J. Rubb. Res , 1(4), 263–277

Effects of Mulching with Rice Straw on Soil Chemical Properties and its Influence on the Performance of Hevea

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The effects of mulching with rice straw on changes in soil chemical properties and its influence on growth and yield performance of Hevea *under pot and field conditions were studied. The pot experiment revealed that the soil K and Mg content increased significantly with time, suggesting the presence of readily available K and Mg in the straw. The P content increased up to the 6th week and decreased thereafter. The levels of N, Mn and Fe also increased whereas the Zn content showed a declining trend. Soil analysis after six years of application of straw indicated a gradual build up of organic C, N, K, P and Mg levels. Mulching also improved the cation exchange capacity of the soil. Girthing during immature period and tappability at the end of 6 years were much higher in mulched fields compared to other management practices* viz. *naturals and legumes. Similarly, the residual effect of mulching has resulted in higher girth increment and better latex yields during the first 8 years of tapping. The response surface analysis indicates a variation in the optimum N, P, K levels according to management practices It further reveals a 12-month reduction in immaturity period and an additional increase in yield of 158 kg ha^{-1} yr^{-1} due to application of rice straw together with optimum NPK levels*

The monocultural cropping system adopted in rubber cultivation over the last several decades using the same agro-management practices and continuous application of inorganic fertilisers have resulted in deterioration of soil fertility[1,2]. Infertile soils cannot sustain economic yields even with a high dosage of inorganic fertilisers. Soil, being a non-renewable resource, should be conserved at all costs for the benefit of future generations. It should be managed properly to avoid depletion of essential plant nutrients and organic matter from the fertile top-soil. In this regard one should think of an environment-friendly approach towards enriching the soil conditions, while ensuring high yields on a sustainable basis. The combined use of inorganic and organic fertilisers is one such way of enhancing productivity in an environment-friendly manner.

Although plant residues, particularly rice straw, are rich in K and contain many other plant nutrients[3–7], insufficient attention has been paid in the tropics towards finding suitable methods

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of recycling straw in plantation agriculture and to evaluate the economic benefits which can be derived under such conditions Large quantities of straw are being burnt in the paddy fields every year Besides losing valuable nutrients and organic matter, burning can cause serious atmospheric pollution and health hazard problems This study investigates the effect of mulching with rice straw on changes in soil chemical properties and its influence on the performance of *Hevea*

MATERIALS AND METHODS

A pot experiment and three field experiments were carried out to investigate the effects of mulching on changes in soil chemical properties and its influence on the performance of *Hevea* In all experiments, the type of soil was shallow, gravelly loam and brown to reddish yellow in colour Pre-treatment soil analysis indicated the following mean values pH 4 5, cation exchange capacity (CEC) 3 0 mol kg^{-1}, organic C, 0 83%, total N, 0 13%, available P, 9 0 mg kg^{-1}, available K, 0 08 cmol kg^{-1} and available Mg 0 07 cmol kg^{-1} (Organic C by Walkly and Black mtd , total N by Indo phenol blue mtd , available P by NH_4F/HCl, available K, Mg and CEC by ammonium acetate at pH 7)

Statistical analyses of all experimental data were done by Analysis of Variance (ANOVA) followed by a mean separation procedure, Duncan's Multiple Range Test (DMRT), at a probability level of 0 05 Mean values of this analysis are presented in tabular form and the values with the same letter are not significantly different at the specified probability level

Experiment 1

A pot experiment was conducted to study the nutrient release pattern of rice straw over a period of 4 months Treatments consisted of (a) without paddy straw, (b) surface mulching and (c) sub-surface mulching (incorporation) These treatments were allocated in a complete randomised design with four replicates Polythene bags of 15 cm diameter were used and each polythene bag was filled with 1 kg of soil, sieved with a 2 5 cm sieve and 25 g of straw was added to each polythene bag The straw was chopped into small pieces of 2–3 cm and spread uniformly on the soil surface for surface mulching treatment and thoroughly mixed with the soil for sub-surface mulching treatment Initially, 250 ml of distilled water was added into each polythene bag and thereafter, 50% field capacity was maintained by adding 50 ml of distilled water once a week For each analysis, four replicates were removed once in two weeks and soils were analysed for total N, available P, K, Mg, Mn, Zn and Fe

Experiment 2

A field experiment was conducted to study the effects of different soil management practices on the changes in soil characteristics and their effects on the performance of *Hevea* (clone PB 86) Three ground cover management practices that were studied in a randomised block design with six replicates are

a Natural cover (weeds)

b Mixed legumes (*Pueraria phaseoloides* and *Desmodium ovalifolium*)

c Mixed legumes + dead mulch (rice straw) around the base, 2–5 kg/plant/ application, once in 6 months

Plots with natural cover had common weeds in rubber plantations The weeds were periodically subjected to slashing for prevention of overgrowth. The leguminous plots had a mixed growth of *Pueraria phaseoloides* and *Desmodium ovalifolium*. A clean weeded circle was maintained around the rubber plants for both treatments as recommended by the Rubber Research Institute of Sri Lanka (RRISL). For the 3rd treatment, *Pueraria phaseoloides* and *Desmodium ovalifolium* were maintained in the inter-row and within-row areas as in treatment (b), but the clean weeded circle around the base of the plant was mulched with rice straw at the rate of 2 kg – 5 kg per application once in 6 months during the experimental period.

N, P, K and Mg fertilisers were applied uniformly to all plots consisting of 25–30 effective trees according to the normal recommendations[8]. Soil pH, CEC, organic C, soil and leaf nutrient contents were recorded at the end of 6 years after planting. Girth, tappability (number of trees that reached a girth of 50 cm measured at 120 cm from the union as a percentage) and yield were also recorded.

Experiment 3

In this long term experiment, the effects of some soil management and fertiliser practices on mineral composition of leaves and soil, growth and latex yield of *Hevea* (clone PB 86) were studied. The design of this experiment was 3×3×3 factorial in which three levels of N, P and K were applied to plots consisting of 25–30 effective rubber trees. The levels of nutrients applied in each year are given in *Table 1*. Two ground cover management practices were adopted in the sub-plots:

- C_0 — without mulch
- C_1 — with mulch (rice straw) 2 kg – 5 kg/plant/application, once in 6 months.

The parameters, as in *Experiment 2*, were recorded.

Experiment 4

Influence of mulching with rice straw and K on mineral composition, growth and latex yield of *Hevea* (clone RRIC 102) were studied in this experiment. A split plot design was used with three replicates in which the two levels of K were applied to the main plots and three different ground cover management practices were adopted in the sub-plots:

- Main plots (fertiliser levels)

  K_0 — nil potassium

  K_1 — recommended level (*Table 1*)

- Sub-plots (ground cover management practices)

  C_1 — *naturals*

  C_2 — mulch (rice straw) 2 kg – 5 kg/plant/application, once in 6 months

  C_3 — *Pueraria phaseoloides*.

Plots with natural cover had common weeds and weeds were periodically subjected to slashing for prevention of overgrowth. For mulching treatment only the clean weeded circle was mulched with rice straw but, *Pueraria phaseoloides* was maintained in the inter-row and within-row areas. A clean weeded circle was maintained around the rubber plants for naturals and *Pueraria* plots as recommended by the RRISL. Soil pH, CEC, organic C, soil and leaf nutrient contents were recorded at the end of 6 years after planting. Girth, tappability and yield were also recorded.

TABLE 1. THE LEVELS OF NUTRIENTS APPLIED EACH YEAR FOR DIFFERENT TREATMENTS

Level	Nutrient ($g\ t^{-1}\ yr^{-1}$)			
	1st	2nd	3rd and 4th	5th until tapping
N_0	Nil	Nil	Nil	Nil
N_1	33	66	99	132
N_2	66	132	198	264
P_0	Nil	Nil	Nil	Nil
P_1	17	33	51	68
P_2	34	68	102	136
K_0	Nil	Nil	Nil	Nil
K_1	33	66	99	132
K_2	66	132	198	264
Mg_1	11	18	24	30

RESULTS

The mineral composition of rice straw is presented in *Table 2*. The changes in major soil nutrient contents with time after application of rice straw in *Experiment 1*, are presented in *Figure 1*. In general, application of rice straw increased the soil N, P, K and Mg content. After 15 weeks, the N content was 73% higher than the initial N content whereas the soil P content increased up to 42% by the 6th week and decreased thereafter. The soil K and Mg content increased significantly with time suggesting the presence of readily available K and Mg in rice straw. The micronutrients, Mn and Fe, also increased over time. However, the Fe content has declined towards the latter stage with the decomposition of rice straw. Application of rice straw decreased the Zn content of the soil. The data also indicate that incorporation of straw into the soil releases more nutrients than surface mulching (*Figure 2*).

In *Experiment 2*, soil analysis after six years of application of straw indicated a gradual build-up of organic carbon and nitrogen (*Table 3*). Mulching also improved the CEC and pH of the soil (*Table 3*). Soil and leaf K contents were much higher in mulched plots compared to other soil management practices (*Table 4*). In general there was a tendency for mulch to increase the soil P and Mg contents (*Table 4*).

Girthing had been much higher with mulching and better growth during immaturity resulted in a higher tappability percentage of the rubber plants at the end of 6 years (*Table 4*). After trees came into tapping, application of straw was discontinued and the residual effect of treatments on girth increment in the virgin panels BO-1 and BO-2 were recorded (*Table 5*). Girth increment was higher in mulched plots compared to other soil management practices. The residual effects of treatments on average yield in the virgin panels BO-1 and BO-2 were recorded in this

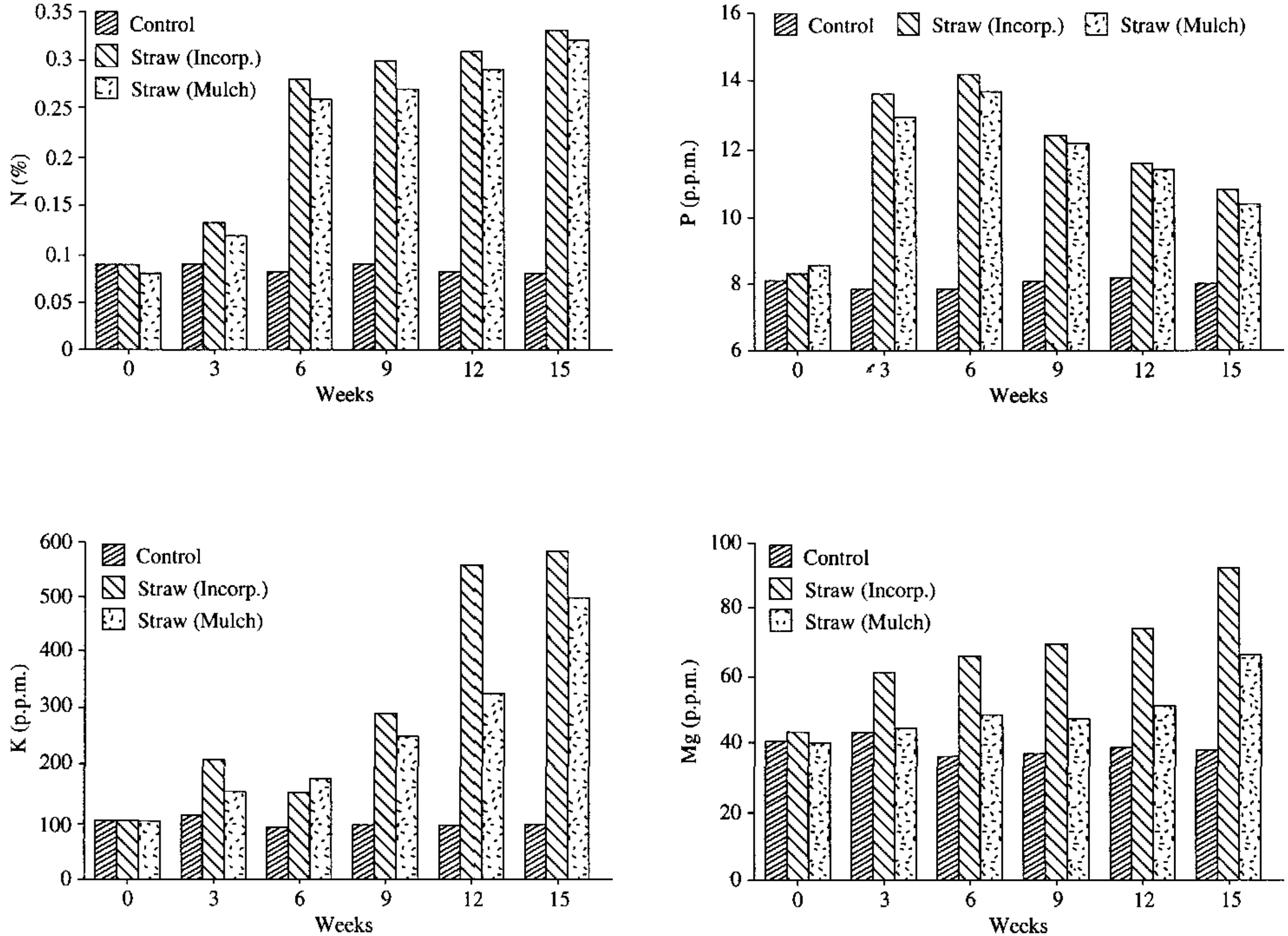

Figure 1. Effect of rice straw on soil N, P, K and Mg contents.

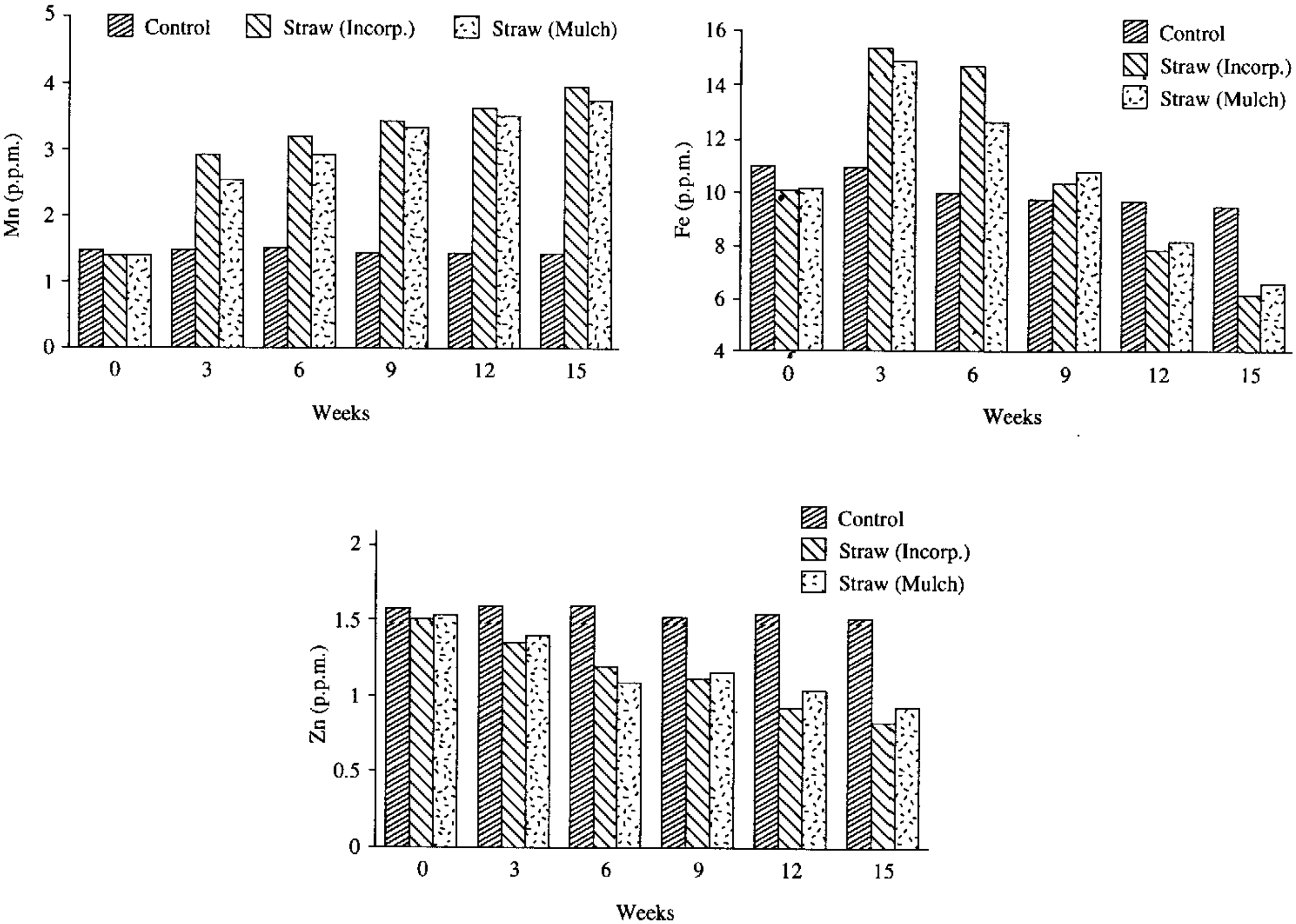

Figure 2. Effect of rice straw on soil Mn, Fe and Zn contents.

TABLE 2 MINERAL COMPOSITION OF RICE STRAW

Nutrient	Amount
N	0.60 – 0.70 (%)
P	0 07 – 0 10 (%)
K	1.40 – 1 90 (%)
Mg	0 20 – 0.30 (%)
C	30 – 40 (%)
C/N	40 – 65

experiment, although the application of straw was discontinued after the trees came into tapping. The effect on average yield is given in *Table 5*. The latex yield was higher in mulched plots compared to other soil management practices.

Residual effect of mulching on leaf N, P, K and Mg was taken into consideration in recommending inorganic fertilisers on the basis of leaf nutrient contents. The economic benefit that could be derived due to cut down in inorganic fertilisers under mulching during the first 8 years of mature stage compared to creeping legumes is given in *Table 6*.

In Experiment 3, girth data up to the 6th year of planting were used to investigate optimum N, P, and K levels under different management practices *viz.* with and without application of straw. An analysis of variance (ANOVA) and a response surface analysis were used on trunk girth for comparison of treatment effects. The present recommended level of N appears to be sufficient irrespective of the management practice. The optimum P and K levels varied according to management practices when the response surface analysis technique was used, indicating that with application of rice straw, an additional 41 g of P per plant has to be added during the immature period, but on the other hand 63 g of K could be saved for the same period (*Table 7*).

The predicted girth under different management practices using optimum fertiliser levels is listed in *Table 8*. As the rubber trees can be tapped at 50 cm girth, the immaturity period could be reduced by one year with application of straw and optimum N, P, K levels.

Yield data were used to derive the optimum N, P, and K levels during the mature period under different management practices *viz.* with and without straw using the response surface analysis technique. The results indicate that the optimum N and K levels varied according to the management practice (*Table 9*). The yields predicted and observed under different management practices are given in *Table 10* This indicates that it is possible to obtain higher yields in the region of 158 kg ha^{-1} yr^{-1} by application of straw at optimum N, P, K levels.

It was noted that soil and leaf K contents of rubber plants with recommended level of K were almost similar to the soil and leaf K contents with no K in combination with rice straw (*Table 11*). Similar results were also obtained for the girth of rubber plants at six years after planting. As would be expected, this resulted in higher tappability in rubber trees with the combination of without K and application of rice straw (*Table 12*). The trend in yield data was also similar to that of the girth data (*Table 13*).

DISCUSSION

Rice straw contains about 0.6%–0.7% N, 0.7%–0.1% P, 1.4%–1.9% K, 0.2%–0.3% Mg and 30%–40% C. Incorporation of 23 MT of rice straw per hectare during the 6 years immature

TABLE 3. EFFECT OF DIFFERENT SOIL MANAGEMENT PRACTICES ON SOIL N, ORGANIC C, CEC AND pH AT SIX YEARS AFTER PLANTING

Treatment	N (%)		Organic C (%)		CEC (cmol kg^{-1})		pH	
	Pre-treatment	After 6 yrs	Pre-treatment	After 6 yrs	Pre-treatment	After 6 yrs	Pre-treatment	After 6 yrs
Naturals	0.13[a]	0.165[a]	0.82[a]	1.100[a]	3.0[a]	3.9[a]	4.6[a]	4.7[a]
Legumes	0.14[a]	0.179[a]	0.87[a]	1.105[a]	3.1[a]	5.3[b]	4.5[a]	4.6[a]
Dead mulch	0.11[a]	0.185[a]	0.80[a]	1.415[b]	2.9[a]	5.5[b]	4.4[a]	4.9[a]

[a,b]The values are significantly different at the 0.05 probability level.

TABLE 4. EFFECT OF DIFFERENT SOIL MANAGEMENT PRACTICES ON SOIL AND LEAF K, P, Mg CONTENTS, GIRTH AND TAPPABILITY OF RUBBER PLANTS AT SIX YEARS AFTER PLANTING

Treatment	Soil K (cmol kg^{-1})	Leaf K (%)	Soil P (mg kg^{-1})	Leaf P (%)	Soil Mg (cmol kg^{-1})	Leaf Mg (%)	Girth (cm)	Tappability (%)
Natural	0.090[a]	0.67[a]	9.3[a]	0.133[a]	0.1260[a]	0.173[a]	40.0[a]	13.17[a]
Legumes	0.094[a]	0.75[a]	11.5[a]	0.138[a]	0.1480[a]	0.178[a]	44.5[b]	25.58[b]
Dead mulch	0.113[b]	0.91[b]	18.5[b]	0.158[a]	0.2153[b]	0.204[a]	50.0[c]	66.85[c]

[a,b,c]The values are significantly different at the 0.05 probability level.

TABLE 5. RESIDUAL EFFECT OF DIFFERENT SOIL MANAGEMENT PRACTICES ON GIRTH INCREMENT AND AVERAGE YIELDS IN THE PANELS BO-1 AND BO-2

Treatment	Girth (panel BO-1 and BO-2)		Average Yield (panel BO-1)		Relative Increase	Average Yield (panel BO-2)		Relative Increase
	Increment (cm)	Relative Increase (%)	(g $t^{-1}yr^{-1}$)	(kg $ha^{-1}yr^{-1}$)	(%)	(g $t^{-1}yr^{-1}$)	(kg $ha^{-1}yr^{-1}$)	(%)
Naturals	11.70[a]	85	18.51[a]	1166[a]	98	18.68[a]	1177[a]	87
Legumes	13.73[b]	100	18.94[a]	1193[a]	100	21.41[a]	1349[a]	100
Dead mulch	18.42[c]	134	22.52[b]	1419[b]	119	27.56[b]	1736[b]	129

[a,b,c]The values are significantly different at the 0.05 probability level.

TABLE 6. SAVINGS ON INORGANIC FERTILISERS UNDER DIFFERENT SOIL MANAGEMENT PRACTICES (UP TO 8TH YEAR OF MATURITY)

Year	Recommended fertilisers (g plant^{-1})		Cost of fertilisers (Rs ha^{-1})		Savings on fertilisers (Rs ha^{-1})
	Legumes	Mulch	Legume	Mulch	
1	1100 g 12:14:14 mix + 250 g Dolomite	200 g urea + 200 g MOP + 150 g ERP	3945	1912	2033
2	200 g urea + 200 g MOP	125 g urea + 125 g MOP	1741	1088	653
3	200 g urea + 200 g MOP	200 g urea + 125 g MOP	1741	1420	321
4	125 g urea + 200 g MOP	125 g urea + 125 g MOP	1409	1088	321
5	200 g urea + 200 g MOP	125 g urea + 125 g MOP	1741	1088	653
6	125 g urea + 200 g MOP	125 g urea + 125 g MOP	1409	1088	321
7	200 g urea + 200 g MOP	125 g urea + 125 g MOP	1741	1088	653
8	125 g urea + 200 g MOP	125 g urea + 125 g MOP	1409	1088	321
				Total	5276

MOP: Muriate of potash; ERP: Eppawela rock phosphate

TABLE 7. OPTIMUM LEVELS OF P AND K DURING IMMATURE PERIOD UNDER DIFFERENT MANAGEMENT PRACTICES USING RESPONSE SURFACE ANALYSIS

Year	P (g plant^{-1}yr^{-1})		K (g plant^{-1}yr^{-1})	
	Without straw	With straw	Without straw	With straw
1	17	17	33	33
2	33	33	66	66
3	51	51	128	99
4	53	75	123	112
5	69	78	175	158
6	70	80	150	144
Total	293	334	675	612

TABLE 8. PREDICTED GIRTH UNDER DIFFERENT MANAGEMENT PRACTICES

Year	Predicted girth (cm)	
	Without straw	With straw
3	32.8	36.1
4	38.4	42.4
5	45.5	51.5
6	51.0	56.7

period would contribute approximately 120 kg of N, 345 kg of K and 23 kg of P. These quantities represent about 43% of N and more than 100% of K presently recommended as *chemical fertiliser for rubber during the immature* period.

When straw is burnt it loses almost all its N, sulphur (S) and C but retains about 80% of the K in the ash[3]. The potassium contained in straw ash is readily leachable on contact with water[4]. These considerations stress the importance of protecting straw by discouraging it being burnt in order to conserve plant nutrients as well as organic matter.

The importance of mulching in enhancing the organic C status of the soil was clearly shown by the experimental data. Although decomposition of organic matter is rapid under tropical conditions[1], organic matter tends to accumulate in the form of mulch of decaying straw due to continuous mulching at six months intervals. The lower organic C content in the natural plots is probably due to the poor return of litter to the soil[9] and greater exposure of soil under naturals compared to leguminous cover or mulching[10]. A possible explanation for the highest amount of organic C found in the mulched plots is that rice straw has a higher C/N ratio than legume litter[5] and therefore could serve as a C source for a longer period of time. The N content of the cover leaves, green matter and litter may be much greater[1] and the C/N ratio of the litter was lesser in the legumes than in rice straw. It is well known that materials with low C/N ratio are expected to mineralise rapidly[12].

In soils of humid regions the soil organic matter (humus) contains almost all the soil N[13]. According to the results obtained, application of rice straw over the years does not bring about an appreciable increase in soil N content. Savings on fertilisers during the first 8 years of mature stage seem to suggest that straw may have directly or indirectly supplied N to the rubber plants. Studies on the chemical kinetics of NH_4^+-N in soil after addition of rice straw in green-house and in field conditions have shown clearly that straw immobilises ammonium N[6]. One objection to the use of straw as a manure to short term crops is that it immobilises available soil N. While addition of straw with its high C/N ratio will immobilise soil N under rubber, this should not be considered as a disadvantage as no adverse effects like retardation of growth or deficiency symptoms were observed. In fact, a certain degree of immobilisation can be advantageous as it will reduce N losses from the rhizophere[2] and also perhaps regulate the N supply to rubber plants to satisfy its needs. In addition, straw is a good source of energy to micro-organisms in the soil[14]. It has been shown that application of rice straw markedly increased both heterotrophic and phototrophic N fixation, as measured by the acetylene-reduction activity[15]. Therefore, application of rice straw may have increased the N fixation capacity in rubber soils.

TABLE 9 OPTIMUM LEVELS OF N, P AND K DURING MATURE STAGE UNDER DIFFERENT MANAGEMENT PRACTICES USING RESPONSE SURFACE ANALYSIS

Nutrient	Without straw ($g\ t^{-1}yr^{-1}$)	With straw ($g\ t^{-1}yr^{-1}$)	Difference ($g\ t^{-1}yr^{-1}$)
N	46.5	21.8	24.7
P	44.9	46 4	–
K	123.8	105 9	17.9

TABLE 10. PREDICTED AND OBSERVED YIELD UNDER DIFFERENT MANAGEMENT PRACTICES

Value/yield	Without straw		With straw		Increase in yield
	($g\ t^{-1}yr^{-1}$)	($kg\ ha^{-1}yr^{-1}$)	($g\ t^{-1}yr^{-1}$)	($kg\ ha^{-1}yr^{-1}$)	($kg\ ha^{-1}yr^{-1}$)
Predicted value maximum point	24 2	1524	26 7	1682	158
Observed mean yield[a]	20 1	1264	22 0	1390	126

[a]Based on 8 years of maturity period

TABLE 11. EFFECT OF MULCHING AND K ON SOIL AND LEAF K CONTENT OF RUBBER PLANTS AT SIX YEARS AFTER PLANTING

Treatment	Soil K ($cmol\ kg^{-1}$)		Leaf K (%)	
	K0	K1	K0	K1
Naturals	0 087[a]	0 118[a]	0 667[a]	0.854[a]
Legumes	0.090[a]	0.117[a]	0 608[a]	0 938[a]
Dead mulch	0.169[b]	0 176[b]	1 104[b]	1 154[b]
LSD	0.028		0 1	

[a,b]The values are significantly different at the 0 05 probability level.

TABLE 12. EFFECT OF MULCHING AND K ON GIRTH AND TAPPABILITY OF RUBBER PLANTS AT SIX YEARS AFTER PLANTING

Treatment	Girth (cm)		Tappability (%)	
	K0	K1	K0	K1
Naturals	42.1[a]	47.9[a]	56[a]	71[a]
Legumes	46.6[b]	49.8[b]	72[b]	83[b]
Dead mulch	49.2[c]	50.2[b]	85[c]	87[b]
LSD	8.5		1.6	

[a,b,c]The values are significantly different at the 0.05 probability level.

TABLE 13. EFFECT OF MULCHING AND K ON YIELD OF RUBBER PLANTS (UP TO 8TH YEAR OF MATURITY)

Treatment	Yield ($g\ t^{-1}\ yr^{-1}$)		Yield ($Kg\ ha^{-1}\ yr^{-1}$)	
	K0	K1	K0	K1
Naturals	11.2[a]	13.2[a]	706[a]	832[a]
Legumes	11.9[a]	16.2[b]	750[a]	1021[b]
Dead mulch	18.9[b]	19.7[c]	1191[b]	1241[c]
LSD	2.5		158	

[a,b,c]The values are significantly different at the 0.05 probability level.

It is evident from the results that rice straw contains about 1.5%–2.0% of K in a highly available form. Incorporating 20–25 metric tons of straw as unburnt material during the 6 year immature period adds about 345 kg of K to the soil. This is in line with the previous studies[3,7] which have reported that rice straw contains about 1%–4% of K and incorporating 5 tons of straw adds about 100 kg of K to the soil. According to the data obtained, mulching with rice straw has improved the soil and leaf K contents. It appears that there was a response to K, suggesting that the soil used for this study was deficient in K. The K_0 treatment indicated a value of 0.08 cmol kg^{-1} of exchangeable soil K and it was considered to be deficient for normal growth of rubber under Sri Lankan conditions[16] and under Malaysian conditions[17].

K is one of the major nutrient elements required and taken up in large amounts by rubber plants beside N and P[18]. Plants cannot achieve maximum growth and yield without K, nor can the functions that K performs be fully carried out by another substituting element.

With application of rice straw, 63 g of K would be saved per plant during the last 3 years of the immature period. The requirement of K (as fertiliser) during the mature period appears to be lower under application of straw compared to without straw condition. It was further noted that the girth of rubber plants with recommended level of K were almost similar to the girth without K in combination with rice straw. As would be expected, this resulted in higher tappability in rubber trees with the combination of without K and application of rice straw. Similar results were also obtained for the yield and this may be due to the substitution of K by straw. It is well documented that an adequate supply of K has an important role in the water relation of plants[19]. It is also known that K plays a specific role in most plant species in opening and closing of stomata, a role which cannot be played by any other cation[20], and that better K^+ nutrition tended to increase the water content of the tissue[21]. It can also be stated that K sufficient plants are capable of an improved production of assimilates. The results of this study also seem to suggest that when rice straw is used for mulching it is possible that the performance of rubber plants may be improved as a result of the contribution of K by rice straw[22].

The currently recommended P level appears to be sufficient under conventional management practices (without straw) as indicated in the ANOVA and response surface analyses. However, an approximate increase of 20% is required in the presence of straw to optimise trunk girth. With application of rice straw, an additional 41 g of P per plant *i.e.* 22 g, 9 g and 10 g of P per plant during the 4th, 5th and 6th years should be given, respectively.[f] It is well documented that straw is a substrate for the growth of soil micro-organisms, as dry straw consists of about 40% (by weight) of biodegradable C. Thus straw incorporation in a soil leads to a burst of micro-organism activity[23] and phosphate will hasten aerobic decomposition[7]. It may be possible that available soil P was used by micro-organisms suggesting that the soil in the experimental area was deficient in P. The natural plots (control) indicated a value of 9 mg kg^{-1} of exchangeable soil P.

The data also indicated that micro-nutrients, Mn and Fe have increased with time after application of rice straw whereas the Zn content of the soil has decreased. However, the Fe content has declined towards the latter stage with the decomposition of rice straw. Hence, rice straw can also be considered as a source of micro-nutrients such as Mn and Fe. Yet, excess organic matter may be undesirable because it decreases the availability of Zn.

The influence of cover plants on soil improvement is of considerable importance although they may compete for essential nutrients with rubber plants (except for N). On the other hand, there is no such competition for nutrients with dead mulch[24]. Additionally, the gradual release of soil nutrient by mulch would have been a contributory factor in increasing the nutrient contents of rubber plants under mulched conditions. Another possible explanation for the better performance of rubber plants with mulching is that weed growth around the base of the rubber plants was significantly less when rice straw was applied as a mulch and the extra labour involved may be compensated by reduced weed growth[25]. Another advantage in application of paddy straw on soil fertility is the increase in CEC.

These results, therefore, seem to suggest that when rice straw is used for mulching, it is possible that the performance of rubber *Hevea* plants could be improved as a result of improvement in soil fertility

ACKNOWLEDGEMENT

The authors wish to thank Mrs Wasana Wijesuriya (biometrician) for her valuable assistance in statistical analysis

Date of receipt June 1998
Date of acceptance December 1998

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