EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON SOIL QUALITY AND GROWTH OF *HEVEA BRASILIENSIS* DURING THE IMMATURE PHASE

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Integrated nutrient management through bio-fertilizers, green manure and chemical fertilizers can sustain soil quality and improve plant growth. An experiment was conducted to study the effect of integrated nutrient management through a bio-fertilizer consortium consisting of *Azotobacter* sp., Phosphobacteria (*Bacillus* sp.), *Pseudomonas* sp. and K-mobilising bacteria (*Fracturia* sp.) along with green manure, *Gliricidia* and chemical fertilizers (NPKMg) on soil quality and growth of natural rubber *(Hevea brasiliensis)* during the immature phase. The experiment was initiated in a farmer's field at Yenthayar, in Kottayam district, Kerala in 2007 and continued for five years till, 2011. The results showed that the organic carbon, total N and available forms of K, Ca and Mg in soil were significantly higher in the treatment with chemical (50 % of the recommended dose of NPKMg) and bio fertilizers, green manure under natural cover compared to the control treatment *viz.*,100 per cent recommended dose of NPKMg in *Mucuna* ground cover. It was also observed that in the same integrated treatment, the soil quality indices *viz.*, soil respiration rate and permanganate oxidizable soil organic carbon were also significantly high compared to the control indicating the beneficial effects of integrated nutrient management through chemical fertilizers, bio-fertilizers and green manure *(Gliricidia)*. The input of chemical fertilizers can be reduced to half upon integration with bio-fertilizers and green manure for immature rubber. No significant difference in growth of rubber plants could be observed among the different treatments.

Keywords: Bio-fertilizer, *Gliricidia*, Green manure, Integrated nutrient management, *Mucuna bracteata*, Natural ground cover, Rubber

INTRODUCTION

Nutrient management through inorganic chemical fertilizers is a common practice in almost all the agricultural crops, so also in the case of natural rubber (*Hevea brasiliensis*). Except for the addition of about 12 kg of farm yard manure in the planting pit initially, most of the farmers apply only chemical fertilizers for nutrient management in their fields. It is a fact that the soil health of the rubber fields of the initial planting cycle could not be sustained in the subsequent planting cycles, instead a declining trend is observed as the planting

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cycle proceeds. Continuous cultivation of rubber resulted in a decline of soil organic carbon content and soil pH (Karthikakuttyamma *et al.*, 1995; Abraham *et al.*, 2001; Ulaganathan *et al.*, 2010). There are also growing environmental concerns over the loss of applied chemical fertilizers to the environment from agricultural fields. In view of all these, it has become an important strategy in nutrient management to increase the efficiency of applied inorganic fertilizers in rubber fields.

There are many reports in different crops that chemical fertilizers when combined with organic manures are more beneficial to the crops and to the environment (Philip *et al.*, 2012). Due to the increased efficiency of chemical fertilizers when integrated with organic manures, less quantity of fertilizer is required which checks the pollution as well. However, the scarcity in the availability of organic manures and their increasing cost are problems and to a certain extent green manure is a solution, especially if it could be generated *in situ*. There are studies which showed that green manures are useful in improving the efficiency of inorganic fertilizers (Becker *et al.*, 1990; Oglesby and Fownes, 1992). Tree pruning, derived from leguminous trees such as *Gliricidia sepium* is a good source of N (Szott and Kass, 1993) and improves organic matter, microbiological activity and physical properties of the soil (Kang *et al.*, 1986; Singh *et al.*, 1991). The utilization of green manures as alternatives to reduce the use of mineral fertilizers is considered as a good agricultural practice (Tejada *et al.*, 2008). In a detailed review of *G. sepium* as a green manure, Srinivasarao *et al.*, (2011), reported improvement in soil biological health in terms of population of fungi, bacteria, actionomycetes, total microbial count, microbial biomass carbon and nitrogen.

Bio-fertilizers include beneficial microorganisms which increase nutrient availability in soil. Bio-fertilizers had been proven to be beneficial for cereal and vegetable crops (Mehrotra and Lehri, 1971; Dewan and Rao, 1979; Venkateswarlu and Rao,1983; Hadas and Okon, 1987; Becker *et al.*, 1990)and for the growth of nutmeg seedlings (Nair and Chandra, 2011), black pepper (Bopaiah and Khader, 1989) and rubber seedlings (Syamala *et al.*, 2012).

The present study is aimed at understanding the effect of integrated nutrient management comprising, chemical fertilizers, bio-fertilizers and green manure on soil quality and growth of natural rubber.

MATERIALS AND METHODS

The study was conducted at Pottamkulam Estate, Yenthayar near Mundakayam in Kottayam district (N 9° 37′, E 76° 54′) during the period 2007 -2011. A field experiment was laid out in randomized block design with seven treatments and three replications. Polybag plants of the clone RRII 414 were planted in the field in June, 2007 with a spacing of 6.7 m x 3.4 m. Gross and net plants per plot were 24 and 6 plants, respectively. The treatments were T_1) natural ground cover (NC, T_2) *Mucuna* ground cover (MC, T_3) natural ground cover + bio-fertilizer (NC+BF, T_4) *Mucuna* ground cover + bio-fertilizer (MC+BF, T_5) natural ground cover + bio-fertilizer + *Glricidia* green manure (NC+BF+G, T_6) *Mucuna* ground cover + bio-fertilizer +*Glricidia* green manure (MC+BF+G and T_7) Control - *Mucuna* ground cover + 100% standard dose of NPKMg. Treatments T_1 to T_6 received 50% of the standard dose of NPKMg. *Gliricidia* stumps were planted at the lower slope side of the rubber plants at 60 cm spacing in the treatments, T_5 and T_6.

Chemical fertilizer mixture (NPKMg) was added in two equal splits during May/June and September/October every year. The recommended rate of NPKMg for rubber is, 10:10:4:1.5 NPKMg mixture @ 450, 900, 1100, 900 g $plant^{-1}$ during year 1 to 4, respectively and 10:10:10 NPK mixture @ 300 g $plant^{-1}$ during the 5^{th} year. The sources of N, P, K, Mg were urea, rock phosphate, muriate of potash and magnesium sulphate. The fertilizers were applied to the plant basin with gentle forking to mix with the soil and mulched with pruning of natural cover, *Mucuna* or *Gliricidia* as per the treatment. In the initial two years the mulching materials were negligible in quantity and in the subsequent years the weight of materials used for mulching was recorded and their nutrient contents were determined.

The microbial inoculants *viz.*, *Azotobacter* sp., phosphobacteria (*Bacillus* spp.) and *Pseudomonas* spp. were selected from rubber plantations in Kerala and *Fracturia* sp. from Regional Centre for Organic Farming, Banglore and multiplied for field application at RRII. Each culture containing a population of 10^8 cfu mL^{-1} was prepared and used for the study. Required volumes of the four cultures were mixed and diluted using cow-dung slurry and applied to the plants. Bio-fertilizer consortium was applied about one month after the application of chemical fertilizer. During the first year, 10 mL of each culture solution was mixed and applied per plant. In subsequent years bio-fertilizer solutions were applied twice per annum and the dose of each culture solution per application were 15 mL during second year, 20 mL during third year and 25 mL during fourth and fifth years per plant.

Three soil samples were collected from each plot and composited and subjected to chemical analyses. The sample collection was carried out one month after the application of bio-fertilizer on an annual basis. Organic carbon, available forms of P, K, Ca and Mg and pH were determined. Permanganate oxidizable soil carbon (POSC) and total N were also analyzed for the samples collected during 2011. Field soil respiration *(in situ)* measurements were taken in 2011 using an automated soil respiration analyzer (Licor USA, model 8100). Measurements were taken from the platform region at three sites near three alternate observation trees in each plot by open chamber technique. Total carbon (TC) and total nitrogen (TN) were estimated following dry combustion method using an automated elemental analyzer (Leco Truspec CN) as described by Nelson and Sommers (1996). The total carbon content estimated is organic carbon (OC) as the soils were acidic and no inorganic forms of carbon present in any of the soils investigated. Other nutrients were estimated following standard methodologies as described in Jackson (1958). The available phosphorus (Av.P) was extracted using Bray II solution and estimated colorimetrically by molybdenum blue method. Available potassium (Av.K) was extracted using Morgan's extractant and estimated by flame photometer method. Available calcium (Av.Ca) and available magnesium (Av.Mg) were estimated using atomic absorption spectrometer after extracting by 1N neutral ammonium acetate solution. POSC was determined as per the method described by Weil *et al.* (2003) and Reddy (2010). Air dried soil sample (3 g) was mixed with 30 mL of 20 m*M* $KMnO_4$ solution and shaken for 15 minutes. After centrifuging the mixture, 2 mL of the aliquot diluted to 50 mL and colour intensity was measured at 560 nm. Amount of $KMnO_4$ reacted and its equivalent soil C was determined using a standard graph. Girth of the rubber plants in each plot was measured at a height of 150 cm from the bud union.

The data generated on soil parameters and girth of plants were subjected to analysis of variance to find out the differences if any among the treatments using SPSS package.

RESULTS AND DISCUSSION

The results of soil chemical analysis before starting the experiment are given in Table 1. The soil organic carbon and available nutrient status were high in the experimental area. The soils of all the plots were highly acidic.

Table 1. **Pre-treatment soil nutrient status of the experiment site**

Soil property	Status
OC (%)	2.1
Av.P (mg 100 g^{-1})	7.1
Av.K (mg 100 g^{-1})	34.0
Av.Ca (mg 100 g^{-1})	13.0
Av.Mg (mg 100 g^{-1})	6.2
pH	4.15

The treatments did not result in significant difference in soil nutrient status and pH in the soil samples during the second and third year of the experiment *viz.* in 2008 and 2009. During the initial two years the amount of mulches incorporated was negligible. During these years, addition of half the recommended rate of nutrients along with ground covers *viz.*, natural weeds or leguminous *Mucuna* cover (T_1 and T_2) or their combination with bio-fertilizers (T_3 and T_4) or green manures (T_5 and T_6) did not change the soil properties significantly.

The average weight of the incorporated mulch materials in each treatment were recorded and are given in Table 2. The quantity of mulch materials generated and incorporated in the treatments with *Gliricidia* (T_5 and T_6)were more compared to all other treatments. The growth of *Gliricidia* was hindered by the twining nature of *Mucuna* in the treatment T_6 and had reflected in the quantity of mulch generated (Table 2).

During the third year of the experiment in 2009, there was no significant variations among the treatments in plant growth or soil nutrient status (Table 3). However, in general, in all the treatments an upward trend in soil OC and pH could be observed compared to the initial soil status.

The soil properties during 2010 (Table 4) shows the variations in OC status among

Table 2. **Mean weight of mulch materials (g $plant^{-1}$) incorporated in different treatments during 2009, 2010 and 2011**

Treatment	2009				2010				2011			
	NC	MC	G	Total	NC	MC	G	Total	NC	MC	G	Total
1. NC	167	-	-	167	200	-	-	200	197	-	-	197
2. MC	-	163	-	163	-	-	-	210	-	285	-	285
3. NC+BF	155	-	-	155	220	-	-	220	182	-	-	212
4. MC+BF	-	182	-	182	-	250	-	250	-	340	-	340
5. NC+BF+G	145	-	475	620	205	-	845	1050	200	-	1155	1355
6. MC+BF+G	-	192	240	432	-	245	320	565	-	320	490	810
7. Control	-	215	-	215	-	275	-	275	-	410	-	410

NC- Natural cover, MC- *Mucuna*, G-*Gliricidia*, BF-Bio-fertilizer

Table 3. **Soil properties under different treatments in 2009**

Treatment	OC (%)	Av.P	Av.K	Av.Ca (mg 100 g^{-1})	Av.Mg	pH
1. NC	2.4	8.5	25.7	15.5	6.2	4.52
2. MC	2.4	15.5	15.7	18.3	8.0	4.49
3. NC+BF	2.3	26.5	18.6	24.0	8.7	4.46
4. MC+BF	2.1	23.5	24.3	19.1	8.3	4.73
5. NC+BF+G	2.2	26.6	17.6	21.1	7.0	4.49
6. MC+BF+G	2.6	11.3	12.2	18.6	6.2	4.29
7. Control	2.7	21.3	17.8	15.9	6.4	4.41
CD ($P < 0.05$)	NS	NS	NS	NS	NS	NS

different treatments. The integrated application of nutrients *viz.* chemical fertilizer (half the recommended rate of NPKMg), bio-fertilizer and the green manure, *Gliricidia* (T_5 and T_6) were found to be effective in building up soil OC status. The treatment, T_5 had significantly higher available nutrients such as K, Ca and Mg compared to the control (T_7). However, no marked differences could be noticed in the case of other nutrients among the treatments in the fourth year of the experiment.

Table 5 shows the effect of different treatments on soil properties during 2011. The treatments T_5 and T_6 recorded significantly higher OC status compared to control. The combination of green manure of *Gliricidia* and the two mulch materials, natural cover or *Mucuna* cover, had significantly improved the soil OC status. There was no significant difference in soil OC status between the treatments T_1 and T_2, indicating that the effects of *Mucuna* or natural ground cover were similar in improving the soil OC status.

In treatments T_5 and T_6, where green manure derived from *Gliricidia* was used, the POSC in the soil also had shown an improvement. It indicates the possibility of improvement of active or labile carbon pool through the application of *Gliricidia* mulch. The active or labile carbon pool in the soil is

Table 4. **Soil properties under different treatments in 2010**

Treatment	OC (%)	Av.P	Av.K	Av.Ca (mg 100 g^{-1})	Av.Mg	pH
1. NC	3.2	2.9	36.6	19.1	5.5	4.57
2. MC	2.8	1.1	29.4	13.7	3.6	4.48
3. NC+BF	2.7	3.0	30.9	16.1	4.8	4.67
4. MC+BF	2.8	1.6	25.1	14.5	4.4	4.48
5. NC+BF+G	3.8	0.9	40.4	28.9	8.1	4.65
6. MC+BF+G	3.7	1.3	33.7	13.2	3.6	4.48
7. Control	2.9	1.4	28.0	14.5	3.7	4.41
CD ($P < 0.05$)	0.63	NS	7.56	8.18	2.67	NS

Table 5. **Soil properties under different treatments in 2011**

Treatment	OC (%)	Av.P	Av.K	Av.Ca	Av.Mg	pH	POSC (ppm)	TN (%)	Respiration rate (μmols $m^{-2}s^{-1}$)
		(mg 100 g^{-1})							
1. NC	3.3	5.0	10.0	19.1	7.3	4.65	638.8	0.29	5.20
2. MC	3.1	2.7	8.4	11.0	2.8	4.55	592.1	0.22	4.47
3. NC+BF	3.3	16.9	21.0	32.8	10.4	5.00	636.8	0.29	4.08
4. MC+BF	3.5	5.9	9.1	14.9	3.4	4.56	694.3	0.25	4.57
5. NC+BF+G	4.0	12.8	30.9	67.5	26.6	5.32	867.7	0.31	8.08
6. MC+BF+G	3.9	2.3	9.9	15.1	3.7	4.54	746.8	0.30	5.93
7. Control	3.4	11.7	9.3	18.2	3.6	4.40	690.1	0.30	4.40
CD (P < 0.05)	0.47	NS	8.35	15.68	6.49	0.36	60.74	0.049	2.06

reported to be greatly influencing the microbial activity. Significantly higher content of POSC in treatment T_5, had reflected in the soil respiration rate (Table 5). The high quality litter of *Gliricidia* and the litter from the diverse weed species might have positively influenced the soil respiration rate in the treatment T_5. Similar observations of improving labile carbon pool in soil by the application of the green manure, *Sesbania* were reported by Verma *et al.*, (2010) who also reported that the POSC is a sensitive and stable index of labile C.

Available cations such as K, Ca and Mg were also found to be significantly higher in treatment T_5 compared to control (T_7, Table 5). It indicates the positive effect of integrating a reduced dose of chemical fertilizer, bio-fertilizer consortium and green manure. The green manure derived from *Gliricidia* when integrated with bio-fertilizer consortium was found to be much more effective in natural ground cover than in *Mucuna* cover in improving the available K, Ca and Mg contents in soil. The available K, Ca and Mg contents were not significantly different in treatments T_1, $T_2$and T_7. Application of half or full dose of fertilizers along with either of the ground cover or *Mucuna* did not result in any significant changes in soil K, Ca and Mg status. However, when half the recommended rate of nutrients was integrated with bio-fertilizers, significant improvement in available K, Ca and Mg (T_3 and T_4; Table 5) was observed. The improvements in the available nutrient status (K, Ca and Mg) were even more significant when green manure derived from *Gliricidia* was integrated with chemical fertilizer and bio-fertilizer.

When the total nitrogen in soil was considered, T_1 was better than T_2 indicating that the half dose of standard NPKMg fertilizer in natural ground cover resulted

Table 6. **Girth of rubber plants under different treatments in the year 2011**

Treatment	Girth of rubber plants (cm) in 2011
1. NC	38.3
2. MC	38.3
3. NC+BF	39.9
4. MC+BF	36.8
5. NC+BF+G	37.5
6. MC+BF+G	33.8
7. Control	36.9
CD	NS

Table 7. **Correlation among different soil properties**

	TN	OC	POSC	pH	Av.Ca	Av.Mg	Av.P	Av.K	Soil respiration
TN	1.00								
OC	0.65 **	1.00							
POSC	0.49 *	0.74 **	1.00						
pH	0.32	0.36	0.38	1.00					
Av.Ca	0.44	0.47	0.63	0.85 **	1.00				
Av.Mg	0.45	0.51	0.62	0.85 **	0.97	1.00			
Av.P	0.25	0.10	0.17	0.48	0.37	0.28	1.00		
Av.K	0.27	0.34	0.59	0.83 **	0.76	0.72	0.63	1.00	
Soil respiration	0.24	0.52 *	0.66 **	0.54 **	0.59	0.57	0.23	0.60	1.00

*Significant at P<0.05; **Significant at P<0.01

in more N in the soil than in *Mucuna* ground cover. Integration of bio-fertilizer with chemical fertilizer (T_4) was not very effective; however, when green manure was also incorporated (T_5) significant improvement in total nitrogen could be observed when *Mucuna* was the ground cover. It indicated the enhancement of the efficiency of bio-fertilizer when applied along with green manure. However, in natural cover no such trend in soil N could be observed. Total N was on par in soils where recommended rate of application of nutrients and integrated application of half the recommended rate of NPKMg, bio-fertilizer and green manure were applied. Similar results were reported earlier. The application of *Gliricidia* green manure had improved soil nutrient status and soil quality. The integration of *Gliricidia* green manure with chemical fertilizers was reported to be beneficial for sustaining stable agricultural systems (Priyanka, 2010).

The soil pH was found to be significantly varying among the different treatments during 2011 (Table 5). In general, the treatments where natural weeds as the ground cover, soil pH was found to be higher than in treatments with *Mucuna* as the ground cover. There was not much variation among the soil pH in treatments where *Mucuna* was the ground cover *viz.*, T_2, T_4, T_6 and T_7. The integration of chemical fertilizer with bio-fertilizer or green manure was not effective in changing the pH in soils under *Mucuna* ground cover. However, the integration of bio-fertilizer or green manure with chemical fertilizers had significantly reduced soil acidity in treatments with natural ground cover (T_3 and T_5). The soils under the treatments T_3 and T_5, in natural ground cover had significantly higher pH or less acidity than the control treatment with full dose of chemical fertilizer in *Mucuna* cover.

Though certain changes could be observed in soil nutrient status and pH, no significant difference was observed for the girth of the rubber plants among the different treatments during the initial period and also in the fifth year of the experiment (Table 6).

Correlation among the different soil properties are shown in Table 7. Soil OC is significantly and positively correlated with POSC. Soil OC is also correlated with soil respiration ($P < 0.05$), while the relationship between POSC and soil respiration is highly significant ($P < 0.01$). Highly significant correlation also existed between pH and soil respiration. Strong relationship observed between soil pH and available forms of Ca and Mg. These results indicate that POSC is a good soil quality indicator to represent soil microbial activity or respiration rate. It also indicated that soil acidity influence soil microbial activity along with organic matter quality.

CONCLUSION

The study indicated that growing *Gliricidia* is feasible in immature rubber fields especially in natural ground cover. The integrated application of green manure derived from *Gliricidia*, biofertilizers and half the recommended rate of NPKMg improved soil health in the immature rubber fields. The combination significantly improved the quality and quantity of organic matter in soil which in turn had reflected on higher soil microbial activity or soil respiration rate. The rate of application of NPKMg in immature rubber fields can be reduced to half if applied along with bio-fertilizer and green manure. It was also observed that the soil pH was slightly lower in treatments under *Mucuna* cover than treatments under natural ground cover. The growth of *Hevea* in the immature phase was not found to be varying among the different treatments.

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