EFFECT OF *PUERARIA PHASEOLOIDES* AND *MUCUNA BRACTEATA* ON THE PHYSICO-CHEMICAL PROPERTIES OF SOILS OF IMMATURE RUBBER PLANTATIONS

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Cultivation of the cover crops *Pueraria phaseoloides* and *Mucuna bracteata* was found to improve the soil physical properties in immature rubber (*Hevea brasiliensis*) plantations when compared to adjacent bare land. The bulk density of the soil was lower and porosity higher in the cover crop established field from the second year. The soil moisture retention was improved. The establishment of cover crops improved the soil nutrient availability and cation exchange capacity.

Key words: Cover crop, *Hevea brasiliensis, Mucuna bracteata, Pueraria phaseoloides,* Soil property.

Establishment of a leguminous cover crop in the immature phase of rubber (*Hevea brasiliensis*) plantation is an accepted agromanagement practice. Leguminous cover crops fix atmospheric nitrogen, enrich soil with organic matter, improve soil fertility, reduce soil erosion and suppress weed growth. Cover crops also help in the improvement of soil structure and other physical properties (Soong and Yap, 1976) resulting in a more favourable soil environment for root growth and proliferation. Legume covers help in enhancing the growth of rubber during the immature phase and reduce the immaturity period (Watson, 1961; Watson *et al.*, 1964; Mathew *et al.*, 1989; Punnoose *et al.*, 1994).

Pueraria phaseoloides and *Mucuna bracteata* are the two common cover crops grown in the rubber plantations in India. The comparative efficiency of these two crops on improvement of soil nutrient and moisture status as well as microbial population after three years of growth has been reported (Kothandaraman *et al.*, 1989). However, the effect of growing these cover crops on the soil physico-chemical properties has not been studied in detail. Hence a field study was conducted to evaluate the effect of establishment of *P. phaseoloides* and *M. bracteata* on physico-chemical properties of rubber growing soils.

Immature (1-5 years) rubber plantations with *P. phaseoloides* and *M. bracteata* as cover crops were identified in the Travancore Rubber and Tea Estate, Mundakayam, in Idukki District of Kerala State. Eight micro plots each 1x1 m size were demarcated at random in the respective areas with either of the cover crops within each age group. Three soil samples (0-10 cm, 10-30 cm and 30-60 cm) were collected from each micro plot.

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The texture, bulk density, particle density, porosity and moisture retention of the surface soil samples were determined. The particle size distribution was determined by the international pipette method (Piper, 1950). The bulk and particle density were determined from core samples (Black, 1965). Total porosity was calculated using the formula:

$$St = 100\ (1\text{-}Db/P)$$

where St is the total porosity, P the particle density and Db the bulk density. Moisture retention at – 0.033 MPa was determined using pressure plate apparatus. Organic carbon, available nutrients, pH and CEC were determined by the standard procedure (Jackson, 1967).

The particle size distribution of soils is given in Table 1. The data indicated that all the *M. bracteata* established fields were sandy clay loam in texture. The texture of *P. phaseoloides* fields from 1 to 5 years were clay loam, sandy clay loam, sandy loam, clayey and sandy clay loam respectively. The texture of bare lands varied from sandy clay loam to sandy loam.

The physical properties of the soil at 0-10 cm depth under the two legume covers and adjacent bare land in each situation are given in Table 2. Bulk density of soil in the cover crop established fields was significantly lower than in the adjacent bare land in all the years except in the one year old field. Both *P. phaseoloides* and *M. bracteata* fields were comparable for the bulk density of soil in all the years. The lower bulk density in the cover crop established fields indicates lesser compaction of soils in these fields than the bare land. This can be attributed to higher root density, which in turn leads to loosening of soil (Balamurugan *et al.*, 2000). No significant difference was observed in the particle density and porosity of soil in the one year old plantation. However, with higher age, lower particle density and higher porosity were evident. Similar results were reported by Soong *et al.* (1976).

Table 1. **Particle size distribution of soil**

Age (years)	Treatment	Components				Textural classification
		Coarse sand	Fine sand	Silt	Clay	
One	*P. phaseoloides*	32.10	8.20	16.50	36.75	clay loam
	M. bracteata	54.20	6.00	5.00	27.50	sandy clay loam
	Bare land	70.00	1.50	8.00	12.90	sandy loam
Two	*P. phaseoloides*	57.00	3.50	3.00	27.50	sandy clay loam
	M. bracteata	40.00	4.50	15.50	35.00	sandy clay loam
	Bare land	65.00	5.00	2.50	22.50	sandy clay loam
Three	*P. phaseoloides*	66.00	2.50	6.50	16.00	sandy loam
	M. bracteata	47.40	3.50	12.80	29.17	sandy clay loam
	Bare land	62.50	9.00	2.50	18.00	sandy loam
Four	*P. phaseoloides*	39.00	5.20	4.00	47.50	clay
	M. bracteata	61.50	8.00	3.00	21.60	sandy clay loam
	Bare land	64.00	3.50	11.50	13.50	sandy loam
Five	*P. phaseoloides*	51.00	6.00	17.00	25.50	sandy clay loam
	M. bracteata	43.50	7.10	10.50	31.50	sandy clay loam
	Bare land	50.00	8.20	16.00	24.30	sandy clay loam

Table 2. **Soil physical properties at 0-10 cm depth**

Property	Treatment	Age (year)				
		1	2	3	4	5
Bulk density (g/cc)	*P. phaseoloides*	1.15	1.25	1.27	0.89	1.01
	M. bracteata	1.13	1.25	1.20	0.96	1.07
	Bare land	1.29	1.50	1.47	1.14	1.29
	SE	0.05	0.03	0.02	0.03	0.04
	CD ($P \leq 0.05$)	NS	0.08	0.07	0.09	0.12
Particle density (g/cc)	*P. phaseoloides*	2.23	2.25	2.21	2.10	2.12
	M. bracteata	2.28	2.18	2.15	2.18	2.11
	Bare land	2.26	2.30	2.24	2.15	2.23
	SE	0.02	0.03	0.02	0.01	0.03
	CD ($P \leq 0.05$)	NS	0.08	0.05	0.04	0.09
Porosity (%)	*P. phaseoloides*	49.00	45.00	42.38	57.50	52.62
	M. bracteata	50.38	41.75	44.38	56.38	49.62
	Bare land	45.75	34.62	34.50	47.12	43.00
	SE	2.24	1.41	1.39	1.55	1.37
	CD ($P \leq 0.05$)	NS	4.16	4.10	4.57	4.03
Moisture retention at -0.033 MPa (%)	*P. phaseoloides*	20.48	17.18	21.56	26.64	22.17
	M. bracteata	19.60	22.21	21.19	24.94	25.43
	Bare land	20.34	16.63	17.75	23.34	18.95
	SE	0.82	0.48	0.57	0.85	0.87
	CD ($P \leq 0.05$)	NS	1.42	1.68	2.50	2.57

Porosity of the two cover crop fields was comparable in all the five years. Loosening of soil by the increased root concentration in the cover crop established fields and higher biological activity due to higher organic matter addition may have contributed to the better soil physical properties of cover crop established fields (Harris *et al.*, 1966; Brady, 2000).

Studies on water retention characteristics showed that soils under cover crop retained more moisture at field capacity (-0.033 MPa) than the bare lands. In one year old field no significant difference was noticed between the three treatments with regard to moisture retention. Later, an improvement in the moisture retention was noted in both the cover crop established fields. Between the two cover crop established fields, moisture retention in the two and five year old *M. bracteata* fields were significantly higher than the *P. phaseoloides* fields of corresponding age, while it was comparable in the third and fourth year fields. The higher moisture retention in the fields under cover crops may be due to the high organic matter addition by cover crops and the difference between the *P. phaseoloides* and *M. bracteata* fields may be attributed to the difference in quantity of organic matter added to the soil by the two crops. Kothandaraman *et al.* (1989) recorded comparatively more biomass in *M. bracteata* fields than *P. phaseoloides* fields. As these cover crops were established in areas differing in soil texture, the contribution of this factor in soil moisture retention could also be significant.

Chemical properties of the soil at 0-10 cm in the various fields are given in Table 3. The data indicated that pH of the soil in areas where *P. phaseoloides* was established were higher and those with *M. bracteata* lower than that of the adjacent bare lands. In the first, second and fifth year plantations significant difference in pH was noticed between the soils under the two cover crops. Tang and Yu (1999) observed that addition of plant residues to soil influences the soil pH depending on the concen-

Table 3. **Soil chemical properties at 0-10 cm depth**

Property	Treatment	Age (year)				
		1	2	3	4	5
pH	*P. phaseoloides*	4.93	4.94	4.35	4.72	4.65
	M. bracteata	4.59	4.39	4.19	4.65	4.40
	Bare land	4.66	4.64	4.10	4.60	4.50
	SE	0.07	0.09	0.08	0.09	0.06
	CD (P≤0.05)	0.20	0.26	NS	NS	0.19
OC (%)	*P. phaseoloides*	1.41	1.65	1.89	2.19	2.36
	M. bracteata	1.90	2.38	2.32	1.82	2.52
	Bare land	1.72	1.46	1.52	1.76	1.55
	SE	0.11	0.10	0.10	0.11	0.15
	CD (P≤0.05)	0.32	0.29	0.28	0.33	0.45
CEC (c moles/kg)	*P. phaseoloides*	6.54	6.92	7.75	8.64	8.90
	M. bracteata	7.75	11.05	8.35	7.78	9.16
	Bare land	6.16	6.52	5.10	6.19	6.19
	SE	0.61	0.60	0.55	0.43	0.60
	CD (P≤0.05)	NS	1.77	1.63	1.27	1.78
Available P (mg/100g)	*P. phaseoloides*	1.15	2.62	1.25	2.94	1.06
	M. bracteata	0.62	0.65	1.27	2.20	2.49
	Bare land	0.95	1.01	0.94	1.14	1.23
	SE	0.23	0.55	0.34	0.42	0.41
	CD (P≤0.05)	NS	1.63	NS	1.23	1.09
Available K (mg/100g)	*P. phaseoloides*	7.46	11.40	8.66	14.52	9.89
	M. bracteata	6.64	8.57	9.02	12.91	10.78
	Bare land	5.61	5.86	6.03	10.97	8.81
	SE	0.88	0.78	0.61	1.61	0.64
	CD (P≤0.05)	NS	2.30	1.81	NS	NS
Available Ca (mg/100g)	*P. phaseoloides*	30.57	20.81	16.97	22.96	27.69
	M. bracteata	9.40	11.50	19.76	18.77	30.12
	Bare land	10.98	14.38	15.76	10.72	13.61
	SE	2.27	2.21	2.35	3.60	4.14
	CD (P≤0.05)	6.68	6.50	NS	NS	12.18
Available Mg (mg/100g)	*P. phaseoloides*	5.45	4.64	4.25	6.43	5.03
	M. bracteata	3.26	4.42	4.87	4.20	5.44
	Bare land	2.86	3.07	3.21	7.31	3.65
	SE	0.61	0.61	0.43	0.98	0.58
	CD (P≤0.05)	1.79	NS	1.27	NS	NS

tration of the excess cations/organic anions and nitrogen present in the residues. Ammonification of nitrogen in plant residue, addition of basic cations and decarboxylation of organic anions also lead to an increase in soil pH (Hoyt and Turner, 1975; Bessho and Bell, 1992; Barekzai and Mengal, 1993). Porter *et al.* (1980), Helyar (1976) and Bolan *et al.* (1991) reported that release of H^+ ions associated with organic anions and nitrification of mineralised nitrogen with a loss of nitrate by leaching result in the decrease of soil pH. The relatively higher soil pH of the *P. phaseoloides* fields may be due to the higher K, Ca and Mg content and faster decomposition of *P. phaseoloides* litter.

In general, organic carbon status of the cover crop established fields was higher than that of the bare land. *M. bracteata* fields of two years and more age registered a significantly higher organic carbon status than the bare land. The same trend was observed in the *P. phaseoloides* fields also from the third year onwards. In the second and third year plantations, organic carbon (OC) of the *M. bracteata* fields was significantly higher than that of the *P. phaseoloides* fields. The higher dry matter production of *M. bracteata* compared to *P. phaseoloides* may lead to higher OC status of the *M. bracteata* fields.

The data indicated that establishment of cover crops improves the cation exchange capacity of the soil. From third year fields onwards, the CEC of soil in the fields under both cover crops were significantly higher than the adjacent bare land. Between the two cover crop established fields, there was no significant difference in the CEC. The higher CEC of the soils in cover cropped fields may be due to their high organic matter content.

In general, available nutrients were higher in the cover cropped fields than the bare land. Between the two cover cropped fields no significant differences were observed. The available K content of the two year old field with *P. phaseoloides* was significantly higher than that with *M. bracteata* while the third year fields were comparable in K status. The first and second year *P. phaseoloides* fields registered a significantly higher available Ca than the *M. bracteata* fields and in the later year fields no such difference was noticed. The available Mg of the one year old *P. phaseoloides* established field was significantly higher than that of the *M. bracteata* field and in the later years no such difference was noticed. The higher availability of nutrients in the cover cropped fields may be attributed to the high organic matter content in these fields. Organic acids produced during the decomposition of organic matter solubilizes bound nutrients and enhances the nutrient availability. Higher microbial population in the legume root rhizosphere also leads to increase in nutrient availability. The higher pH of soil and more K, Ca and Mg content of *P. phaseoloides* litter and its faster decomposition than that of the M. *bracteata* may lead to higher availability of nutrients under the former.

Soil chemical properties at 10-30 cm depth are given in Table 4. The pH of the two and three year old *P. phaseoloides* fields was significantly higher than that of *M. bracteata* fields. In the older plantations there was no significant difference between the soils in pH. Organic carbon content of the *M. bracteata* cover cropped field was significantly higher than that of *P. phaseoloides* in the initial three years and in the older fields there was no significant difference. In

Table 4. **Soil chemical properties at 10-30 cm depth**

Property	Treatment	Age (year)				
		1	2	3	4	5
pH	*P. phaseoloides*	4.74	4.77	4.32	4.57	4.60
	M. bracteata	4.61	4.28	4.05	4.44	4.43
	Bare land	4.67	4.61	4.01	4.54	4.50
	SE	0.05	0.09	0.08	0.08	0.07
	CD (P≤0.05)	NS	0.28	0.24	NS	NS
OC (%)	*P. phaseoloides*	1.10	1.11	1.30	1.85	2.05
	M. bracteata	1.68	1.82	1.70	1.61	1.96
	Bare land	1.40	1.22	1.41	1.61	1.39
	SE	0.08	0.07	0.10	0.10	0.13
	CD (P≤0.05)	0.24	0.21	0.29	NS	0.39
Avaialble P (mg/100g)	*P. phaseoloides*	0.88	0.46	0.46	1.84	0.61
	M. bracteata	0.33	0.38	0.57	1.42	1.15
	Bare land	0.66	0.59	0.45	1.21	1.10
	SE	0.21	0.13	0.19	0.35	0.24
	CD (P≤0.05)	NS	NS	NS	NS	NS
Avaialble K (mg/100g)	*P. phaseoloides*	6.33	6.92	6.65	13.38	8.40
	M. bracteata	4.81	5.84	8.02	12.98	9.56
	Bare land	5.74	4.88	5.27	8.01	7.97
	SE	0.62	0.58	0.47	1.51	0.82
	CD (P≤0.05)	NS	NS	1.37	4.45	NS
Avaialble Ca (mg/100g)	*P. phaseoloides*	18.04	8.71	8.73	8.89	12.67
	M. bracteata	2.87	3.63	9.56	9.56	15.93
	Bare land	8.10	8.77	11.58	7.69	8.15
	SE	1.95	1.79	1.55	1.78	3.30
	CD (P≤0.05)	5.75	NS	NS	NS	NS
Avaialble Mg (mg/100g)	*P. phaseoloides*	2.85	2.06	1.94	3.07	2.76
	M. bracteata	1.28	1.75	2.48	2.53	3.48
	Bare land	2.29	1.90	2.40	5.57	2.16
	SE	0.43	0.43	0.25	0.90	0.59
	CD (P≤0.05)	NS	NS	NS	NS	NS

all the five years there was no significant difference in available phosphorus and magnesium content of the three fields. The available K content in the cover cropped fields was higher than that in the bare land in the three and four year old fields though there was no significant difference in the other age groups. There was no significant difference in available calcium of the three treatments in all the five years of growth except in the first year.

Table 5 shows the soil chemical properties at 30-60 cm depth and it indicates a similar trend as that in the 10-30 cm depth. pH of the *P. phaseoloides* cover cropped fields was higher than that of *M. bracteata* fields. Organic carbon content of the one and two year old *M. bracteata* fields was significantly higher than that of the *P. phaseoloides* fields though in the following years there was no

Table 5. **Soil chemical properties at 30-60 cm depth**

Property	Treatment	Age (year)				
		1	2	3	4	5
pH	*P. phaseoloides*	4.62	4.55	4.22	4.59	4.64
	M. bracteata	4.65	4.27	4.00	4.65	4.62
	Bare land	4.70	4.49	3.98	4.54	4.46
	SE	0.05	0.06	0.07	0.05	0.07
	CD (P≤0.05)	NS	0.18	0.19	NS	NS
OC (%)	*P. phaseoloides*	0.91	0.79	0.95	1.57	1.55
	M. bracteata	1.48	1.32	0.98	1.53	1.66
	Bare land	1.18	1.04	1.15	1.48	1.37
	SE	0.08	0.08	0.07	0.09	0.14
	CD (P≤0.05)	0.24	0.23	NS	NS	NS
Available P (mg/100g)	*P. phaseoloides*	0.38	0.12	0.29	1.18	0.48
	M. bracteata	0.29	0.26	0.24	0.91	0.92
	Bare land	0.49	0.44	0.23	1.08	0.88
	SE	0.11	0.07	0.05	0.25	0.15
	CD (P≤0.05)	NS	0.22	NS	NS	NS
Available K (mg/100g)	*P. phaseoloides*	5.79	5.48	6.00	11.98	6.61
	M. bracteata	3.91	4.42	6.01	11.22	8.81
	Bare land	4.60	4.86	5.53	10.71	6.98
	SE	0.55	0.59	0.52	1.43	0.94
	CD (P≤0.05)	NS	NS	NS	NS	NS
Available Ca (mg/100g)	*P. phaseoloides*	10.44	8.28	8.44	7.70	13.02
	M. bracteata	2.01	3.96	6.82	10.24	17.46
	Bare land	5.83	10.2	12.43	8.12	7.55
	SE	1.52	1.46	1.75	1.85	2.72
	CD (P≤0.05)	4.48	4.30	NS	NS	NS
Available Mg (mg/100g)	*P. phaseoloides*	1.98	1.52	1.94	2.61	2.67
	M. bracteata	1.49	1.47	2.26	2.37	3.41
	Bare land	1.82	2.09	2.25	5.09	2.12
	SE	0.28	0.23	0.26	0.82	0.53
	CD (P≤0.05)	NS	NS	NS	NS	NS

significant difference. In fields of all the five years age the three treatments showed no significant difference in their available P, K and Mg at 30-60 cm depth. In the initial two years, available Ca of the areas cover cropped with *P. phaseoloides* was significantly higher than that with *M. bracteata*. However, in the older fields no significant difference was noticed. The results in the Tables 4 and 5 indicate that in deeper soil there was not much difference between areas with the two cover crops in their organic carbon and available nutrient contents.

The present study indicates that growing of leguminous cover crops in the immature phase of rubber improves soil physical properties and availability of nutrients. Both *P. phaseoloides* and *M. bracteata* are comparable in improving the soil physical properties. The *M. bracteata* fields registered a higher organic carbon status than the *P. phaseoloides* fields.

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REFERENCES

Balamurugan, J., Kumaraswamy, K. and Rajarajan, A. (2000). Effect of *Eucalyptus citriodora* on the physical and chemical properties of soils. *Journal of the Indian Society of Soil Science*, **48**(3) : 491-495.

Barekzai, A. and Mengal, K. (1993). Effect of microbial decomposition of mature leaves on soil pH. *Zeitschrifttur Ptlanzenernahrung and Bodenkude*, **156** : 93-94.

Bessho, T. and Bell, L.C. (1992). Soil solid and solution phase changes and mung bean response during amelioration of Al toxicity with organic matter. *Plant and Soil*, **140** : 183-196.

Black, C.A. (1965). Methods of Soil Analysis. Part I. American Society of Agronomy, USA, 770p.

Bolan, N.S., Hedley, M.J. and White, R.E. (1991). Process of soil acidification during nitrogen cycling with emphasis on legume based pastures. *Plant and Soil*, **134**: 53-63.

Brady, N.C. (2000). The Nature and Properties of Soils. Ed. 10. Prentice Hall of India, New Delhi, 621p.

Harris, R.F., Chesters, G. and Allen, O.N. (1966). Dynamics of soil aggregation. *Advances in Agronomy*, **18** : 107-169.

Helyar, K.R. (1976). Nitrogen cycling and soil acidification. *Journal of Australian Institute of Agricultural Science*, **42** : 217-221.

Hoyt, P.B. and Turner, R.C. (1975). Effects of organic materials added to very acid soils on pH, Al, exchangeable NH_4 and crop yields. *Soil Science*, **119** : 227-237.

Jackson, M.L. (1967). Soil Chemical Analysis. Prentice Hall of India, New Delhi, 498p.

Kothandaraman, R., Mathew, J., Krishnakumar, A.K., Joseph, K., Jayarathnam, K. and Sethuraj, M.R. (1989). Comparative efficiency of *Mucuna bracteata* D.C. and *Pueraria phaseoloides* Benth. on soil nutrient enrichment, microbial population and growth of *Hevea*. *Indian Journal of Natural Rubber Research*, **2**(2) : 147-150.

Mathew, M., Punnoose, K.I., Potty, S.N. and George, E.S. (1989). A study of the response in yield and growth of rubber grown in association with legume and natural ground cover during the immature phase. *Journal of Plantation Crops*, **16**(Supplement) : 433-441.

Piper, C.S. (1950). Soil and Plant Analysis. University of Adelaide, Adelaide, 368p.

Porter, W.M., Cox, W.J. and Wilson, I. (1980). Soil acidity: Is it a problem in Western Australia? *Western Australian Journal of Agriculture*, **21** : 126-133.

Punnoose, K.I., Mathew, M., Pothen, J., George, E.S. and Lakshmanan, R. (1994). Response of rubber to fertilizer application in relation to type of ground cover maintained during immature phase. *Indian Journal of Natural Rubber Research*, **7**(1) : 38-45.

Soong, N.K. and Yap, W.C. (1976). Effects of cover management on physical properties of rubber growing soils. *Journal of Rubber Research Institute of Malaysia*, **24**(3) : 145-159.

Tang, C. and Yu, Q. (1999). Impact of chemical composition of legume residues and initial soil pH on pH change of a soil after residue incorporation. *Plant and Soil*, **215** : 29-38.

Watson, G.A. (1961). Cover plants and soil nutrient cycle in *Hevea* cultivation. *Proceedings of Natural Rubber Research Conference*, 1960, Kuala Lumpur, pp. 352-361.

Watson, G.A., Wong Phui Weng and Narayanan, R. (1964). Effects of cover plants on soil nutrient status and on growth of *Hevea* III. A comparison of leguminous creepers with grasses and *Mikana cordata*. *Journal of Rubber Research Institute of Malaya*, **18**(2) : 80-95.