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EFFECT OF INCREASING LEVELS OF PHOSPHATE ON SULPHUR MINERALIZATION OF AN ULTISOL UNDER JUNGLE AND TEA

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A laboratory incubation investigation was undertaken to study the effect of increasing levels of phosphate (0-300 kg P_2O_5 ha^{-1} an^{-1}) on sulphur mineralization of jungle and mature tea soils. There was no difference in $SO_4^{=}$ -S content in the tea soil due to increasing levels of phosphate. However, the jungle soil released more $SO_4^{=}$ -S to the soil solution. With time both soils mineralized more $SO_4^{=}$ -S. In both soils ,after 4 weeks of incubation, the extractable phosphorus did not vary significantly. The pH of both soils decreased significantly over a period of 12 weeks. The increasing levels of phosphate had no effect on exchangeable potassium and magnesium content of both soils.

INTRODUCTION

Sulphur occurs in soils mainly in organic forms, together with smaller amounts of inorganic sulphur. The mechanism of the mineralization of sulphur in soils is still unknown (Williams, 1967). The uptake of sulphur by plants from the soils is generally in the form of sulphate (Chopra, 1966). Therefore, the availability of sulphur to plants depends to a large extent on the capacity of the soil to supply adequate amounts of soluble sulphate, which also depends on the rate of mineralization of organic sulphur.

A close relationship exists between nitrogen, sulphur and soil organic matter (Tabatakai, *et al.*, 1980; Kowalenka, 1985). Many workers have reported that the addition of calcium carbonate to the soils influences the mineralization of sulphur. This may be due to the increase in the pH, which favours microbial activity (Williams, 1962; Singh, 1984). Further release of sulphur from the soil depends on moisture, temperature and pH (Williams, 1967; Elkins, *et al.*, 1971).

Some workers have reported that soils rich in phosphate are not likely to retain much sulphate in the surface layer (Hue, *et al.*, 1985 ; Ensmingar, 1954; Chao, *et al.*, 1962).

Urea and sulphate of ammonia are the commonly used nitrogenous fertilizers for mature tea in Sri Lanka. However, recently urea is being used as the sole source of nitrogen for mature tea. The high yielding tea fields (>3500 kg made tea ha^{-1} an^{-1}) annually receive 360 kg of nitrogen as urea with 180 kg of K_2O as muriate of potash and 60 kg of P_2O_5 as rock phosphate (27% P_2O_5) or Eppawella apatite (29-33% P_2O_5).

Since urea based fertilizer mixtures do not contain any sulphur, the tea plant has to depend entirely on soil sulphur and atmospheric sulphur. It is possible that high levels of phosphate applied to the high yielding fields, may affect the availability of sulphur to the tea plants. Therefore, a laboratory investigation was undertaken to study the effect of increasing levels of phosphate on sulphur mineralization in jungle and tea soils.

MATERIALS AND METHODS

Soils were sampled with a post-hole augur at 0—15 cm depths from a mature tea field (experiment A14) and from an adjacent jungle area and composite soil samples were obtained from each area. The mature tea field did not receive any NPK fertilizer for the last 3 years but prior to that it was receiving an NPK fertilizer mixture.

The soil in the above two areas belongs to the red-yellow podzolic great soil group and the Mattakele series (de Alwis, Jayasooriya and Perera, 1980).

The air dried soil samples were sieved using a 2 mm mesh and 100 g samples were taken in polythene bags and nitrogen (at 240 kg N ha^{-1} an^{-1} as urea) and potassium (120 kg K_2O ha^{-1} an^{-1} as muriate of potash) were added in solution form, to bring the moisture level to 35% (w/w) field capacity. Rock phosphate (27% P_2O_5) was added at the following rates : 0, 30, 60, 90, 150, 300 kg P_2O_5 ha^{-1} an^{-1} to the soils from each area, mixed thoroughly and incubated at room temperature (22 ± 1°C) in the laboratory. Each phosphate level was replicated thrice.

Prior to the treatments the two types of soil were analysed for total nitrogen (Kjeldhal method), organic carbon (Walkey Black), SO_4-S, phosphorus, potassium, magnesium and pH. Samples were drawn at fortnightly intervals and analysed separately for the following over a period of 12 weeks.

1. Sulphate sulphur was extracted with CH_3COONH_4 (pH 4.8) and S was determined turbidimetically.

2. Borax extractable (pH 1.5) phosphorus was done by phosphomolybdate blue method.

3. IN NH_4Cl extractable (pH .7) potassium and magnesium were done by flame photometer and atomic absorption spectrophotometer respectively.

4. Soil pH was measured at a soil to a solution ratio 1 : 2.5 using glass calomel electrode.

The results were statistically analysed using phosphate levels as main treatments and time (weeks) as sub treatments using split plot design. Both tea and jungle soils were analysed separately.

RESULTS AND DISCUSSION

The analysis of jungle and tea soil showed that tea soil contains more phosphorus, potassium and sulphate sulphur than jungle soil (Table 1). This is mainly because it had been manured with NPK fertilizers for some time.

TABLE 1—*Chemical properties of jungle and tea soils*

Type of soil		*N* (%)	*P* (*mg/kg*)	*K* (*mg/kg*)	*Mg* (*mg/kg*)	SO_4^{--}*-S* (*mg/kg*)	*pH* (*mg/kg*)	*C* (%)
Jungle soil	..	0.33	2.51	78	100	10	4.7	5.4
Tea soil	..	0.31	38.71	148	82	156	4.5	5.2

Ammonium acetate extractable SO_4^{--}-S levels are given in Table 2. The tea soil when compared to the jungle soil, has substantial amount of sulphate sulphur, because it has been manured (prior to the A 14 experiment) for the past 30-40 years with ammonium sulphate. It is evident from Table 2 that the increasing levels of phosphorus (30-300 kg P_2O_5 ha^{-1} an^{-1}) have no significant effect on SO_4^{--}-S release in tea soil. With the jungle soil, phosphate treated soil gave higher values of extractable SO_4^{--}-S at all levels of phosphate. The SO_4^{--}-S content in both jungle and tea soils increased significantly up to 8 weeks except in the control. After 8 weeks both the soils mineralized to a lesser extent than in the initial stage.

TABLE 2—*Effect of increasing levels of phosphate on* SO_4^{--} *-S (mg/kg) content in jungle and tea soil*

Period of incubation (weeks)	*Jungle soil Levels of phosphate*						*Tea soil Levels of phosphate*					
	Po	*P30*	*P60*	*P90*	*P150*	*P300*	*Po*	*P30*	*P60*	*P90*	*P150*	*P300*
2	11	13	14	19	21	19	159	159	164	160	158	162
4	19	25	26	46	31	33	159	166	162	166	159	160
6	25	27	34	36	23	31	166	171	179	164	169	163
8	24	38	53	54	50	50	197	204	161	203	195	188
10	26	49	42	46	62	54	167	146	158	153	158	158
12	23	30	32	30	31	32	158	146	151	144	163	150

Jungle soil		Tea soil	
LSD for main treatments (P = 0.05)	6.29	LSD for main treatments (P = 0.05)	NS
LSD for sub treatments (P = 0.05)	5.37	LSD for sub treatments (P = 0.05)	8.37

In both soils, even after 2 weeks of incubation the borax extractable P content remained high and increased with increasing levels of rock phosphate added (Table 3).

TABLE 3—*Effect of increasing levels of phosphate on borax extractable —P (mg/kg) in jungle and tea soil*

Period of incubation (weeks)	Jungle soil Levels of phosphate						Tea soil Levels of phosphate					
	Po	P30	P60	P90	P150	P300	Po	P30	P60	P90	P150	P300
2	7	23	23	30	32	40	52	75	79	88	85	115
4	1.2	4.9	2.5	4.4	6.3	19.8	49	48	51	61	65	95
6	1.4	3.0	4.6	3.2	7.5	4.5	54	57	73	73	77	93
8	5.6	3.2	6.3	3.5	10.6	23.7	66	69	66	76	77	87
10	2.9	3.7	5.1	6.4	1.5	18.7	67	66	76	83	107	92
12	3.8	2.6	3.1	5.2	7.7	21.3	61	62	70	74	75	90

LSD for main treatment (P = 0.05) 2.71 — LSD for main treatment (P = 0.05) 7.17

LSD for sub treatment (P = 0.05) 2.30 — LSD for sub treatment (P = 0.05) 6.98

In both soils, after 4 weeks the levels of borax extractable phosphate did not vary significantly. Red yellow podzolic soils contain high levels of aluminium and iron and when phosphate is added to the soil it gets gradually fixed in the form of insoluble aluminium and iron phosphate. Many workers (Singhe, 1984, Mattson, 1977, Lichtennwutner *et al.*, 1923) have reported that the absorption of sulphate by soils are influenced by aluminium and iron oxides. Keter *et al.* (1971) reported that among a number of absorbents tested for sulphate absorption, those containing oxides of aluminium and iron and organic colloids showed highest retention and the clay or clayey soil showed the lowest retention of sulphate ions.

Table 4 shows the effect of increasing levels of phosphate on pH with time. The initial jungle soil pH was slightly higher than that of the tea soil. For the past 30—40 years, the tea had been fertilized with sulphate of ammonia as a source of nitrogen and the acidity of the applied ammonium sulphate has decreased the pH. When urea is applied to the soil, it too acidifies the soils ,but to a lesser extent. As a result the pH of both jungle and tea soils has decreased significantly, over a period of twelve weeks. This decrease in pH for the 8 weeks helps to release more SO_4 -S in the soil. This agrees with the work of Elkins and Ensminger (1971) and Korentajar *et al.* (1983).

TABLE 4—*Effect of increasing levels of phosphate on pH in jungle and tea soil*

Period of incubation (weeks)	Jungle soil Levels of phosphate						Tea soil Levels of phosphate					
	Po	P30	P60	P90	P150	P300	Po	P30	P60	P90	P150	P300
2	4.5	4.50	4.50	4.50	4.56	4.50	4.40	4.43	4.36	4.40	4.40	4.40
4	4.48	4.46	4.50	4.56	4.50	4.50	4.20	4.21	4.23	4.21	4.22	4.25
6	4.40	4.36	4.33	4.36	4.40	4.33	4.10	4.10	4.10	4.10	4.16	4.10
8	4.26	4.36	4.30	4.30	4.36	4.40	4.00	4.10	4.10	4.13	4.20	4.20
10	4.40	4.33	4.30	4.30	4.36	4.40	4.13	4.16	4.10	4.20	4.20	4.20
12	4.30	4.26	4.25	4.26	4.26	4.28	4.05	4.08	4.08	4.10	4.13	4.10

LSD for main treatment (P = 0.05) NS — LSD for main treatment (P = 0.05) 0.030

LSD for sub treatment (P = 0.05) 0.031 — LSD for sub treatment (P = 0.05) 0.024

Exchangeable potassium and magnesium of the soil are given in Tables 5 and 6 respectively. A decrease in pH will decrease the CEC of soil. As the soil used was a kaolinitic soil, with a large pH dependant charge, the lowering of pH will lower the negative charge of the clay colloidal complex, thereby releasing some of the cations mainly divalent Mg into the soil solution (Table 6). After 8 weeks the Mg release was significantly lower. Up to 8 weeks the mineralized SO_4 ions would have formed soluble $MgSO_4$.

TABLE 5—*Effect of increasing levels of phosphate on K content (mg/kg) in jungle and tea soil*

Period of incubation (weeks)	*Jungle soil Levels of phosphate*						*Tea soil Levels of phosphate*					
	Po	*P30*	*P60*	*P90*	*P150*	*P300*	*Po*	*P30*	*P60*	*P90*	*P150*	*P300*
2	137	139	136	141	141	139	197	210	209	213	213	203
4	137	145	143	126	137	135	220	194	210	208	209	208
6	146	138	146	124	129	137	217	213	200	186	224	187
8	136	131	139	120	136	135	210	213	199	201	199	207
10	144	139	137	149	142	139	206	197	190	193	200	208
12	136	135	138	142	149	145	206	197	161	219	215	185

Jungle soil		Tea soil	
LSD for main treatment (P = 0.05)	NS	LSD for main treatment (P = 0.05)	NS
LSD for sub treatment (P = 0.05)	5.67	LSD for sub treatment (P = 0.05)	NS

TABLE 6—*Effect of increasing levels of phosphate on Mg content (mg/kg) in jungle and tea soil*

Period of incubation (weeks)	*Jungle soil Levels of phosphate*						*Tea soil Levels of phosphate*					
	Po	*P30*	*P60*	*P90*	*P150*	*P300*	*Po*	*P30*	*P60*	*P90*	*P150*	*P300*
2	109	109	108	107	106	102	85	86	75	71	84	76
4	135	143	123	141	143	142	115	101	100	96	115	117
6	136	140	131	141	136	137	114	142	105	116	146	109
8	125	120	129	118	129	121	96	96	99	89	91	105
10	127	124	118	124	121	121	97	90	82	95	85	67
12	121	124	134	131	136	115	93	107	95	100	99	93

Jungle soil		Tea soil	
LSD for main treatment (P = 0.05)	NS	LSD for main treatment (P = 0.05)	NS
LSD for sub treatment (P = 0.05)	5.67	LSD for sub treatment (P = 0.05)	11.90

The above findings show that the use of high levels of phosphate in high yielding tea will not have any depressing effect on sulphur availability to the tea plant.

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