) on an alluvial soil.

Materials and Methods

A field experiment was conducted during rabi seasons of 2009-10 and 2010-11 at Crop Research farm of the Department of soil science, Allahabad school of Agriculture, Sam Higgintbottom Institute of Agriculture, technology and sciences, Allahabad, which is situated in the alluvial belt of the south eastern region of the Uttar Pradesh, India and is positioned at 25º18'N latitude and 81º50' E longitude at an altitude of 98 meter above the mean sea level. Climate of the area is sub-tropical and arid with an average annual rain fall 1090 mm, most of which is received from June to September. The experiment soil was entisol with sandy loam in texture. It had pH 7.71, electrical conductivity 0.37 dsm^{-1}, organic carbon 0.53%, available nitrogen 182.10 kg/ha, available phosphorus 16.34 kg/ha and available potassium 239.45 kg/ha, exchangeable calcium 2.04 Meq/100g, exchangeable Mg 1.42 Meq/100g, cation exchange capacity 15.49 Cmol/kg. The DTPA-extractable micronutrients and heavy metals i.e., iron 3.32 ppm, cadmium 0.61 ppm, lead 0.56 ppm, chromium 0.96 ppm and Zn 0.82 ppm. The experiment was laid out in randomized block design with three replications. The treatment consisted of four level of mussoorie rock phosphate (0,100,150 and 200kg/ha) applied through fine powdered farm. The direct effect of levels of MRP was studied with spinach (spinacia *oleracia*) *var*. All green. Mussoorie rock phosphate was applied three weeks before of sowing spinach. A basal dose of 90 kg N, 130 kg P_2O_5 and 80kg K_2O/ha was applied through urea, di-ammonium phosphate and murate of Potash, respectively. Half dose of N and full dose of P & K were applied at the time of sowing remaining N was top-dressed after 20 & 30 days of sowing. Crop was harvested at fourty days after sowing. Fresh weight & dry weight of the crop were recorded at harvest. Powdered plant samples were digested in di-acid mixture of conc. HNO_3, $HClO_4$ (3:1) and plant content of micronutrients and heavy metals (Cd, Pb, Cr & Zn) were determined by atomic absorption spectrophotometer [2]. Post-harvest soil samples collected after two years of experiment, were air dried ground to pass through 2mm sieve and analyzed for pH, EC, exchangeable calcium, magnesium and cation exchange capacity [2], organic carbon%, walkley and Black method, available nitrogen [3], available phosphorus [4], available potassium [5]. Soil content of micro nutrients and heavy metals (Iron, Cadmium, Lead, Chromium and Zinc) were extracted with DTPA-TEA, (*0.005 M*DTPA, *0.01 M* $Cacl_2$ and *0.1 M* TEA pH 7.3) and determined directly by using atomic absorption spectrophotometer [6, 7]. The data thus obtained were analyzed statistically using analysis of variance technique for various parameters at 5% level of significance [8]. The chemical characteristics of mussoorie rock phosphate used in experiment was as phosphorus as P_2O_5 19.28%, calcium as CaO 39.43%, magnesium as MgO 6.44%, potassium as K_2O 0.33%, Iron as Fe_2O_3 5.05, organic carbon 1.17%, cadmium 171.87 ppm, lead 315.73 ppm, chromium 1.05 ppm and Zinc 173.13 ppm.

Results and Discussion

Soil chemical properties and build up of nutrients

The data relates to the effect of direct applications of mussoorie rock phosphate on soil chemical properties such as (organic carbon %, available N, P, K, exchangeable Ca, Mg & CEC) are depicted in Table 1. Change in organic carbon over the test period was not significantly influenced. However a gradual increase in organic carbon content was recorded. The maximum increase (0.58%) in organic carbon content was recorded in treatment receiving MRP 200kg/ha which was over the control (0.56%). This could be envisaged due to increase in phosphate nutrition of the soil and growing crops resulting in vigorous root and shoot growth which produces higher biomass, consequently leading to increased organic matter content in soil [9-11].

Available soil nitrogen value showed no significant difference among treatments. A marginal increase in available soil nitrogen content was recorded. The maximum available nitrogen content (192.74 kg/ha) were noticed in treatment receiving MRP 200kg/ha and the minimum was (191.25 kg/ha) with their respective control. This marginal increase in available nitrogen content by the application of increasing levels of MRP is due to possible role of phosphorus to root and shoot growth which produces higher biomass, consequently leading to increase organic matter content and available nitrogen content in soil.

Data relates to the effect of direct application of MRP on available soil phosphorus content (Table 1) showed that increasing levels of mussoorie rock phosphate up to 200kg/ha significantly increased the available soil phosphate content over their respective control, the maximum increase (28.6 kg/ha) was recorded with treatment receiving MRP 200kg/ha and the minimum (17.14) was recorded with control. This result could be attributed to the dissolution of added phosphate rock to available phosphate ions $H_2PO_4^-$ and HPO_4^{--} with the time and their transformation into different forms after the crop harvest [12]. Increase in content of available phosphorus due to application of increasing rates of Rock Phosphate [13, 14]. There was a very marginal increase in available potassium (243.38-249.02 kg/ha) were recorded with the application of MRP up to 0-200kg/ha respectively. This could be due to the fact that K was applied annually and the replenishment from the potassium pool at the end of experiment. Among the different levels of MRP, maximum exchangeable Ca and Mg (4.79 and 3.79 Meq/100g) respectively were recorded with the application of MRP 200kg/ha which was over their respective controls. Increasing levels of MRP significantly increase the exchangeable Ca & Mg in soil after crop harvest. This could be explained on the basis of as MRP contains considerable amount of calcium and magnesium leading release of these nutrients during decomposition of soil organic matter & mineralization and of partly due to production of organic acids which brought down the pH of soil and ultimately lead to higher availability of exchangeable calcium and magnesium [15]. Data relates to the cation exchange capacity of the soil at crop harvest showed that increasing level MRP considerably increase cation exchange capacity of the soil. This may be ascribed to the enhancement of mineral matter of the soil leading to increase cation exchange capacity with the increasing rates of MRP. The maximum value of CEC (15.70 Cmol/kg) was observed with plot receiving MRP 200 kg/ha which was over the control (15.59 Cmol/kg). PR fertilizer's have a higher content of calcium ranging from 24-33%. This makes PR beneficial in increasing soil pH, cation exchange capacity (CEC) resulting in yield increase crops [16].

Tables 1 Soil chemical properties as influenced by direct application of mussoorie rock phosphate- (mean of 2years)

Mussoorie Rock phosphate (kg/ha)	Organic carbon%	Available nitrogen kg/ha	Available phosphorus kg/ha	Available potassium kg/ha	Exchangeable calcium (Meq/100g)	Exchangeable magnesium Meq/100g	Cation exchange capacity Cmol/kg
0	0.56	191.25	17.14	243.38	2.54	1.97	15.59
100	0.56	192.01	21.37	245.41	3.93	2.55	15.63
150	0.57	192.29	24.39	246.61	4.30	2.83	15.67
200	0.58	192.74	28.36	249.02	4.79	3.79	15.70
SEm±	NS	NS	0.80	0.75	0.054	0.046	0.008
CD(P=0.05)	NS	NS	1.70	1.59	0.12	0.096	0.017

The results clearly indicate that the increasing rate of MRP significantly increase the status of available N, P, K, exchangeable Ca, Mg & CEC of the post harvest soil. The higher buildup of soil available N, P, K exchangeable Ca, Mg & CEC in post harvest soil were recorded in treatment receiving MRP 200 kg/ha.

Micronutrients and heavy metals contents in soil (DTPA-Fe, Zn, Cd, Pb & Cr)

Data pertaining to soil content of DTPA-extractable micronutrients and heavy metals (Fe, Zn, Cd, Pb and Cr) after crop harvest are presented in Table 2.

Table 2 Soil content of DTPA-extractable micronutrients and heavy metals as influenced by direct application of mussoorie rock phosphate- (mean of 2years)

Mussoorie rock phosphate Kg/ha	DTPA-extractable iron (ppm)	DTPA - extractable zinc (ppm)	DTPA - extractable cadmium (ppm)	DTPA - extractable lead (ppm)	DTPA-extractable chromium (ppm)
0	3.69	1.10	0.84	0.74	1.18
100	3.61	1.10	0.78	0.74	1.14
150	3.56	0.99	0.71	0.71	1.06
200	3.47	0.99	0.64	0.67	0.95

SE±	0.022	0.02	0.008	0.02	0.02
CD(P=0.05)	0.047	0.04	0.02	0.03	0.03

Data showed that the soil content of all these micronutrients and heavy metals (Fe, Zn, Cd, Pb& Cr) were tends to reduce gradually with every increasing rates of mussoorie rock phosphate. The higher reduction were observed with the treatment receiving MRP@ 200kg/ha inwhich the value were (Fe- 3.47ppm, Zn-0.99ppm, Cd-0.64ppm, Pb-0.67ppm and Cr-0.95ppm) respectively. This could be ascribed due to the antagonistic effect of phosphorus to fix and form complexes with these micronutrients and heavy metals and decrease their DTPA-extractable content [17].

Yield attributes

Data relates to the effect of direct application of mussorie rock phosphate on yield attributes and plant content of micronutrients and heavy metal in spinach are presented in Table 3.

Table 3 Yield attributes and plant content of heavy metals and micronutrients as influenced by direct application of mussoorie rock phosphate (mean of two year's)

Mussoorie rock phosphate kg/ha	Fresh weight q/ha	Dry weight q/ha	Plant contents of heavy metals and micro nutrients			
			Cadmium (ppm)	Lead (ppm)	Chromium (ppm)	Zinc (ppm)
0	104.40	17.88	0.16	0.17	0.23	0.35
100	128.51	22.30	0.16	0.16	0.24	0.34
150	151.54	25.02	0.15	0.15	0.23	0.34
200	171.14	27.88	0.14	0.14	0.22	0.33
SE±	27.49	7.15	NS	0.005	0.004	0.004
CD(P=0.05)	58.59	15.24	NS	0.010	0.007	0.008

It was noticed that the addition of mussoorie rock phosphate fertilization resulted in an increase of both fresh and dry weight of spinach at different stages of the growth and at maturity over control. The increase in these parameters were noted with increase in MRP dose from 0-200kg/ha. The maximum fresh and dry weight (171.14 and 27.88 q/ha) respectively was observed with the plot received MRP 200kg/ha fallowed by MRP 150kg/ha (151.54 and 25.02 q/ha). Whereas the least (104.40 and 17.88 q/ha) were recorded with their respective controls. This result may be due to supply of adequate quantity of phosphorus and other nutrients to plant which produces vigorous and proliferous root system. Absorption enhanced by biomass followed by the uptake of plants resulting in favorable increase in fresh and dry weight of plant [18, 19].

Plant content of heavy metals and micronutrients

The data relates to the plant content of heavy metals and micronutrients (Cadmium, Lead, Chromium and Zinc) are presented in Table 3. Data showed that the plant content of heavy metals and micronutrients (Cd, Pb, Cr, & Zn) were tends to reduce with every enhance levels of mussoorie rock phosphate up to 200kg/ha and the higher reduction were observed with plot receiving MRP 200 kg/ha in which (Cd-0.14 ppm, Pb-0.14 ppm, Cr-0.22 ppm and Zn- 0.33 ppm) respectively which were below the critical level of toxicity. This may be attributed to the antagonistic effect of phosphorus to fix and form complexes with different toxic heavy metals and decrease their bioavailability reflecting into reduced content of these heavy metals by growing crops.

The overall results of the present investigations, lead us to the conclusion that there is a significant positive effect of direct application of rock phosphate fertilizer @200 Kg ha^{-1} to soil chemical properties, nutrient availability in soil and plant, spinach (Spinacia *oleracia*) yield and quality without any detrimental effects and critical levels of heavy metals in soil and plants structure were protected. Thus Mussoorie rock phosphate at this levels can be used for agricultural purposes without any detrimental effects under Allahabad conditions.

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