Availability of Plant Nutrients from Encapsulated Fertilizers Based on Rubber Latex and Coir Dust

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Abstract

Fertilizer use efficiency can be increased by controlled release of nutrients to the soil and it synchronize with the crop nutrient demand. The technique of encapsulation of fertilizers as a coir based product is an effective and economical method for overcoming some management problems associated with fertilizer applications. The study was conducted to determine the nutrient releasing pattern from inorganic fertilizers through membranes based on rubber latex and coir dust. Successful development of coir encapsulated inorganic fertilizers and non-coir encapsulated inorganic fertilizers were tested under *in-vitro* conditions with Red Yellow Podzolic (RYP) soils packed in poly bags with soil only and soil with no fertilizer coir blocks as control treatments. Fertilizer encapsulated treatments did not show any extreme values of soil pH compared to direct fertilizer application treatment and it was ranging from 4 - 5. Moreover, encapsulated nitrogen fertilizer showed increasing trend during the experimental period and direct fertilizer application treatments gave a very high initial value and showed a marked decline from beginning to end of the experiment. Direct fertilizer application treatments gave higher values throughout the incubation period for exchangeable potassium and magnesium. Similarly encapsulated fertilizer gave lower values compared with direct fertilizer application and much higher values compared to control and this pattern continued throughout the experimental period. Moreover, the amount of exchangeable magnesium and potassium made available through fertilizer encapsulation, has apparently been able to synchronize with crop demand over an extended period, making it more beneficial than the conventional form of direct fertilizer application. However, fertilizer encapsulation is little or no advantage for P fertilizers. There is a possibility to release nutrients at controlled rates with N, K and Mg fertilizer encapsulation than direct fertilizer application.

Keywords: *Coir dust, Controlled release, Red yellow podzolic, Rubber based, Soil nutrients*

Introduction

In general, most of the traditional rubber growing soils are gravelly, highly porous and lack in plant nutrients and belong to a major soil group of Red Yellow Podzolic. Moreover, these soils were considered as less suitable for arable farming according to the standard land classification (Dissanayake *et al.,* 1999). In order to maintain the overall soil fertility, it is essential to apply fertilizers, manure and practice matching land management (Samarappuli and Yogaratnam, 1996).

In relation to plant nutrients, the Rubber Research Institute of Sri Lanka (RRISL) recommends fertilizer mixtures containing the major nutrients required by the rubber tree *viz* nitrogen (N), phosphorus (P), potassium (K), and magnesium(Mg) based on long-term field experiments (Jeevaratnam, 1969; Silva, 1971; Pushparajah and Haridas, 1977; Yogaratnam and Weerasuriya, 1984; Yogaratnam *et al.,* 1984; Samarappuli *et al.*, 1993; Dissanayake *et al.*, 1992 & 1994; Dharmakeerthi *et al.*, 1997 & 2004).

As at present, mineral fertilizers are considered the major source especially for maintaining soil chemical fertility. Data from Bockman *et al.*, 1990 shows that in 1970 at global level, 48 % of the nutrients used by crops were derived from soil, 13 % from the manure and 39 % from fertilizer. Twenty years later, in 1990, these percentages had changed to 30, 10, and 60 respectively. The projected percentage by 2020 will be 20, 9, and 70 respectively and these figures highlight the role of mineral fertilizers in global agriculture for intensive crop production. Rubber plantations in Sri Lanka, fertilizer usage has increased from 9.1 million tons in 2001 to 12 million tons in 2012. Their widespread use has also roused concern about possibilities of environmental pollution. With only about half of the applied fertilizers getting into the crop (Bockman *et al.,* 1990), there is a potential for marked economic loss of nitrogen and phosphorus which could occur through leaching and runoff while nitrogen could get lost also through volatilization and denitrification. Besides, cost of fertilizers, low fertilizer use efficiency of inorganic fertilizers and their consequent negative repercussions have drawn attention to think of alternative novel approaches in fertilizer use.

Depleted soil nutrients have to be counter balanced through efficient use of plant nutrients and the use of slow release fertilizers (SRF) has been shown to reduce risk of nutrient losses from the crop root zones, as nutrient release rate is synchronized with crop nutrient demand (Hauk, 1985; Goertz, 1991; De Silva *et al.,* 1996). The prevention of environmental hazards and wastage, due to extreme leaching loss of nutrients, possible pilferage and adulteration of fertilizers, reduction of labour cost associated with repeated fertilizer applications are some of the benefits associated with SRF.

Generally, SRF can be divided in to several groups such as reservoir type, chemically control release and matrix form (Trinh and Kushaari, 2016). Reservoir type is quite common method among them and the fertilizers are encapsulated with inert materials and release nutrients in a control manner by the diffusion through the coating. Sulfur-coated urea was developed and manufactured commercially for almost 30 years (Sempeho, 2014) and alkyd type resin-coated fertilizer (Osmocote) was produced in Califonia in 1967. At present, researchers have identified novel coating materials based on SRF techniques, acetate coated granule (Wu and Lin, 2008), attapuigite (APT) clay and guar gum (Ni *et al.*, 2012), starch-g-poly (L-lactide) coating (Chen *et al.*, 2012), urea-kaolinite fertilizer (Roshanravan *et al.*, 2015) etc. Natural rubber has also been used for the formation of SRF and the process involves blending with natural rubber latex with soluble fertilizers (Yeoh *et al.*, 1977). Moreover, natural rubber coated fertilizers appeared to be degraded by microbiological attack with in a period of three months and those conditions could not be observed by combine use of natural rubber latex with synthetic rubber (Cundell and Mulcock, 1971). Therefore, the production of encapsulated or coated SRF based on rubber latex and coir dust could improve the efficiency of nutrient use and an effective and economical method for overcoming some management problems in the field. The objective of this study was to investigate the effects of coir dust and latex based SRF on soil chemical fertility.

Materials and Methods

This experiment was conducted in polythene bags which did not have drainage holes. Before incubation, the soil was air dried; stubbles, and root particles were removed by hand and crushed gently to pass through 2 mm sieve. Approximately, 2 Kg of soil was put in polybags. For the encapsulated fertilizer treatments, first the bags were half filled with the soil and thereafter the fertilizer encapsulated coir blocks were placed in the middle of the bag and after which the bag was filled with the remaining soil. Rubber Research Institute recommended one of the popular fertilizer mixture, R/U 12:14:14 was used with the treatments associated with NPK mixture and other treatments were maintained with straight fertilizers used for rubber plantation. For the direct fertilizer application treatments the same amount of encapsulated fertilizer was applied directly to the soil. These bags were kept at room temperature and initially the soil was wetted 60 % of the water holding capacity (WHC). Then the soil was allowed to dry slowly and distilled water was added weekly to bring the soil to its 60 % WHC.

To make the coir block quantity of inorganic fertilizer was placed in the middle of the coir dust and it was dipped in dialuted latex and oven dried at 60 °C to firm it when handling (Figure 1 and 2). There were 14 treatment combinations (Table 1) and the experimental design was a completely randomized block design with three replicates.

Table 1. Treatment combinations of the experiment

Treatment	Combination
T1	Soil only
T2	Soil + Coir blocks (without fertilizers)
T3	Soil + Coir blocks (50 g NPK + 25 g Ks)
T4	Soil + 50 g NPK + 25 g Ks
T5	Soil + Coir blocks (100 = g NPK + 50 g Ks)
T6	Soil + 100 g NPK + 50 g Ks
T7	Soil + Coir blocks (50 g urea)
T8	Soil + 50 g urea
T9	Soil + Coir blocks (50 g MOP)
T10	Soil + 50g MOP
T11	Soil + Coir blocks (50 g Ks)
T12	Soil + 50 g Ks
T13	Soil + Coir blocks (50 g ERP)
T14	Soil + 50 g ERP

Figure 1. General view of the coir block

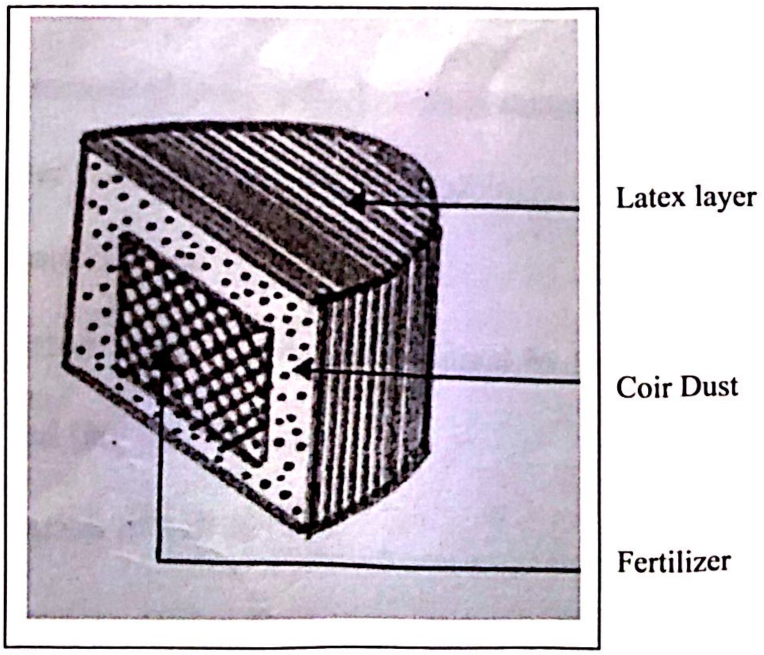

Figure 2. Vertical cross section of the coir block

Assessment of chemical characteristics of the soil

Samples were taken six times during the incubation period at 1.5 months intervals by removing complete sample sets.

Preparation of soil sample

Each polybag was cut vertically from top to bottom and carefully removed the coir blocks containing fertilizer, soil lumps were broken, spread out on papers and allowed to air dry. Dried soil was sieved through a 2 mm sieve. The soil was used for all analysis except for determination of N. For these, the soil was hand ground using a pestle and mortar and was then passed through a 100 mesh sieve (0.5mm).

(a). Soil pH

Soil pH was measured using a Beckman pH meter in water suspension at 1 : 2.5, soil : water ratio.

(b). Determination of soil nitrogen

Ground samples (0.5g) that were passed through a 0.5 mm sieve were weighted into pyrex tubes. One gram of sodium sulphate and 5 ml of conc H_2SO_4/Se mixture were added and was mixed well and digested. After digestion and cooling, the contents of each test tube were poured into 100 ml volumetric flask and made upto mark with distilled water and were kept overnight. The contents of each flask was filtered through Whatman No. 2 filter paper and filtrate was analyzed for ammonium (NH_4^+) nitrogen using Technicon – Auto Analyzer by Indo phenol blue method (RRIM 1971a).

(c). Determination of acid extractable phosphorus

The extraction was done by weighing 2 g of air dried soil into 50 ml containers and adding 20 ml of extracted solution (200 ml of 0.5N HCl and 15 ml of 0.03N NH_4F diluted upto 1L with distilled water, pH adjusted to 1.8). This was shaken for 1 minute and kept for the soil settle (Anorld, 1947).

The solution was filtered through Whatman No. 2 filter paper and the filtrate was measured calorimetrically on the Auto Analyzer by the molybdenum blue – method (Fog and Wilkinson, 1958).

(d). Determination of exchangeable K, Ca, and Mg

10g of soil was mixed 50 ml of conc. NH_4OAC solution of pH 4.8 in polythene bottles and shaken for 1 hour with a 30 minute interval in between and the solution was filtered using Whatman No. 2 filter paper. 10 ml of the above extract was pipetted into a 50 ml flask and 5 ml of micro grams/ ml strontium solution was added and diluted upto the mark with distilled water. Concentration of the K, Ca, and Mg were determined by atomic absorption spectrophotometry on a single beam atomic absorption spectrophotometer model GBC 903. (RRIM 1971a).

Statistically analysis

Statistical analysis of the experimental data was done by analysis of variance followed by a mean separation procedure; Duncan's Multiple range Test (DNRT), at probability level of 0.05.

Results and Discussion

Soil pH

The data obtained showed in general that all the direct fertilizer application treatment namely T4, T6, T8, T10, T12 and T14 gave significantly higher pH values compared to control treatments, T1 and T2. Fertilizer encapsulated treatments T3, T5, T7, T9, T11, and T13 did not show significant differences compared to control treatments T1 and T2 during the experimental period of 7.5 months. Furthermore, fertilizer encapsulated treatment T7 maintained soil pH ranging from 4-5 and was not observed significant difference compared to control treatments T1 and T2. The direct fertilizer application treatment, T8 maintained soil pH ranging from 5.5-8,2 and was observed significant difference compared to control treatments T1 and T2. Rubber generally grows well in acidic soils in Sri Lanka. Soil pH ranging from 4 to 6 is considered as optimum condition for establishment of rubber (Samarappuli, 2001) and these optimum conditions were maintained with fertilizer encapsulated treatment (T7) throughout the experimental period. However, extreme pH conditions were observed with direct fertilizer application treatment (T8) is not favorable for good performance of rubber tree.

Table 2. Effect of difference fertilizer treatments on soil pH

Treatment	0 month	1.5 months	3 months	4.5 months	6 months	7.5 months
T1	5.8^{b}	5.7^{b}	5.01^{b}	5.11^{b}	4.91^{b}	4.94^{b}
T2	5.3^{b}	5.4^{b}	5.2^{b}	5.1^{b}	5.2^{b}	5.11^{b}
T7*	4.9^{b}	5.0^{b}	4.7^{b}	4.4^{b}	4.5^{b}	4.2^{b}
T8**	7.8^{a}	7.04^{a}	8.17^{a}	6.9^{a}	6.53^{a}	5.51^{a}

T1 = Control * - Encapsulated treatment ** - Direct fertilizer application treatment

Soil total nitrogen

Fertilizer encapsulated treatment T3, T5 and T7 included nitrogen fertilizers and gave significantly higher values of total nitrogen over the control treatment (T1) from 1.5 months onwards. They showed an increasing trend in nitrogen levels. In contrast, the direct fertilizer application treatments T4, T6, and T8 gave a very high initial value compared with control treatment (T1) which however showed a marked decline from beginning at 1.5 months and continued to show a decreasing trend to the end (Table 3). High amount of nitrogen availability could be observed at the beginning of the experiment with direct fertilizer application treatments enhance loss of applied nitrogen fertilizers. Nitrogen is vitally important plant nutrient and possibility of loss of applied fertilizer nitrogen resulted in reduced uptake efficiency of applied nitrogen by target crop which is an agricultural and environmental problem. The loss of applied nitrogen fertilizers can be reduced through fertilizer management practices (Rao, 1987; Fiez *et al.*, 1995). According to the results of fertilizer encapsulated treatments, a high level of soil N has been maintained over a prolonged period, compared to direct fertilizer application treatments without coir encapsulation.

Table 3. Effect of difference fertilizer treatments on soil nitrogen (%)

Treatment	0 month	1.5 months	3 months	4.5 months	6 months	7.5 months
T1	0.178^{c}	0.135^{d}	0.141^{c}	0.130^{d}	0.110^{c}	0.169^{d}
T3*	0.180^{c}	0.375^{bc}	0.321^{b}	0.445^{b}	0.413^{ab}	0.405^{ab}
T4**	0.802^{a}	0.276^{cd}	0.385^{b}	0.280^{c}	0.298^{b}	0.129^{d}
T5*	0.148^{c}	0.562^{a}	0.216^{b}	0,519^{b}	0.349^{b}	0.416^{ab}
T6**	0.731^{a}	0.556^{a}	0.448^{ab}	0,498^{b}	0.506^{a}	0.279^{c}
T7*	0.190^{c}	0.379^{bc}	0.271^{b}	0.559^{b}	0.428^{ab}	0.357^{bc}
T8**	0.735^{a}	0.441^{ab}	0.595^{a}	0.482^{b}	0.503^{a}	0.398^{ab}

T1 = Control * - Encapsulated treatment ** - Direct fertilizer application treatment

Soil available Phosphorus

The Table 4 indicated the available P content in soil for T1, T3, T4, T5, T6, T13, and T14 treatments. The results indicated that the direct fertilizer application treatments T4, T6, and T14 gave significantly very high value over the control for all treatments. In contrast, the fertilizer encapsulated treatments T3, T5, and T13 gave very low values and there were no significant differences between these values compared to control treatment (T1) (Table 4). With regard to soil phosphorus which is also an essential nutrient for rubber. Moreover, the low availability of phosphorus in the soil is due to its immobilization as a result of interaction with the components and forms frequently insoluble calcium, aluminium, and iron phosphates (Tan, 1993; Dey, 1998; Yadav and Dadarwal, 1997; Vasslleva *et al.*, 1998; Barber, 1984; Vassilev and Vassileva, 2003). However, the coir dust encapsulation with inorganic fertilizer for the formation of encapsulated fertilizer treatments did not bring about an appreciable increase in available soil P. Therefore, the encapsulation of fertilizer is little or no advantage for P fertilizers was observed (Table 4).

Table 4. Effect of difference fertilizer treatments on soil available phosphorus (ppm)

Treatment	0 month	1.5 months	3 months	4.5 months	6 months	7.5 months
T1	6^{e}	7^{e}	6^{e}	19^{e}	9^{d}	8^{e}
T3*	7.6^{e}	8.6^{e}	6.3^{e}	7.4^{e}	10.8^{d}	9.2^{e}
T4**	1271^{c}	1315^{c}	1481^{c}	1476^{c}	1153^{b}	1410^{cd}
T5*	6.5^{e}	10.3^{e}	9.1^{e}	9.6^{e}	14.0^{d}	11.2^{e}
T6**	2126^{b}	2543^{b}	1902^{b}	2620^{b}	1205^{b}	2551^{b}
T15*	6.5^{e}	6.8^{e}	9.2^{e}	11.4^{e}	8.5^{d}	8.2^{e}
T16**	815^{cd}	802^{d}	1160^{c}	1402^{cd}	786^{c}	1948^{bc}

T1 = Control * - Encapsulated treatment ** - Direct fertilizer application treatment

Soil exchangeable magnesium

The results of soil exchangeable magnesium was observed for direct fertilizer application treatments and fertilizer encapsulated treatments are presented in table 5. Direct fertilizer application treatments, T4, T6, and T10 gave significantly very higher values of exchangeable Mg throughout the experimental period compared to fertilizer encapsulated treatments and control treatment (T1). However, Fertilizer encapsulated treatments, T3, T5 and T9 gave significantly lower values compared to direct fertilizer application treatments and much higher compared to control treatment (T1). The quantity of fertilizer recommended for immature *Hevea* (RRISL, 1995) for a period of two months and five months were encapsulated in treatments T3 and T5 respectively. However, high values of Mg could be observed up to 7.5 months at the end of the experimental period and these values were comparatively higher than the rubber growing soils of Sri Lanka which was categorized under Red Yellow Podzolic soils (Yogaratanam *et al.*, 1984; Dharmakeerthi *et al.*, 2005). Therefore, the amount of exchangeable magnesium made available through fertilizer encapsulation be able to synchronize with crop demand over an extended period making it more beneficial than the direct fertilizer application

Table 5. Effect of difference fertilizer treatments on soil exchangeable magnesium (ppm)

Treatment	0 month	1.5 months	3 months	4.5 months	6 months	7.5 months
T1	22^{c}	33^{d}	26^{d}	27^{d}	32^{d}	31^{d}
T3*	30^{c}	187^{d}	209^{d}	177^{d}	179^{d}	144^{d}
T4**	2332^{b}	2408^{c}	1891^{c}	4247^{c}	3842^{c}	4583^{c}
T5*	28^{c}	228^{d}	272^{d}	303^{d}	205^{c}	168^{d}
T6**	4326^{a}	4496^{ab}	3154^{ab}	8791^{a}	8057^{a}	8591^{a}
T9*	24^{c}	214^{d}	256^{d}	198^{d}	181^{d}	157^{d}
T10**	2967^{b}	3927^{b}	2683^{b}	6529^{b}	5582^{b}	6149^{b}

T1 = Control * - Encapsulated treatment ** - Direct fertilizer application treatment

Soil exchangeable potassium

The highest exchangeable potassium contents were observed throughout the experimental period with direct fertilizer application treatment T10 and gave approximately 180 times higher value over the control treatment (T1). However, fertilizer encapsulated treatment, T9 gave higher values compared to control treatment (T1) and on average it was five times greater than the control treatment (Table 6).Moreover, these values were comparatively higher than the rubber growing soils of Sri Lanka was categorized under Red Yellow Podzolic soils (Yogaratanam *et al.*, 1984 and Dharmakeerthi *et al.*, 2005) and therefore, fertilizer encapsulation for Mg is more beneficial than their direct fertilizer application

Table 6. Effect of difference fertilizer treatments on soil exchangeable potassium

Treatment	0 month	1.5 months	3 months	4.5 months	6 months	7.5 months
T1	56.2[b]	31.8[b]	49.8[b]	55.0[b]	53[b]	48[b]
T9*	210[b]	198.6[b]	199.8[b]	365.7[b]	345[b]	364[b]
T10**	10358[a]	10276[a]	10837[a]	13709[a]	14963[a]	17722[a]

T1 = Control * - Encapsulated treatment ** - Direct fertilizer application treatment

Conclusion

Fertilizer encapsulation with rubber latex and coir dust was found to release nitrogen, potassium and magnesium at their optimum levels over an extended period of time. However, this technology was no advantage for P fertilizers.

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