

## TOLERANCE OF RUBBER PLANTATIONS TO DROUGHT AND ATMOSPHERIC WARMING: A REVIEW

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### SUMMARY

*Cultivation of deep rooting perennial crop like rubber is considered as a very desirable form of land use. They not only provide a canopy which reduces the adverse effects of excessive atmospheric warming but also many beneficial effects such as non removal of significant amount of soil water per unit area of land. Rubber plantations simulate to a natural forest condition but with an economical benefit.*

**Key words:** atmospheric warming, *Hevea brasiliensis*, moisture stress

### INTRODUCTION

Environmental issues like drought and atmospheric warming have become increasingly important not only in global context but also in maintaining the long-term productivity of Sri Lankan agricultural sector. The diverse impacts of these environmental issues are not confined to agricultural sector alone. By the short-falls in agricultural production, the sectors servicing agricultural crops could also be adversely affected. The exact reasons behind recent changes in weather patterns are still not known. Scientists feel that this is one of nature's ploys to conceal its intricate workings from man!. Nevertheless, it is not possible to completely avoid adverse weather condition or its impact on the agricultural sector. What is most important is to introduce agricultural systems that could withstand such adverse weather conditions or make it more bearable and thereby to protect the country's agricultural system. The introduction of the rubber tree (*Hevea brasiliensis*) to Sri Lanka from its native Amazonian habitat occurred during the late nineteenth century. Since then many rubber plantations have undergone three replanting cycles of approximately 30 years per cycle without having any unfavourable effect of adverse weather conditions. In Sri Lanka, rubber is generally grown in environments where

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no other agricultural crop could be grown economically (Samarappuli & Yogarathnam, 1995). This paper highlights how rubber plantations withstand drought and atmospheric warming, under two broad categories. Firstly, the **adaptability of rubber tree**, such as water regulating latex system, presence of leaf epicuticular waxes, leaf tissue membrane thermostability, low water use, osmotic adjustment, canopy characteristics and the extensive root system, which has enabled it to be established in many unfavourable environments. Secondly, some **soil management practices** that have been designed to conserve moisture and protect its environment from high temperature due to atmospheric warming.

### Adaptability of rubber tree

#### *Water regulating latex system*

Noting the development of a system of tubes running throughout the rubber plant which could be filled with water during the wet season and then gradually drawn upon during times of drought, a possible function of latex was identified as reserve water supply (Parkin, 1900). The genus *Euphorbia* chiefly inhabits dry regions and is one of the richest in latex and regard the latex system as a very important ecophysiological factor in the adaptation to the dry environment (Sen & Chawan, 1972). The correlation of yield of *Hevea* with rainfall and temperature indicates that the latex functions as a system regulating water within the plant. The ability of the plant to survive and grow satisfactorily under drought conditions appears to improve with increased capacity for latex production (Fernando & Tambiah, 1970).

#### *Presence of leaf epicuticular waxes*

Amount of epicuticular wax on the leaf surface is reported to be an important parameter associated with drought and heat tolerance (Rajagopal *et al.*, 1988a). Presence of epicuticular wax on the leaf surface of rubber is identified and discovered as that helps in reducing cuticular transpiration and stomatal transpiration and promotes reflection of radiant energy by canopies (Gururaja Rao *et al.*, 1988). Higher reflectance of radiant energy results in lower leaf temperature, thus reducing thermal injury. Therefore, accumulation of epicuticular wax resulting in high reflection of radiant energy appears to be an adaptive feature in rubber plants for drought conditions and atmospheric heat. It also indicated that measurements on amount of leaf epicuticular waxes or optical properties in different rubber clones can

be regarded as a method of screening for drought tolerance (Gururaja Rao *et al.*, 1988).

*Leaf tissue membrane thermostability*

Scorching or drying of leaf margins, whole leaves, twigs *etc.* of rubber plants can be caused by the direct effect of high ambient temperature or by the elevated leaf temperature caused by soil water deficit (Vijayakumar *et al.*, 1988). Existence of leaf tissue membrane thermostability identified in rubber plants appears to be an adaptive feature for heat tolerance (Rajagopal *et al.*, 1988b). It is observed that high atmospheric temperature of 50-55°C causes only about 30% thermal injury to rubber plants (Rajagopal *et al.*, 1988b).

*Low water use*

Among the terrestrial ecosystems, natural forests sustain the most efficient moisture conservation system. However, the water use by rubber plantations is estimated to be 500mm to 600mm lower than typical tropical rain forest ecosystem (Vijayakumar *et al.*, 1989). The rate of evapo-transpiration is lower for rubber plantation compared to the forest ecosystem and mean daily evapo-transpiration of rubber is about 4.5 mm per day (Samarappuli *et al.*, 1998a). The crop coefficient values of rubber tree are reported to be lower during dry seasons and even under wet conditions (Table 1), the transpiration rate is lower compared to many other forest species. It seems therefore, rubber plantations conserve soil moisture more efficiently compared to most of the forest species.

Table 1. *Ratio of transpiration to potential evapo-transpiration of rubber*

Season	transpiration/potential evapo-transpiration
Wet	1.058
Dry	0.179

High levels of epicuticular wax observed in the rubber leaves are associated with high reflectance of heat energy and probably reduce transpirational water loss. With the increase in soil moisture stress, stomatal conductance and transpiration rate of rubber plants decrease and it seems to suggest that rubber plants appear to close stomata and reduce transpiration readily with the onset of drought conditions (Fig. 1),

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(Samarappuli, 1988; Samarappuli *et al.*, 1992a). Moreover, when rain falls, about 19% of the rain intercepts (Haridas *et al.*, 1985) and stays on trees and most of this water either re-evaporates or may be directly absorbed by the plant tissues (Teoh, 1971). This intercepted water probably suppresses water loss (transpiration) from the rubber leaves (Table 2). Further, it is evident that efficiency of water use by rubber is better at low soil moisture conditions (Table 3), (Haridas & Subramaniam, 1980; Samarappuli, 1992a). This shows that rubber plants are capable of growing and producing latex even in drought conditions.

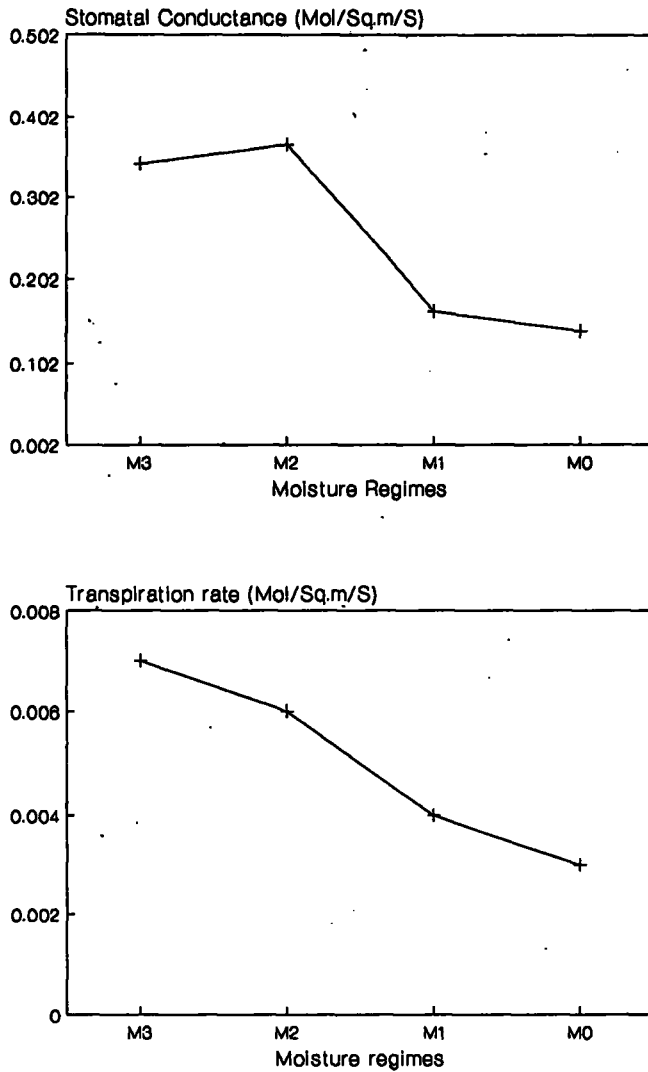
### *Osmotic adjustment*

Soil water deficit causes a progressive decrease in leaf water potential and in osmotic potential in rubber plants (Fig. 2), (Samarappuli *et al.*, 1993). Decreased osmotic potential results in maintenance of turgor, which helps enlargement of cells or in other words plant growth. It was documented that, cell elongation the basic event of whole plant growth, is initiated by cell wall relaxation, causing osmotic potential driven water uptake and consequently turgor driven cell expansion (Lindhauer, 1989). Measurement of relative water content of rubber leaves under the influence of decreasing water availability in the soil revealed a better water status of leaf tissues of rubber plants (Fig. 3) (Samarappuli, 1992b). The capability of plants to retain more water and more efficient or sensitive turgor regulation is of importance as Boyer (1973) revealed that plant growth responds more sensitively to water stress than to other physiological processes as photosynthesis. However, optimal turgidity of the plant tissue is one of the prerequisites for cell expansion and for plant growth and yield production (Bradford & Hsiao, 1982). High latex vessel turgor and low latex solute potential in rubber in the dry season reveal osmotic adjustment. These results seem to prove the adaptive ability of the rubber plant to stress conditions.

Table 2. *Interception of rain-fall, stemflow and throughfall of a 15 year-old rubber plantation*

Component of rain fall	Mean percentage (%)
Interception	19
Stemflow	2
Throughfall	79
Total	100

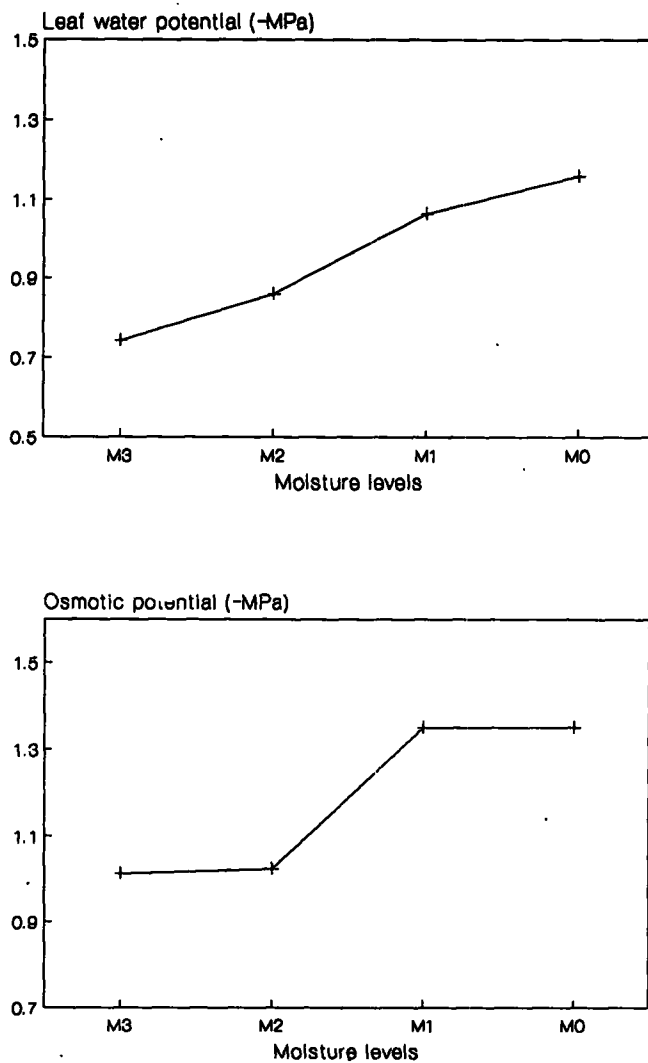
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- M<sub>3</sub>** - Watering at 30% depletion of available water
- M<sub>2</sub>** - Watering at 50% depletion of available water
- M<sub>1</sub>** - Watering at 70% depletion of available water
- M<sub>0</sub>** - Watering at 90% depletion of available water

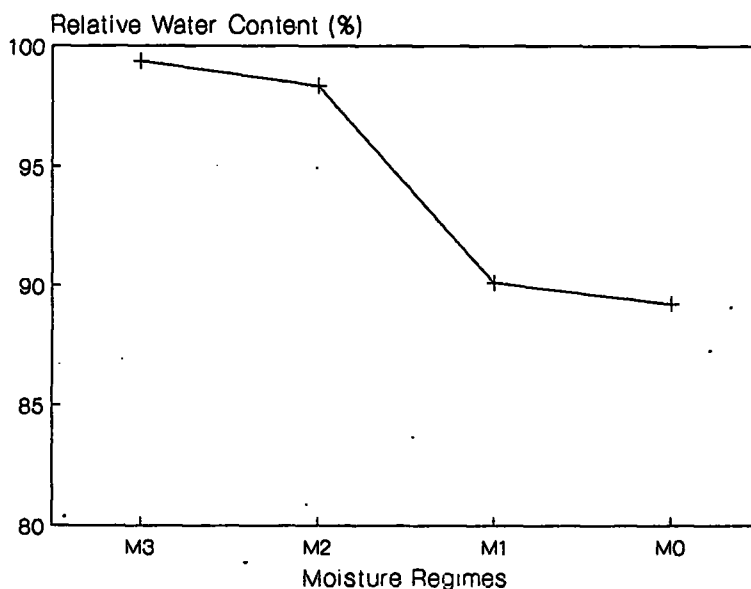
Fig. 1. Effect of different soil moisture regimes on stomatal conductance and transpiration rate

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Fig. 2. Effect of different soil moisture regimes on leaf water potential and osmotic potential



- $M_3$  - Watering at 30% depletion of available water
- $M_2$  - Watering at 50% depletion of available water
- $M_1$  - Watering at 70% depletion of available water
- $M_0$  - Watering at 90% depletion of available water

Fig. 3. Effect of different soil moisture regimes on relative water content

### *Capability of capturing more rainfall*

The proportion of water from rainfall reaching the ground as stemflow and throughfall, which also called "net rainfall" is of great importance to rubber tree, which totally depends on rainfall for its moisture requirement. This amount of rainfall that percolates through and accumulates in soil is used by rubber plants for their growth and productivity. Eventhough, a 5-6 years old rubber stand is capable of providing an excellent thick tree cover to the land, the rainfall interception by the canopy is only about 19% and 81% of the rainfall reaches the ground as throughfall and stemflow (Table 2), (Haridas & Subramaniam, 1985). This indicates the adaptability of the rubber tree in capturing most of the rainfall received for its productivity process.

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Table 3. *Water use efficiency of rubber under different soil moisture tensions*

Moisture tension (bars)	Water used (cc/g dry matter)
1.0	403
0.3	460
0.1	598

### *Interception of solar energy*

The interception of solar energy by the thick tree canopy of rubber is around 80-90% and the reflectance is comparable to that of different forests (Table 4). Therefore, the amount of radiant energy reaching the soil surface is low which results in reduced atmospheric and soil temperatures to the order of 8°C compared to open (Table 5), (Vijayakumar *et al.*, 1989).

Table 4. *Comparison of reflectance (albedo) of different canopy surfaces*

Vegetation	reflectance (albedo) (%)
Rubber plantation	14-16
Tropical rain forest	7-15
Coniferous forest	15-18

Table 5. *Mean soil temperature at 10cm depth*

Item	Mean soil temperature (°C)
Open condition	37.4
Under rubber	29.4
Difference	8.0

Like other green plants, rubber (*Hevea brasiliensis*) can also be considered as a plant factory for solar energy conversion and a carbon sink by virtue of the process of photosynthesis. A monoculture of rubber has been reported to be a relatively

efficient converter of solar energy into dry matter production. It has been estimated that the rate of dry matter production of a 5 to 6 years stand of rubber is 35.5 metric tonnes/ha/year, a relatively high value among tree species. At this rate of dry matter production, the efficiency of utilization of solar radiation in a stand of rubber trees with a closed canopy has been calculated to be about 2.8 per cent.

As rubber is mainly cultivated in regions of highest photosynthetic productivity and has a capacity to fix 90 million tonnes of carbon per year, it would appear that a rubber plantation is almost as effective during photosynthesis in consuming the products of fossil fuel burning, which is one of the main causes of global warming and at the same time producing life sustaining oxygen (Vijayakumar *et al.*, 1989).

### *Reduction of soil evaporation*

A mature rubber stand is capable of adding about 7 metric tonnes (MT) of dry matter to soil every year through wintering of leaves (Table 6), (Samarappuli & Yogaratnam, 1995). This itself reduces the evaporation loss of moisture from soil surface. Further, a stand of rubber trees with a closed canopy is also liable to reduce the evaporation loss of moisture from the soil surface in addition to the benefit of a low transpiration loss. These indicate the adaptability of the rubber stand in minimizing moisture loss from the soil.

Table 6. *Litter fall under different vegetation systems*

Vegetation	Mean annual litter fall (dry weight) (MT/ha)
Forest	9.4
Legume cover	4.2
Rubber	6.8

### *Root system*

The rubber tree possesses an extensive root system, which accounts for about 15-25 percent of the total dry weight of a mature rubber tree. The root system consists of a well developed tap root, several whorls of lateral roots and large numbers of fine rootlets (feeder roots). These roots are capable of exploiting a large volume of soil to enhance the tree's absorptive capacity for mainly moisture.

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A significant feature of the rooting habit of rubber is the formation of lateral roots well below the soil surface. The fine feeder roots which arose from these laterals are therefore capable of absorbing moisture from deep soil layers (Samarappuli, 1996). Further, during refoliation considerable amounts of water is required for formation new leaves and also this coincides with a drought period. This heavy demand exerted by the tree, therefore, generates a greater development of feeder roots. Moreover, the feeder root concentration in the 60-90 cm depth in the soil, close to the rubber tree, is considerably greater than in the center of the inter row area (Samarappuli *et al.*, 1996). The lower feeder roots close to the tree is important in absorbing moisture in the clean weeded circle (Table 7). These adaptations seem to prove the ability of the rubber plant in absorbing soil water more efficiently in drought conditions.

Table 7. Feeder root densities (mg/1000cc) of rubber plants at various soil depths in relation to different distances from the base of the plant

Distance (cm)	Depth (cm)					
	0-10	10-20	20-30	30-50	50-70	70-90
60	215.5 <sup>a</sup>	289.9 <sup>a</sup>	95.1 <sup>a</sup>	28.0 <sup>a</sup>	13.9 <sup>a</sup>	6.0 <sup>a</sup>
120	213.5 <sup>a</sup>	293.7 <sup>a</sup>	93.5 <sup>a</sup>	20.0 <sup>b</sup>	10.0 <sup>b</sup>	3.4 <sup>b</sup>
160	208.7 <sup>b</sup>	281.4 <sup>b</sup>	84.6 <sup>b</sup>	8.2 <sup>c</sup>	2.6 <sup>c</sup>	0.7 <sup>c</sup>

The values with the different letters in each column are significantly different at the 0.05 probability level

### Management practices

The portion of rainfall, which reaches the ground could be lost to the rubber trees by way of surface run-off depending on the adopted management practices (Samarappuli & Yogaratnam, 1996). This would seriously impede the storage of water in the soil and consequently availability of soil moisture during stress periods. However, rubber cultivation involves soil management practices designed to conserve soil moisture (Table 8), (Samarappuli & Yogaratnam, 1997) and protect its environment by high temperature.

Table 8. *Effect of soil management practices on run-off and soil moisture storage capacity in young rubber plantations*

Situation	Run off* (liters)	Soil moisture storage capacity (cm)
With proper soil management	1973	24.3
Without proper soil management	3701	18.3

\* Cumulative values for first 3 years after planting rubber

### *Contour planting*

On hilly and steep terrains, rubber is planted on contours, with minimum disturbance to the inter-row areas which help water to remain for longer period on the soil surface thereby increasing the infiltration of rain water into the soil (Samarappuli, 1984).

### *Drains and silt pits*

Drains and silt pits can act as a series of storage tanks, trapping water from surface runoff and through fall, which can be readily used by the rubber trees during dry weather (Samarappuli, 1995). The construction of silt pits mid way along a slope seems to create a catchment effect at that level, with the rubber trees above silt pits benefiting from the stored water in these pits. The effect of this is more pronounced during the dry periods (Haridas *et al.*, 1987).

### *Ground cover management*

The influence of cover plants on moisture conservation is of considerable importance. This is brought about by the addition of organic matter to the soil through the natural decaying of leaves, stems and roots (Yogaratnam *et al.*, 1977; Yogaratnam *et al.*, 1984).

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**Table 9. Effect of soil management practices on soil moisture content, six years after planting of rubber**

Treatment	Soil moisture content (%)			
	Inter-row area		Clean weeded circle	
	0-15 cm depth	15-30 cm depth	0-15 cm depth	15-30 cm depth
Naturals	15.3 <sup>a</sup>	13.9 <sup>a</sup>	12.5 <sup>a</sup>	12.1 <sup>a</sup>
Legumes	18.1 <sup>b</sup>	16.9 <sup>b</sup>	14.3 <sup>b</sup>	13.5 <sup>a</sup>
Mulch	18.7 <sup>b</sup>	16.8 <sup>b</sup>	20.8 <sup>c</sup>	19.1 <sup>b</sup>

The values with the different letters in each column are significantly different at the 0.05 probability level

### ***Mulching***

A 8-10 cm layer of mulch on the soil surface could prevent the direct impact of rain drops thus preventing the breakdown of soil structure. In addition, a mulch serves as a cushion against the destructive action of the rain drops. Mulching also reduces the flow velocity and carrying capacity of the runoff. Marked increase in infiltration rate with mulching (Fig. 4), indicates that the soils have higher water intake capacity thus reducing runoff and minimizing erosion (Samarappuli *et al.*, 1992b).

Generally, there is an increase of 43% in the moisture storage capacity for 90cm soil profile under mulching (Table 10) and in drought conditions more water retains in the soil under mulch. Mulching also tends to reduce the rate of evaporation of soil moisture thus allowing moisture to remain in the soil for a longer period (Table 11). Therefore, it appears possible to eliminate or at least minimize the adverse effects of moisture stress by mulching (Samarappuli *et al.*, 1998b).

It is also evident that more moisture is lost by transpiration from the leguminous covers than what is conserved by the litter it produces during the early stages (1-2 years) of planting rubber. However, with the luxuriant growth of leguminous covers, eventually more moisture will accumulate under the cover plants. It is, therefore, very important to find a way to reduce evapo-transpiration losses along the planting row during the early stages of a rubber plantation. This can be achieved very effectively by mulching with rice straw and it is a very strong argument in favour of mulching being carried out along the planting rows during the early years in the life of a rubber plantation (Samarappuli & Yogaratnam, 1984).

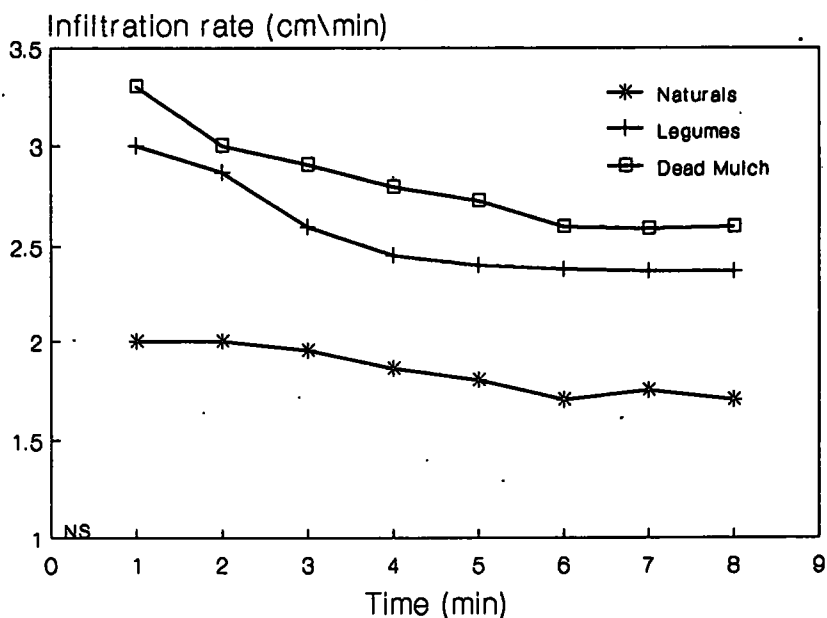


Fig. 4. Effect of different soil management practices on infiltration rate

Table 10. Effect of soil management practices on moisture storage capacity for 90 cm soil profile at six years after planting

Treatment	Soil moisture storage capacity (cm)	
	Inter-row area	Clean weeded circle
Naturals	21.7 <sup>a</sup>	19.1 <sup>a</sup>
Legumes	22.9 <sup>b</sup>	19.3 <sup>a</sup>
Mulch	23.3 <sup>b</sup>	27.6 <sup>b</sup>

The value with the different letters in each column are significantly different at the 0.05 probability level

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Table 11. *Effect of soil management practices on volumetric moisture content at different soil potentials, six years after planting*

Treatment	Volumetric moisture content (%)					
	Inter-row area			Clean weeded circle		
	-10 kPa	-500 kPa	-1500 kPa	-10 kPa	-500 kPa	-1500 kPa
Naturals	38.3 <sup>a</sup>	33.9 <sup>a</sup>	32.7 <sup>a</sup>	35.4 <sup>a</sup>	32.5 <sup>a</sup>	32.1 <sup>a</sup>
Legumes	43.1 <sup>b</sup>	34.5 <sup>a</sup>	32.9 <sup>a</sup>	36.9 <sup>b</sup>	33.1 <sup>a</sup>	32.8 <sup>a</sup>
Mulch	43.7 <sup>b</sup>	35.0 <sup>a</sup>	31.8 <sup>a</sup>	45.9 <sup>c</sup>	34.3 <sup>b</sup>	31.8 <sup>a</sup>

The values with the different letters in each column are significantly different at the 0.05 probability level

Weed growth in general, can also be reduced markedly by mulching (Samarappuli, 1993) and thereby reduces unnecessary evapo-transpiration and conserves soil moisture specially during a drought period.

In conclusion, from the ecological point of view, cultivation of deep rooting perennial rubber is a highly desirable form of land use. Rubber plantations not only provide a canopy which reduces the impact of sun as well as the atmospheric warming but they root over a greater depth, and therefore, on the whole remove less amount of soil water per unit land area. It concludes that rubber plantations, can therefore, be considered as a self-sustaining, environmentally acceptable ecosystem which can withstand drought and atmospheric warming very successfully.

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