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Impact of rubber effluent on some chemical properties of an ultisol and early growth of maize (*Zea mays L.*)

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ABSTRACT: A preliminary pot trial was conducted in a greenhouse to determine the influence of rubber effluent on some chemical properties of an Ultisol and growth and nutrient uptake of maize (*Zea mays* L). Results of chemical analysis of the effluent indicated that it contains N, P, K, Ca, Mg, Fe, Mn and Zn. It was observed that the effluent was pungent in odour and colourless. At the end of the trial, soil pH, N, Ca, Mg, K, Na, Fe, Mn, ECEC as well as exchangeable acidity were raised compared to the control. The P and %C were, however, reduced. The N and P content of maize increased with increased effluent concentration up to 0.12% while the cations as well as trace elements in maize were not consistent in the trial. The N, P, Ca, K, Mn and Zn uptake were higher at 0.12% effluent concentration while Mg uptake was higher at 0.20% effluent concentration. Fe uptake was higher at 0.08% concentration. There was no significant difference among treatments in germination studies. All the treatments were not significantly different from one another in all the growth parameters two weeks after sowing. At final harvest, plant height, stem girth, leaf area and number of leaves obtained from pots amended with 0.12% effluent concentration was significantly better than those from other treatments.

Key Words: Rubber effluent, concentration, maize, nutrient uptake, soil.

Introduction

Rubber is important because its latex is a valuable source of raw materials for numerous items such as shoes, tyres, tubes, foam mattresses, and electrical appliances. In addition to being one of the major economic crops in Nigeria it also strengthens the forest cover thereby contributing towards continuity of environmental balance. The latex of rubber plant consists of colloidal suspension of rubber particles in an aqueous serum. Thus, natural rubber is an amorphous hydrocarbon poly-isoprene, which has the property of being highly extensible. The latex also contains many non-rubber constituents such as protein, resins, sugars, glycosides, tannin, alkaloids and mineral salts (Onwueme and Sinha, 1999).

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The serum phase of the latex according to Seneviratne (1997) is known to constitute 70% of the total volume and contains large amounts of major nutrients required for plant growth He reported further that rubber effluent mostly contains an approximate percentage non-rubber constituents such as carbohydrate (methyl inositol (2.5%)) protein (1%) free amino acid (0.018%) and other organo nitrogenous bases (chlorine, methyl amine 0.08%), inorganic anion ($P0_4^{3-}$, $C0_3^{2-}$) and metallic ions (K^+, Mg^{2+}, Na^+, Cu^{2+}) and formic acid (0.12%) used for latex coagulation.

The processing of the latex impacts on the environment to varying degrees. The most suspected noticeable effect is caused by factory effluent, which contains a large amount of non-rubber substances in addition to traces of various processing chemicals. The amount of rubber effluent produced in Nigeria has been increasing steadily during the past few years with increase in the number of several processing factories in the country.

The practice of indiscriminate discharge of large volumes of these effluents onto soil and watercourses as a means of disposal is wasteful in terms of resource utilization and contradicts the present day agricultural technical development. Also, the abundance of the effluent and the suspected adverse effects on the environment due to the offensive odour pose a challenge to agronomist to seek valuable and positive uses for it.

The controlled applications of rubber effluent on land have been reported to cause changes in soil as well as growth of some plants.. Yeow and Zin (1981) observed improved water retention of soil when rubber effluent was used. Poon (1982), Lim and P'ng (1983), Lim *et al.* (1983) reported an increased pH, K, Ca, Mg and organic matter content when rubber effluent was applied. Seneviratue (1997) also observed an increase in soil N, P, K, Na, Mg and Ca in an estate, which had been exposed to rubber effluent for 20 years while a reduced organic carbon and Mg was reported for rubber effluent affected soil (Orhue *et al* 2005). Seneviratne(1997) while citing Yapa (1980) reported that with exception of few places, the pH of with rubber effluent affected soil was found to be higher than that of unaffected soil. Yeow and Yeop (1983) described rubber effluent as excellent soil conditioner.

Effluents have also been reported to have varying effect on plants. For example, the application of block rubber effluent was reported to increase oil palm yield and there was no adverse effects on growth and nutritional status (Lim *et al.* 1983). The growth of Nappier grass (Tan *et al*. 1975) and *Dialium guineense* seedlings (Orhue *et al.* 2005) were enhanced significantly with rubber effluent. Orhue *et al* (2005) reported increased uptake of N, P, Mg, Na as well as decreased K uptake by *Dialium* seedlings with the

application of rubber effluent. This examined the influence of rubber effluent on some chemical characteristics of an Ultisol as well as the growth of maize (*Zea mays* L.).

Materials And Methods

The trial was conducted in a greenhouse at the experimental site of the Faculty of Agriculture, University of Benin, Benin City, Nigeria. The robber effluent was obtained from Odia rubber factory while suwan 1 maize variety was obtained from Agricultural Development Project (ADP) both in Benin City. The top soil used was collected from the floor of *Gmelina arborea* plantation at a depth of 0-15cm. The soil was bulked, mixed thoroughly and a composite sample collected, air-dried and then sieved to remove debris. Thereafter, 2Kg of the composite soil was weighed into polythene bags.

The total number of polythene bags used was 108. Each polythene bag was filled with 2Kg soil and then labeled for the various treatments. The experiment was organized in a Completely Randomized Design (CRD) with 3 replicates. Each replicate had 36 bags with 6 bags per treatment. The rubber effluent was applied volume/weight (v/w) at the rates of 0, 50, 100,150,200 and 250ml/2Kg soil equivalent to 0, 50,000, 100,000, 150,000, 200,000 and 250,000litres/ha or 0, 0.04, 0.08, 0.12, 0.16 and 0.20% concentration respectively. The rubber effluent was thoroughly mixed with the soil and then left for 2 weeks to allow for mineralization. The day before sowing, the soil was moistened to 70% field capacity with deionized water. Four seeds of maize were initially sowed and later thinned to one seedling per pot 2 weeks after emergence. Thereafter, the plants were watered every other day with deionized water. Data collection on plant height, stem girth, number of leaves and leaf area were carried out at 14 days interval starting from 2 weeks after emergence till 8 weeks when the plants were harvested and dried in ventilated oven at 72^{o}C for 48 hours to a constant dry weight to determine the N, P, .K, Ca, Mg, Al, Fe, Mn and Zn nutrient uptake using the method of Pal (1991).

Prior to commencement of the trial, a germination test was carried out in petri dishes kept moist by a layer of cotton wool and a coarse filter paper (Whatman No 15). 30-seeds/petri dishes of maize seeds were used. Three replicates were maintained for the maize and for each effluent rate at 0, 50, 100, 200 and 250ml. A portion (15ml) of each effluent was added to the petri plate on alternate days. The control received the same amount of distilled water. The germination percentage was calculated 5 days after germination.

Soil analysis was carried out before and after harvesting of maize plant. The rubber effluent was analysed before application to the soil while the plant analysis was done at the end of the experiment. Particle size analysis was determined by hydrometer method of Bougoucos (1951) while the soil pH was determined at a soil to water ratio of 1:1 using a glass electrode pH meter. The pH of the rubber effluent was read directly from the pH meter. The electrical conductivity of soil was determined also at a soil to water ratio of 1:1 using the CIBA-CORNING conductivity meter as described by Ademoroti (1996) whereas the rubber effluent conductivity was read directly from the CIBA-CORNING meter. The organic carbon content of both soil and rubber effluent was determined by using the chromic acid wet oxidation procedure as described by Jackson (1962). The total nitrogen, available phosphorus, exchangeable bases as well as exchangeable acidity were determined using methods of Jackson (1962), Bray and Kurtz (1945), Black (1965) and Mclean (1965) respectively. The effective cation exchange capacity was calculated as the sum of exchangeable bases and exchangeable acidity. The aluminum, iron, manganese were determined by methods described by Chanery (1955), Mehra and Jackson (1960) and Bradfield (1957) respectively.

Results

Properties of Rubber Effluent

The physico-chemical properties of rubber effluent (Table 1) indicated that the effluent was slightly acidic, colourless and contained several elements.

Table1: Analysis of the Rubber effluent used in the Experiment

Effluent property	value
pH	5.00
Conductivity (Scm-1)	58.00
Total Nitrogen (%)	2.10
Phosphorus (ppm)	5.26
Organic carbon (%)	0.14
Potassium (mg/L)	12.25
Calcium (mg/L)	8.82
Sodium (mg/L)	1.54
Magnesium (mg/L)	2.92
Iron (mg/L)	0.04
Manganese (mg/L)	0.02
Zinc (mg/L)	0.91

Properties of soil before and after harvesting

The properties of soil used in the trial are shown in Table 2. The soil is moderately acidic. It is classified as Ultisol, Dystric Nitosol, Benin fasc, grey in colour and texturally sandy (Enwezor, 1990).

Table 2: Physico - Chemical analysis of amended and unamended soil used in experiment after harvesting

Soil Property	**Before amendment**	**After amendment (% concentration)**						**After Harvesting (% concentration)**					
		0.0	**0.04**	**0.08**	**0.12**	**0.16**	**0.20**	**0.0**	**0.04**	**0.08**	**0.12**	**0.16**	**0.20**
PH(1:1H,O)	5.10	5.21	5.26	5.35	5.27	5.22	5.47	5.25	6.46	6.50	6.56	6.60	6.70
Carbon (%)	1.32	1.32	1.13	1.14	1.11	1.18	1.15	1.14	1.14	1.14	1.13	1.16	1.15
Nitrogen (%)	0.05	0.05	0.81	0.80	0.77	0.81	0.79	1.04	0.86	0.84	0.88	0.82	0.89
P (ppm)	4.71	4.73	4.37	4.06	4.08	4.09	4.30	1.91	1.48	1.50	1.85	1.84	1.56
K(Cmolkg'¹)	0.04	0.05	1.95	1.97	1.89	1.87	1.88	2.04	2.10	2.18	1.94	2.10	2.03
Ca($Cmolkg^{-1}$)	0.01	0.01	1.21	1.41	1.21	1.61	1.41	2.01	7.21	6.41	6.41	5.61	6.41
Mg($Cmolkg^{-1}$)	1.39	1.38	2.37	2.91	3.40	2.91	2.43	2.31	5.86	4.84	4.37	4.84	4.37
Na ($Cmolkg^{-1}$)	0.08	0.08	1.05	1.10	1.06	1.02	0.99	1.45	1.09	1.09	1.07	1.05	1.01
Exch Acidity ($Cmolkg^{-1}$)	0.08	0.09	2.20	2.00	2.00	2.40	2.20	2.40	2.40	2.60	2.60	2.40	2.40
ECEC ($Cmolkg^{-1}$)	1.60	1.61	8.78	9.39	9.56	9.81	8.91	10.21	18.66	17.12	16.39	16.00	16.22
Fe☹ ppm)	0.01	0.03	0.81	0.91	0.99	0.72	0.80	1.21	0.84	0.97	0.92	0.79	0.82
Mn (ppm)	0.05	0.05	0.39	0.34	0.40	0.36	0.41	0.30	0.30	0.31	0.31	0.30	0.30
Zn (ppm)	0.098	0.097	0.087	1.042	0.091	0.099	0.098	0.096	1.02	0.98	0.99	0.98	0.90
Sand(g $kg-^{1}$)	740	741	742	773.30	735.10	755.00	743.30	755.00	748.00	762.00	742.50	752.00	737.00
Silt($gkg-^{1}$)	140	154	143	142.80	182.70	153.70	173.70	141.00	150.50	135.00	152.00	143.00	173.00
Clay(g $kg-^{1}$)	120	105	105	83.90	82.20	91.30	83.00	104.00	101.50	103.00	105.50	105.00	90.00
Soil Texture	SL	SL	SL	SL	SL	SL	SL	SL	SL	SL	SL	SL	SL

SL=Sandy loam

Table 3: Effect of rubber effluent on the nutrient content of maize plant in experiment

	TREATMENTS (%CONCENTRATION)					
CHARACTERISTICS	**0.0**	**0.04**	**0.08**	**0.12**	**0.16**	**0.20**
Nitrogen (%)	1.63^{c}	2.20^{a}	2.27^{a}	2.27^{a}	2.06^{b}	1.88^{c}
Phosphorus (%)	0.07^{a}	0.08^{a}	0.09^{a}	0.09^{a}	0.08^{a}	0.08^{a}
Calcium (%)	0.05^{c}	0.08^{b}	0.07^{b}	0.10^{a}	0.1 l^{a}	0.07^{b}
Magnesium (%)	0.1 94^{b}	0.25 l^{b}	0.139^{C}	0.044^{d}	0.1 02^{C}	0.625^{a}
Potassium (%)	1.404^{c}	1.269^{d}	1.620^{a}	1.566^{c}	1.701^{a}	1.539^{C}
Aluminum (mgkg^{-1})	150^{b}	147^{b}	134 ^{c}	126^{c}	125^{c}	206^{a}
Iron (mgkg^{-1})	69^{b}	68^{b}	66^{b}	54^{c}	56^{c}	72^{a}
Manganese (mgkg^{-1})	53^{a}	54^{a}	53^{a}	52^{a}	51^{a}	55^{a}
Zinc . (mgkg^{-1})	42^{a}	43^{a}	42^{a}	42^{a}	41^{a}	44^{a}

Values followed by the same letter within a row are not significantly different P$\leq$ 0.

Table 4: Nutrient uptake (mg) by maize plant at various treatments with rubber effluent in experiment

		TREATMENTS (%CONCENTRATION)					
CHARACTERISTICS		0.0	0.04	0.08	0.12	0.16	0.20
Nitrogen		263.73[c]	377.20[c]	473.29[b]	596.55[a]	439.19[b]	409.08[b]
Phosphorus		11.98[c]	13.19[c]	16.47[b]	23.91[a]	18.57[c]	18.96[b]
Calcium		9.06[d]	14.74[c]	15.01[c]	27.33[a]	23.91[b]	15.69[c]
Magnesium		31.40[c]	43.02l[b]	28.98[c]	11.56[c]	21.77[d]	136.25[a]
Potassium	mg/g	227.30[c]	217.50[c]	337.77[b]	408.91[a]	363.16[b]	335.5[b]
Aluminum		0.24[c]	0.25[c]	0.27[c]	0.33[b]	0.26[c]	0.44[a]
Iron		0.11[a]	0.11[a]	0.18[a]	0.14[a]	0.11[a]	0.15[a]
Manganese		0.08[a]	0.09[a]	0.11[a]	0.13[a]	0.10[a]	0.12[a]
Zinc		0.06[a]	0.07[a]	0.08[a]	0.11[a]	0.08[a]	0.09[a]

Values followed by the same letter within a row are not significantly different ($P \leq 0.05$)

The results of the analysis (Table 2) showed that soil pH increased with increase in the application of rubber effluent. The soil pH was raised from 5.10 to 6.70 at 0.20% effluent concentration. The percentage carbon declined from 1.32% to a mean of between 1.13 and 1.16% in 0.12% and 0.16% effluent concentration treatments respectively. The total nitrogen increased from 0.05% to a mean of between 0.82% and 1.04% whereas the available phosphorus decreased from 4.71ppm to a mean of between 1.48 and 1.91ppm in 0.04% effluent concentration and control respectively. The exchangeable cation also increased after harvesting. The monovalent cations such as K and Na increased from 0.04Cmolkg^{-1} and 0.08Cmolkg^{-1}in control to a value of between 1.94 and 2.18Cmolkg^{-1} and 1.05 and 1.45Cmolkg^{-1} in 0,12%, 0.08%, 0.16% and control respectively. The divalent cations Ca and Mg were raised from 0.14Cmolkg^{-1} and 1.39Cmolkg^{-1} in control to a mean value of 2.01 and 7.21Cmolkg^{-1} and 2.31 and 5.86 Cmolkg^{-1} respectively. The effective cation exchange capacity also increased to a mean value of between 10.21 and 18.66Cmolkg^{-1} though not consistent while that of exchangeable acidity was raised from 0.08Cmolkg^{-1} to a mean of between 2.40 and 2.60Cmolkg^{-1}. The trace elements, iron, zinc and manganese increased from 0.01ppm, 0.09ppm, 0.05ppm to mean values of between 0.79 and 1.21ppm, 0.96 and 1.02ppm, 0.03 and 0.31ppm respectively. The soil texture was not influenced by various levels of rubber effluent treatments at harvesting.

Nutrient content of maize plant

The N content of maize plants treated with 0.04%, 0.08% and 0.12% effluent concentration were not significantly different from one another but better than control, 0.16% and 0.20% effluent treatment (Table 3). In the case of P all the treatments including control were not significantly different from one another but the highest values were recorded at 0.08% and 0.12% effluent treatments whereas for Ca content, 0.12% and 0.16% treatments were not significantly different from each other but better than other treatments including control. At 0.20% effluent treatment, Mg, Al and Fe contents were significantly better than other treatments while in the K content, 0.08% and 0.16% effluent treatments did not differ significantly from each other but better than other treatments. For Mn and Zn contents there were no significant differences among the various treatments.

Nutrient uptake by maize plant

Nitrogen, phosphorus and calcium uptake increased from 0.0% up to 0.12% concentrations and then decreased as from 0.16% concentration treatment (Table 4). The potassium uptake was highest in 0.12% concentration compared to control as well as other treatments. The magnesium uptake increased up to 0.04% concentration, declined from 0.08% to 0.16% concentration, then increased in 0.20% concentration. The aluminum uptake increased from control to 0.12% concentration and then decreased at 0.16% concentration. The iron uptake was similar in control and 0.12% concentration and was raised at 0.08% concentration and then declined at 0.12% concentration up to 0.16% concentration and was raised again at 0.20% concentration. The manganese and zinc uptake increased with increase in application of rubber effluent up to 0.12% concentration, declined at 0.16% concentration and then rose again at 0.20% concentration. However, treatment 0.12% was significantly better than other treatments in nitrogen, phosphorous, calcium and potassium uptake while treatment 0.20% was significantly better than other treatments in aluminum and magnesium uptake. The uptake of iron, manganese and zinc was not affected by the effluent treatments. .

Germination percentage study

Percentage germination of maize in the various treatments was not significantly different from one another. Germination was > 98% in all cases.

Vegetative growth

The plant height, number of leaves, leaf area and collar girth are shown in Figures 1, 2, 3 and 4 respectively. At 2 weeks after sowing (2WAS), the plant height, number of leaves, leaf area and collar girth did not differ significantly among treatments. Plant grown in an effluent concentration of 0.12% were significantly taller than those in other treatments at 4, 6 and 8 WAS (Fig 1). At 4 WAS, the number of leaves (Fig 2) was similar in all effluent treatments but at 6 and 8 WAS plants under 0.12% effluent concentration had significantly more leaves. At 8 WAS, all effluent treated plants had more leaves. The 0.12% effluent concentration produced a significantly larger leaf area (Fig 3) at 4 and 8 WAS. From 4 WAS, the effluent concentration of 0.16% and 0.20% produced a similar leaf area, which was better than the control, 0.04% and 0.08% concentration treatments. The 0.08% treatment was significantly better than control and 0.04% at 4, 6 and 8 WAS. The largest collar girth (Fig 4) at 8 WAS occurred in the effluent concentration of 0.12%. Plants treated with concentration of 0.16% and 0.20% had similar girths which were lager than those treated with 0.04% and 0.08% effluent concentration including the control. The applied 0.04% and 0.08% concentration were significantly better than the control.

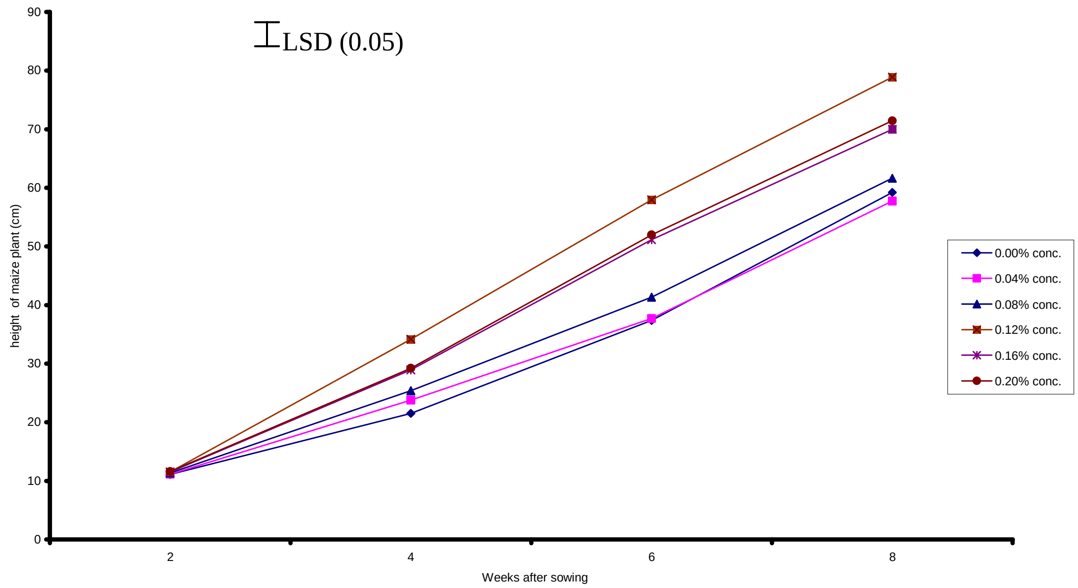

Fig 1:Effect of rubber effluent on plant height of maize plant

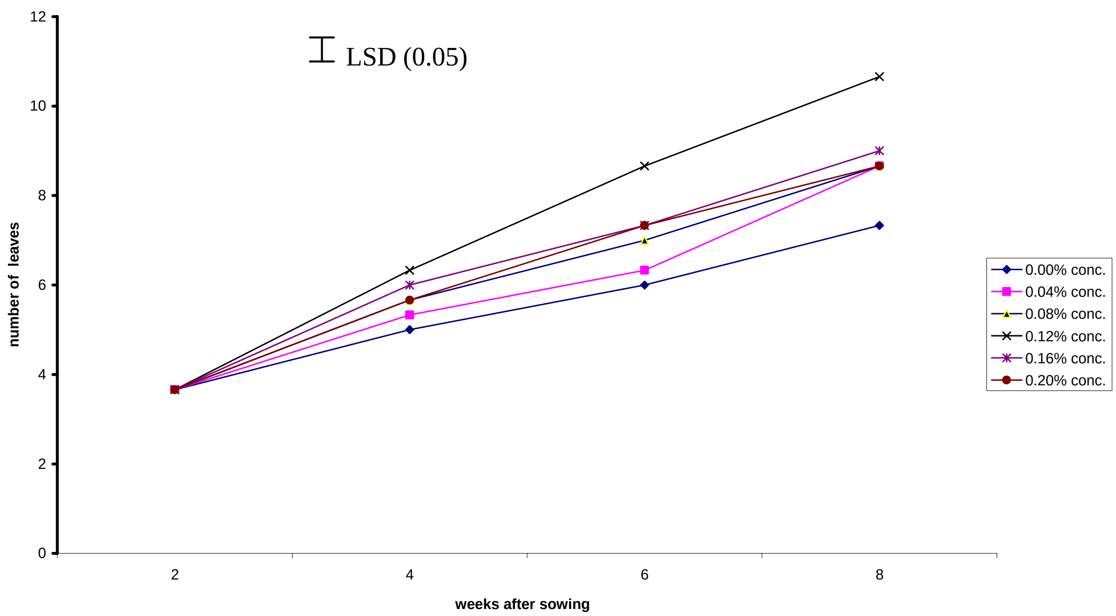

Fig 2: Effect of rubber effluent on number of leaves of maize plant

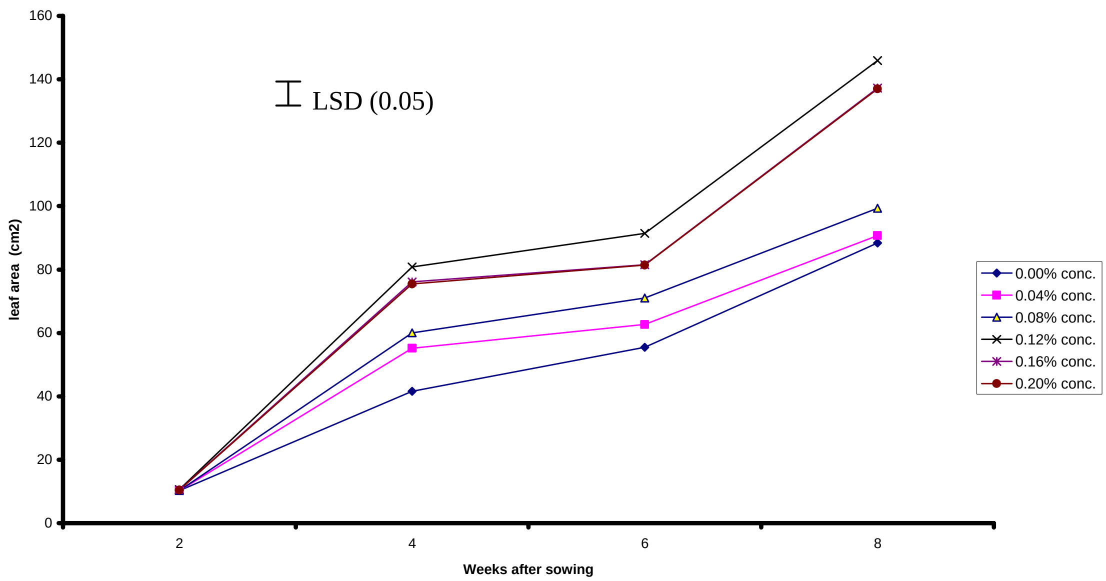

Fig 3: Effect of rubber effluent on leaf area (cm2) of maize plan

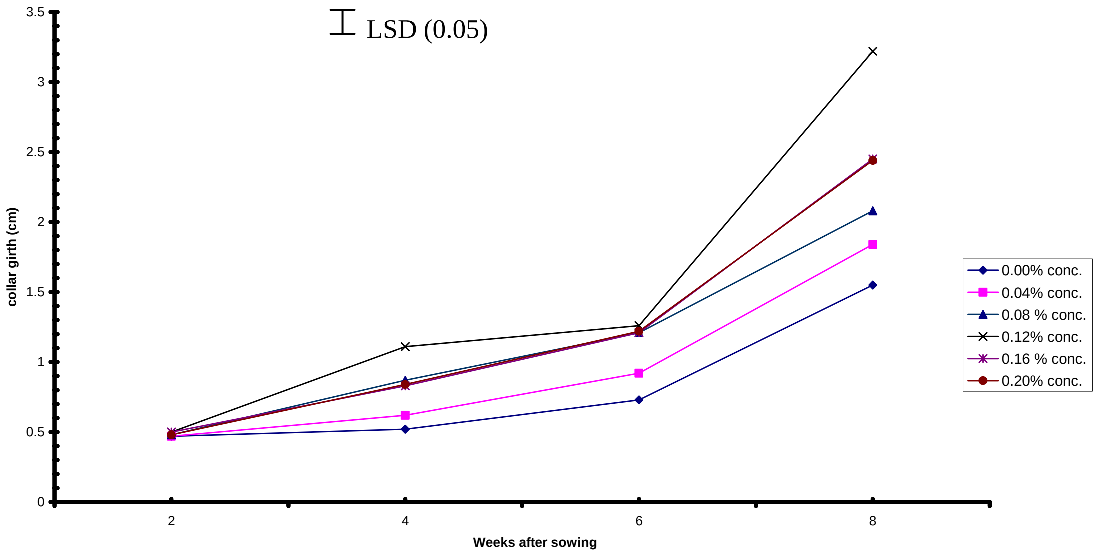

Fig 4: Effect of rubber effluent on the collar girth (cm) of maize plant

Discussion

The result of the effluent analysis (Table 1) when compared to that of Seneviratne (1997) indicated that most of the parameters were dependent on the source of the effluent. The fact is that at any stage of processing (creep, crumb and concentrate latex) the effluents contain some basic plant nutrients. The properties of the soil used (Table 2) indicated that the soil was low in fertility, which is typical of an Ultisol (Agboola and Ogunkunle 1993).

The increase in soil pH, N, K Ca, Mg and Na (Table 2) are similar to the report of Poon (1982), Lim and P'ng (1983) and Lim *et al.* (1983). These increases were attributed to the nutrient properties (serum) of the effluent. This further confirms that applying effluent alone is not problematic especially when the rate of application is geared to supplying nutrients at levels corresponding to those in inorganic fertilizers normally applied to promote satisfactory crop performance and that controlled application of effluent causes no detrimental changes in soil. Rather it improves soil fertility with no apparent adverse effect on the environment. The beneficial properties of rubber effluent as an excellent "soil conditioner" imply that it is a good source of fertilizer. The reduction in soil carbon is, however, contrary to the finding of Lim *et al.* (1983) and Seneviratne (1997). Although, there were no definite patterns or trend in availability of exchangeable acidity, ECEC, Fe, Mn and Zn, there were slight increases compared with the control. The soil texture was not influenced or changed by the effluent.

The increase in the nutrient contents of maize plants except N and P in this trial was not consistent. This may be attributed to nutrient uptake ability of maize, soil nutrient interaction implying that the effluent should be applied at rates corresponding to crop nutrient requirements. There is generally a relationship between some of the major elements especially N, P K and Mg in terms of nutrient uptake. The supply of one element can increase, decrease or maintain their ratios in dry matter in the leaves (Remison, 1997).

Such effects are described as antagonistic when the leaf nutrient element is reduced by the application of another nutrient element and synergetic when availability of one nutrient element influences the availability of another. These effects influenced nutrient uptake and subsequent content in plant. The increase in N, P, K, Ca, Al and Mn uptake up to 0.12% concentration showed that the effluent should be applied at this rate. The uptake of other nutrient such as Mg, Na, Zn, and Fe were, however, not consistent. This variation in nutrient uptake might have been influenced by certain factors such as temperature, aeration, plant age, concentration of competing ions as well as nutrient interaction in the soil. All these are known to have differential effects on nutrient uptake rate and subsequent different nutrient composition (O'Conner and Anderson, 1974), (Clinton and William, 1981) and Drewes and Blum, 1997). Loos *et al.* (1979) asserted that reduced nutrient uptake in the presence of effluent could occur due to strong adsorption or degradation in the soil and that the extent of adsorption or degradation does not only depend on the properties of the effluent but also on the properties of the sites, soil types, kind of soil organisms and climatic conditions.

The absence of any effects on germination showed that rubber effluent chosen concentrations were not toxic to maize seeds. This finding is, however, contrary to the reports of Neeta and Sahai (1987) with distillery effluent and that of Bahara *et.al* (1995) with chloro-alkali industrial effluent. The increase in plant height, leaf area, collar girth and number of leaves up to 0.12% effluent concentration was attributed to the presence of rubber serum. The serum phase of the latex is known to constitute 70% of the total volume and contains large numbers of micro and major nutrients needed for plant growth (Seneviratne, 1997). Several workers namely Sahai *et al.* (1979), Singh *et al.* (1980), Sisoda and Bedi (1985), Sahai and Srivastava (1986) and Srivastava and Mathur (1987) have reported retardation in most vegetative growth of plant at higher concentration by different industrial effluent as confirmed our data.

Conclusion

The physiological and nutritional implications of rubber effluent on maize as well as soil chemical properties were studied. Rubber effluent from analysis contained vital plant nutrients which may be favourable to soil fertility improvement and maize growth at application rates of from control up to 0.12%. Therefore, it could be concluded that rubber effluent has a potential value as a fertilizer for maize. However, more trials need to be carried out in both the greenhouse and field over a wide range of time and soil to confirm this potential.

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