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Full Length Research Paper

Effects of rubber effluent, urea and rock phosphate on soil properties and rubber seedlings in an acid sandy soil

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A field experiment was conducted to compare the effect of rubber effluent and urea/rock phosphate on the growth of rubber seedlings and soil chemical properties in an ultisol. A randomized complete block design was adopted with three treatment replicated three times. T_1 received no soil amendment and served as the control, T_2 received 5, 3330 L/ha of rubber factory effluent while T_3 received 30 kg/ha P_2O_5 as rock phosphate and 112 kg N/ha as urea. Pre-cropping soil analysis showed that the area was loamy sand characterised by low pH, low ECEC and low water holding capacity. There were no significant differences in the height, leaf area, leaf number and girth of the seedlings among the treatments at early growth stage, at a later stage of growth, seedlings treated with rubber effluent performed as well as those treated with inorganic fertilizers. The highest mean value was recorded in seedlings treated with urea/rock phosphate which had mean values of 19.13 and 0.77 cm for height and girth respectively. The use rubber effluent should be encouraged, since the general performance of the seedlings treated with rubber effluent is as good as that of inorganic fertilizer.

Key words: Rubber effluent, inorganic fertilizer, rubber nursery, soil properties.

INTRODUCTION

An important basis for increase in rubber (*Hevea brasiliensis* [Muell. Arg.]) latex production lies in the development and distribution of planting materials (seedlings) that are disease free, early maturing and vigorous that could ensure high field survival rate. This can only be achieved through proper soil fertility management in the nursery where these seedlings are produced. Rubber nurseries in the past were raised mostly in newly cleared forests which are quite rich in plant nutrients but over time the situation has changed, new forests became unavailable and rubber had to be raised on denuded and less fertile crop lands.

In Nigeria most soils in the rubber growing areas are predominantly sandy to sandy-loams textured in the surface layer and are therefore susceptible to leaching, erosion and nutrient losses. Soil fertility management of rubber at the nursery stage is critical to the budding success and subsequent field establishment of rubber seedlings. The soils of the rubber belt of Nigeria with few exceptions have sub-optimal nutrient status. Low available phosphorous (P) had been reported (Uzu, 1973). Nitrogen content is also low as a result of excessive leaching and high rates of organic matter mineralization. The available potassium (K) content is invariably low except in some soils North of Calabar (Onuwaje and Uzu, 1982), hence, the need for soil amendments. The principal method of overcoming the problems posed by inadequate nutrient in the soil is the judicious use of fertilizers to enhance the growth and development of rubber. However, some problems of fertilizer use in Nigeria include in-adequate production of chemical fertilizers, non- availability of fertilizers to farmers at the time of need due to poor distribution network and the prohibitive cost which is beyond the reach of average small-holder rubber farmers (Lal and Kang, 1982; Ugwa et al., 2002). This necessitates the need for alternative sources of nutrients that are readily

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Table 1. Some the pre-cropping physico-chemical properties of the soil used for the experiment.

Soil properties	Soil test values
Sand (g kg^{-1})	880.4
Silt (g kg^{-1})	19.6
Clay (g kg^{-1})	100.0
Tex. (US)	LS
pH (H_20)	5.7
Organic. C (g kg^{-1})	13.8
Total N (g kg^{-1})	03.3
Availble P (mg/kg)	8.03
Exch Ca (cmol/kg)	1.15
Exch Mg (cmol/kg)	0.85
Exch Na (cmol/kg)	0.1
Exch K (cmol/kg)	0.18
Exc. acidity (cmol/kg)	2.6
ECEC (cmol/kg)	4.88
Base sat. (%)	46.72
Extc. Mn (mg/kg)	121.08
Extc. Fe (mg/kg)	70.25
Extc. Cu (mg/kg)	6.96
Extc. Zn (mg/kg)	17.32
Bulk density (g cm^{-3})	1.6

available, relatively cheap, and environmentally friendly such as rubber effluent.

Rubber effluent is considered as a waste from rubber processing and needs labour and money for disposal. Their use as soil amendments therefore will go a long way in the reduction of the cost of raising rubber seedlings while solving the problem of disposal for rubber processing factories. This study therefore was conducted to determine the effect of rubber effluent and urea/rock phosphate on some physico-chemical properties an acid soil and the growth and development of rubber seedlings in the high rainforest zone of South-Western Nigeria.

MATERIALS AND METHODS

This study was conducted in 2007/2008 cropping season at Rubber Research Institute of Nigeria Iyanomo near Benin City Edo State. The study area falls between latitude 6°00¹ and 7°00¹ North and longitude 5°00¹ and 6°00¹ East of the equator. The rainfall pattern is bimodal with the peaks in the month of July and September but the highest in July and a short dry spell in August. The soils of this humid forest belt are mainly ultisols with pH range between 4.0 and 5.5, the soil have been described as the acid sands derived from unconsolidated grits and sand stones containing clay peds of varying proportions (Vine, 1956).

A randomized complete block design (RCBD) was adopted with three treatments in three replicates. Each plot measured 1.5 x 1 m with 1 m furrows in between the plots. The treatments include: control (T_1), rubber effluent (T_2) and urea/rock phosphate (T_3). T_1 received no soil amendment, T_2 received 5,333.6 L/ha of rubber effluent while T_3 received 30 kg P_2O_5 as rock phosphate and 112 kg N/ha as urea. The rates of application were based on the concentration of nutrient in the soil and the soil amendments were applied at the rates recommended by previous studies (Onuwaje and Uzu, 1982; Ugwa et al., 2005). Pre- germinated rubber seedlings (NIG 800 series) were transplanted at a spacing of 30 x 30 cm in the beds a week after treatment application. Soil sampling was carried out before, three, and six months after the application of the soil treatments. Data on growth parameters such as stem girth, plant height, number of leaves and leaf area of the rubber seedlings were taken at monthly intervals.

The soil samples were analysed using standard laboratory procedures. Soil pH was determined at 1:1 soil to water ratio using glass electrode digital pH meter. Organic carbon was determined by chromic acid wet oxidation procedure as described by Jackson (1962). Available P was extracted using Bray-1 solution (Bray and Kurtz, 1945) and the phosphate in the extract was analysed colourimetrically by the molybdenum blue colour method as described by Murphy and Riley (1962). Exchangeable bases were extracted using 1 N neutral ammonium acetate solution. Ca and Mg content of the solution were determined volumetrically by EDTA titration while K and Na were determined by flame photometry. The total Nitrogen of the soil was determined by Micro- Kjedhal procedure as described by Jackson (1962) and the exchangeable acidity was determined by the KCl extraction and titration method of Mclean (1965).

RESULTS

Pre-cropping properties of the soil and rubber effluent used for the study

Some of the physico-chemical properties of the soil before the commencement of the experiment are as shown in Table 1. The soil was loamy sand in texture with

Table 2. Analysis of rubber effluent used in the experiment.

pH	5.00
Nitrogen (%)	2.10
Phosphorous (mg/L)	5.26
Organic C. (%)	0.14
Potassium (mg/)	12.25
Calcium (mg/l)	8.82
Sodium (mg/l)	1.54
Magnesium (mg/l)	2.29
Iron (mg/l)	0.04
Manganese (mg/l)	0.02
Zinc (mg/l)	0.91

moderate compaction. The soil is acidic with pH value of 5.7 with low base saturation and contained reasonable amount of organic carbon, total nitrogen and available phosphorous. Exchangeable cations were generally low with Ca (1.15 cmol kg^{-1}) being the highest. The exchangeable acidity is somewhat high and effective cation exchangeable capacity was lower than the critical value of 5 cmol kg^{-1} required by rubber (Watson, 1989). Extractable micro nutrients are somewhat high especially Mn and Fe which are 121.08 and 70.25 mg kg^{-1} respectively. The elemental contents of the rubber effluent (Table 2) showed that it is also acidic pH of 5.00, low in available P and micronutrients but, relatively higher in N and K.

Physico-chemical properties of the soil at three months after soil amendment

Table 3 shows the effect of the soil amendments on some soil chemical properties three month after application. There was general decrease in soil pH after application of the soil amendments in all the treatments from 5.7 in the pre-cropping to the mean of 4.88 in the plots treated with urea/rock phosphate and 4.75 in the plot treated with rubber effluent. Also there was slight decrease in the control plots from 5.7 to 5.22. Base saturation increased tremendously for all the treatments from 4.672% in the pre-cropping to a mean of 9.365, 8.813 and 8.374% for control, urea/rock phosphate and rubber effluent treatments respectively. The total Nitrogen shows an increase in their mean value except for the control. Whereas the available phosphorous decrease from 8.03 mg kg^{-1} in the pre-cropping to 7.5 mg kg^{-1} in the control plot, while the plots treated with urea/rock phosphate and rubber effluent rose to the mean values of 8.90 and 25.8 mg/kg respectively. The monovalent cation such as potassium (K) and sodium (Na) did not show significant difference among the treatments ($P \leq 0.05$). The divalent cations (Ca and Mg) increased from a mean value of 1.15 cmol/kg in the control to 1.83 cmol/kg for calcium while magnesium rose from the mean value of 0.85 to 1.03 cmol/kg. Calcium content of the soil in the plot treated with urea/rock phosphate rose from the mean value of 1.15 cmol/kg to 1.74 cmol/kg while magnesium rose from 0.85 to 0.96 cmol/kg. The effective cation exchange capacity (ECEC) generally reduced from 4.88 cmol/kg in the pre-cropping to 3.32, 3.37 and 2.43 cmol/kg for control, urea/rock phosphate and rubber effluent treatments respectively.

Extractable Fe increased in the means of all the treatments from 70.25 mg/kg in the pre-cropping to the mean value of 101.2, 89.9, and 79.2 mg/kg for control urea/rock phosphate and rubber effluent respectively. The organic carbon of the soil at three months after application of the treatments shows decrease from the mean value of 13.8 g kg^{-1} in the pre-cropping to 12.0 and 7.3 g kg^{-1} for urea/ rock phosphate and rubber effluent while the control remain the same.

Physico-chemical properties of the soil at six months after soil amendment

Table 4 shows some selected properties of the soil as affected by soil amendments six months after application (6 MAA). Soil pH though, still lower than the pre-cropping value of 5.7 has increased to 5.20, 5.12 and 5.09 for control, urea/rock phosphate, and rubber effluent respectively which are slightly higher than three months previously. The base saturation of the soil rose from 46.72 to 86.39% and 77.65% for the control and urea/rock phosphate treatments respectively, and increased to 88.26% in the soils treated with rubber effluent. The nitrogen shows decrease in the mean values for all the treatments as compared to the value obtained in the pre-cropping and as well as soils analysed three month after application of soil amendments. The divalent cations (Mg and Ca) showed an increase over the control from the Mg value of 0.85 cmol kg^{-1} in the pre-cropping to 0.94 cmol kg^{-1} while decrease was noticed in the other treatments. Calcium recorded, 1.300, 1.047 and 1.030 cmol kg^{-1} for the control, urea/rock phosphate, and rubber effluent respectively, as against the pre-cropping value of 1.15 cmol kg^{-1}. The effective cation exchange capacity decreased from 4.88 cmol kg^{-1} at the pre-cropping to 2.93 and 2.76 cmol kg^{-1} at 6 MAA for the control and urea/rock phosphate respectively, but increased to 5.14 cmol kg^{-1} with rubber effluent treatment. The exchangeable acidity reduced in all the treatments which accounted for increases in base saturation signifying that the soil amendments increased the cations in the exchange sites of the soil colloids in preference to reserved acidity. The organic carbon content of the soil however, reduced in all the treatments from the pre-cropping value with rubber effluent having a higher reduction than the other treatments. The extractible micronutrients increased in

Table 3. Effect of rubber effluent and inorganic fertilizer on some soil physico-chemical properties three months after application.

Treatments	Sand	Silt	Clay	pH (H_2O)	BS	K	Na	Mg	Ca	EA	CEC	N	Org C	P	Zn	Mn	Cu	Fe
	g/kg				(%)	Cmol/kg						g/kg		Mg/kg				
Control	840.4	26.3	140.0	5.2	92.10	0.18	0.11	1.03	1.83	0.27	3.32	3.3	13.18	7.50	27.73	193.4	8.15	101.2
Urea/rock P	860.4	16.3	123.3	4.9	88.10	0.17	0.09	0.96	1.74	0.40	3.37	5.3	12.00	8.90	22.97	179.8	8.43	89.9
Rubber effluent	853.7	26.3	120.0	4.7	83.70	0.17	0.08	0.78	1.03	0.47	2.430	4.8	7.30	25.80	19.82	112.2	6.90	79.2
LSD	NS	NS	NS	NS	4.65	NS	NS	0.23	0.32	NS	0.473	0.5	1.2	7.91	2.57	8.60	0.70	46.7

Table 4. Effect of rubber effluent and inorganic fertilizer on some soil physico-chemical properties six months after application.

Treatments	Sand	Silt	Clay	pH (H_20)	BS	K	Na	Mg	Ca	EA	CEC	N	Org C	P	Zn	Mn	Cu	Fe
	g/kg				(%)	Cmol/kg						g/kg		mg/kg				
Control	860.4	19.6	120.0	5.2	86.39	0.19	0.11	0.94	1.30	0.47	2.93	2.73	9.9	4.75	63.8	142.70	8.65	85.9
Urea/rock P	870.4	19.6	113.3	5.12	77.65	0.17	0.09	0.81	1.05	0.53	2.76	3.10	12.0	4.76	23.7	111.58	8.38	82.2
Rubber effluent	843.7	22.9	133.3	5.09	88.26	0.16	0.08	0.76	1.03	0.27	2.30	2.03	8.4	7.69	15.6	108.6	7.55	65.2
LSD	NS	NS	NS	NS	NS	0.02	NS	0.14	0.17	0.24	0.40	0.54	1.66	1.45	10.70	27.73	0.532	4.83

value with soil treatments especially in Zn and Mn.

Effect of soil amendment on growth of *Hevea* seedling

The result of the effect of soil amendments on plant girth of *Hevea* seedlings is shown on Figure 1A. The results indicate that from 2 to 4 months after application of the treatments, rubber effluent accounted for higher values but showed no significant effect (P ≤ 0.05) on the girth of the rubber seedlings and except At 3 MAA, when mean girth of 3.44 cm in rubber effluent treatment was significantly different from the 2.92 and 2.68 cm girth recorded for urea/phosphate and the control respectively. At 5, 6 and 7 MAA, significant differences occurred among the treatment means with the plots treated with soil amendments being superior to the control. Figure 1B shows the effect of soil amendments on plant height of *Hevea* seedlings. The treatments did not significantly affect the mean height of rubber seedlings (P ≤ 0.05) in the second and third months after application (MAA) of soil amendments, though at 3 MAA the mean height of rubber seedlings treated with effluent was higher (87.7cm) compared to those in the control with the mean height 82.2 cm. The results showed a significant difference (P ≤ 0.05) in plant height of rubber at 4, 5, 6 and 7 MAA. At 4 MAA, rubber effluent had the highest mean of 113.3 cm compared to urea/rock phosphate which has the mean of 105.6 cm and an average of 98.9 cm for the control. This trend was maintained till the 5 MAA. At 6 MAA, the urea/rock phosphate treatments with 161.7 cm became higher (but not statistically significant) than rubber effluent treatment with 159.0 cm while the control had 137.4 cm. This trend continued till the 7th month. The average number of leaves counted on rubber seedling at different sampling period with respect to the application of different soil amendments applied (Figure 1C) showed that at month 2 and 3 after application of soil amendments, no significant effect (P ≤ 0.05) was observed. However, from 4 MAA the soil amendments showed significant effects on the number of rubber leaves with the highest number (23) recorded in the urea/rock phosphate treatment At 5 MAA. In the 7th MAA, the plots treated with urea/rock phosphate and rubber effluent had approximately the same number (30) while the control plot had approximately 23 leaves per plant.

The effect of soil amendment on the leaf area of *Hevea* seedlings is displayed in Figure 1D. Though there was no significant effect of the soil

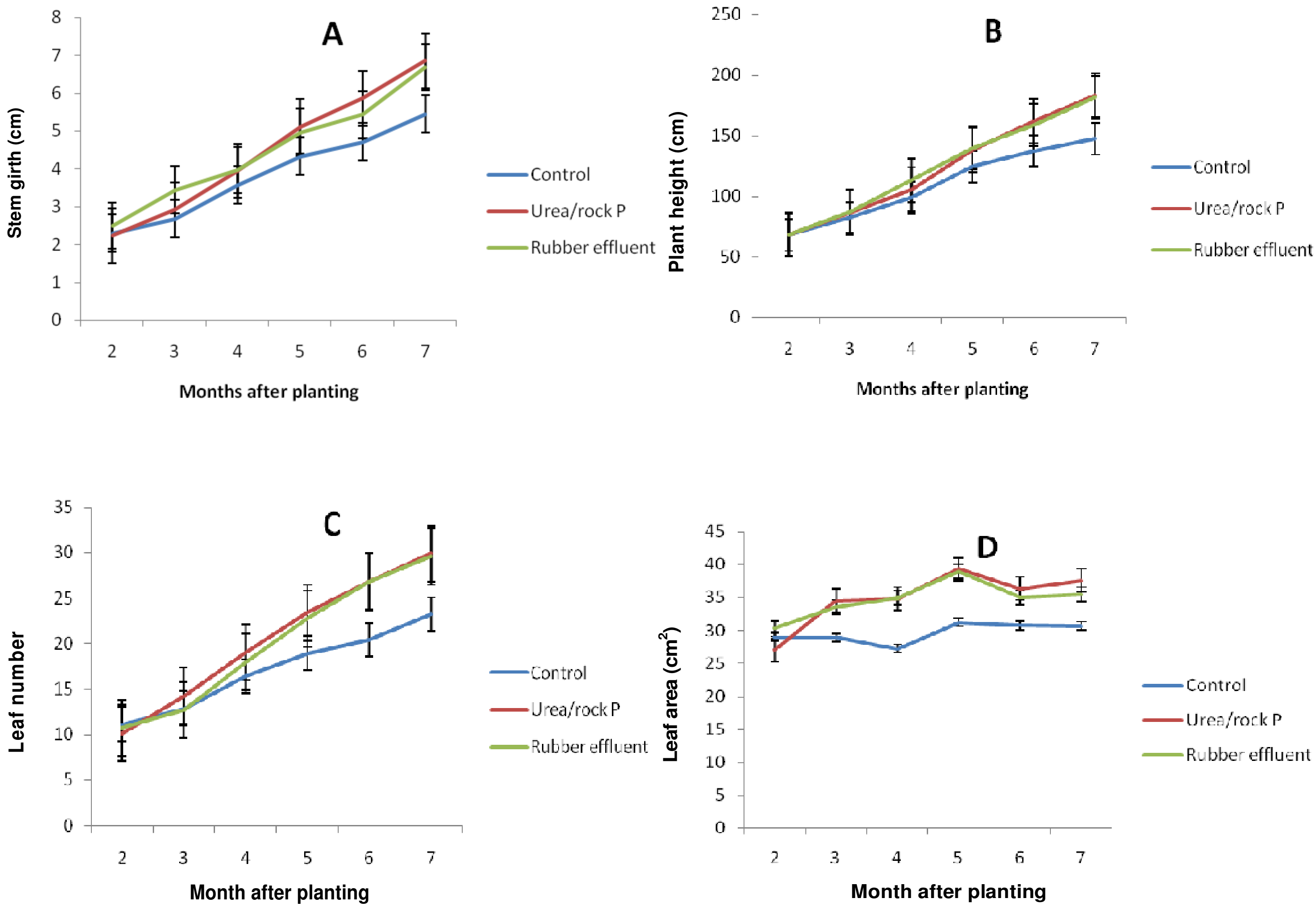

Figure 1. Effects of rubber effluent and urea/rock phosphate on the growth parameters of rubber seedlings (A) stem girth, (B) plant height, (C) leave number and (D) leaf area.

amendments ($P \leq 0.05$) on the control at 2 MAA, at 3, 4, 5, 6 and 7 MAA the seedlings treated with soil amendment had significantly larger leaf area than the control. The plots treated with rubber effluent recorded the largest leaf area with the value of 34.90 cm^2 while the urea/rock phosphate and control had 34.76 and 27.18 cm^2 respectively. At 6 MAA, leaf area in all the treatments reduced compared with 5 MAA, some physiological processes occasioned by the hardening of rubber leaves could have accounted for this observation. By 7 MAA, rubber seedlings urea/rock phosphate was having higher leaf area of (39.32 cm^2) than rubber effluent (38.90 cm^2).

DISCUSSION

The soils of the study area was loamy sand in texture, characterised by low pH, low nutrient status, low ECEC and low water holding capacity as observed by Juo (1981) and Kang and Juo (1986). The sandy nature of the soils is principally influenced by the coastal-plain sand parent material that is inherently sandy (Ojanuga, 2006). This also explains why the soil have low potassium reserve as typical sandy soils have low ion exchange capacity, which determine the quantity of ion that a soil can retain against leaching (Edem, 2007). The fertility status of the soils is greatly determined by the capacity of the soil to hold and exchange ions (both anions and cations). Coarse textured soils are deficient in this quality and as such generally have low fertility status. In addition soil pH is a very important soil property and that tends to correlate with other properties like degree of base saturation, nutrient release and availability (Fitzpatrick, 1983). The acidic nature of the soils may be attributed to high rainfall in the region that makes the soil susceptible to erosion and leaching as the highly mobile basic cations are generally washed away leaving the sesquioxides, to occupy the exchange sites of the soil colloids (Donahue, 1983). The presence of Aluminium (Al) and Iron (Fe) and their oxides and hydroxides increases P-fixation (Sample et al., 1980) resulting in low native phosphorus. Hue (1992) reported that increasing the pH of acidic soils improve plant availability of macronutrient but reduces the solubility of elements such as Al and Mn. The percentage base saturation was expectedly low since the basic cations were low which is as a result of high precipitation leading to strong weathering and leaching condition of the area. The increase in the mean plant height, leaf area, girth and leaf number in seedlings treated urea/rock phosphate at latter growth stage could be attributed to increase in amount of micro and macro nutrients available due to the soil amendments applied, though inorganic fertilizer performed better in leaf area with mean value of 37.58 compared to rubber effluent that had 35.44 (Figure 1D). Application of rubber effluent resulted in enhanced plant growth comparable to the urea/rock phosphate fertilizer at the latter growth stage when the mineralization of the organic nutrients might have been intensified and more nutrient were released into the soil for plant use. Urea treated plots as well as rubber factory effluent treated plots were not different from each other at the end of the experiment, this could be due to the fact that with longer duration of growth Urea-N may have lost through leaching and volatilization. Soil chemical properties before and after application of the treatments showed that application of urea and rubber effluent fertilizer in the experiment improved the general soil chemical properties at three months after application. This could be ascribed to increase in the soil nutrient level and a more conducive ground for the activities of soil micro-organism which aid in improving the soil status. At 6 MAA, there was general decrease in the chemical properties which might have been as a result of nutrient uptake by plant and leaching caused by high precipitation in the area. Addition of phosphate fertilizer in acid sandy soil usually faces the risk of added P being fixed by oxide and hydroxide of Fe and Al which are usually present in abundance in the ultisols and oxisols. Therefore insoluble or slow release forms of phosphate fertilizers such as rock phosphate and rubber factory effluent or latex sludge are preferred as recommended by various authors (Manurung, 1993; Nair et al., 1998; Orimoloye et al., 2004). This further confirms that the rubber factory effluent are not problematic to rubber seedlings, especially when the rate of application is geared to supply nutrient level corresponding to those in inorganic fertilizer which are applied to promote satisfactory crop performance and causes no detrimental change to the soil rather they improve soil fertility with no apparent adverse effect in the environment (Mohd and Abu, 1989).

Conclusion

In conclusion, the result showed that rubber effluent compared favorably with inorganic fertilizers in improving the growth of rubber seedlings while the result of soil chemical analysis after application of the treatment showed improvement in general soil properties. The use of rubber effluent as a fertilizer material is very promising in rubber nurseries while long term implications on the soil is still being further investigated.

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