GROWTH & YIELD OF TEA AND SOIL NUTRIENT AVAILABILITY AS INFLUENCED BY TEA – RUBBER CROPPING SYSTEM

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By

Rishika Borah

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ASSAM AGRICULTURAL UNIVERSITY

FACULTY OF AGRICULTURE

CERTIFICATE – I

This is to certify that the thesis entitled **"GROWTH & YIELD OF TEA AND SOIL NUTRIENT AVAILABILITY AS INFLUENCED BY TEA – RUBBER CROPPING SYSTEM"** submitted to the Faculty of Agriculture, Assam Agricultural University, Jorhat in partial fulfillment for the degree of **Masters of Science (Agriculture)** in **Tea Husbandry & Technology** is a record of research work carried out by **Rishika Borah** under my personal supervision and guidance.

All help received by her have been duly acknowledged.

No part of this thesis has been reproduced elsewhere for any degree.

Date: Jorhat

The.......................August, 2023

(G.K Saikia)
Major Advisor
Professor
Department of Tea Husbandry & Technology
College of Agriculture
Assam Agricultural University
Jorhat – 785 013 (Assam)

CERTIFICATE II

This is to certify that the thesis entitled **"GROWTH & YIELD OF TEA AND SOIL NUTRIENT AVAILABILITY AS INFLUENCED BY TEA – RUBBER CROPPING SYSTEM"** submitted by **Rishika Borah, Roll No. 2021-AMJ-199** to the Assam Agricultural University in partial fulfillment of the requirements for the degree of Master of Science (Agriculture) in the discipline of Tea Husbandry and Technology, has been examined and approved by the Student's Advisory Committee after viva-voce.

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(G.K Saikia)
Major Advisor

………………………

Chairman
Board of Examination

Members of the Advisory Committee

1. ……………………………
   (M. Gogoi)

2. ……………………………
   (N. Borah)

3. ……………………………
   (H. Saikia)

……………………………

Professor & Head
Department of Tea Husbandry and Technology
Assam Agricultural University
Jorhat – 785 013 (Assam)

....

Director
Post graduate Studies
Assam Agricultural University
Jorhat – 785 013 (Assam)

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Sir Isaac Newton

"Dedicated to those who inspired me"

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ABSTRACT

Tea is generally grown as a monoculture. However to augment farm income of small tea growers the concept of tea based cropping system where other crops are raised within a tea plantation is being tried.

Two cropping systems- one with tea under conventional shade and the other with tea under intercrop situation were studied. The experiment was carried out in Experimental Garden for Plantation Crops, Department of Tea Husbandry and Technology, Assam Agricultural University, Jorhat during 2022. Effect of rubber on growth and yield of tea in tea based cropping system was studied along with the nutrient availability in the soil.

Tea under conventional shade tree *Albizzia chinensis* gave highest yield when compared to tea under rubber plant's shade as the uptake of nutrients was more. The light penetrating through the dense canopy of rubber is very low, which is a direct factor for lowered yield under rubber shade. Even the thickness of the tea stem, plucking point density, shoot weight, bush spread of tea was found to be highest in the tea- *Albizzia chinensis* plot. The nutrient uptake by the tea shoot was higher in the control plot due to proper penetration of light and adequate nutrients in the soil. Rubber tree shows increment in girth which is an important parameter for the rubber yield. For the growth and development of the rubber tree, canopy is also an important factor as it regulates the exchange of carbon. Tea under rubber shade was more prone to moisture stress due to higher rate of transpiration. The soil carbon content was found to higher in the tea-rubber intercropped plot due to faster rate of decomposition of leaf litters in a well shaded condition. The available NPK content was found to be higher in the intercropped plot due to releasing of nutrients by the tree to meet crop demands.

The rubber plant had no adverse effect on the soil status but due to the dense canopy spread of the rubber interplanted with narrow spacing the light transmission is quite low which eventually effects the yield and growth of the tea plants.

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LIST OF ABBREVIATIONS

%	: Per cent
et al.	: Et Alia (and others)
Fig.	: Figure
Viz.	: Namely
resp.	: Respectively
ha	: Hectare
i.e	: That is
wt.	: Weight
kg	: Kilogram
g	: Gram
m	: metre
cm	: centimeter
N	: Nitrogen
P	: Phosphorus
K	: Potassium
SOC	: Soil Organic Carbon
TV	: Tocklai Vegetative
CD	: Critical Difference
SE	: Standard Error
EGPC	: Experimental Garden For Plantation Crops
RBD	: Randomised Block Design
Temp.	: Temperature
BSH	: Bright Sunshine Hour
S	: Significant
NS	: Non- Significant

CHAPTER I
INTRODUCTION

Tea (*Camellia sinensis*) is a perennial evergreen woody plants which is heterogenous in nature. It is one of the economically important crop in many countries like China, India, Sri Lanka, Bangladesh, Vietnam and Kenya. Mostly grown as monocrop and in wide range of soil and climatic conditions with many overlapping morphological, biochemical and physiological attributes. The life duration beneficial for the tea bushes is around 40 years and gradually the yield decreases when the bushes turns around 100 years old. Intercropping system is a traditional agricultural method practiced from many decades which aims at increasing the efficiency of utilization of the land for maximum profitability. With the exception of Japan, Russia, and other nations where the winter time temperature is low, intercropping systems in tea allow the plant grow luxuriantly in plain areas by interplanting shade trees.

In every tea-growing location in the world, small-scale tea production has become extremely popular. As a result, the practise of intercropping with a suitable cash crops like pepper, clove, rubber, coconut, arecanut and also leguminous crops like soyabean, pea as well as different fruit crops is increasing income per acre of land.Due to the heavy population strain on the limited amount of land in the tea zones that may be used for food production, some farmers have chosen to intercrop tea with alternative cropping options including multistorey, where a short annual crop is grown (Nelliat Bavappa, Nair, 1974).

Out of 6,36,557 ha area under tea in India, Assam covers an area of 3,37,690 ha. (Ann.Report.,2019) Assam's plantations have completed a full circle as many small farmers have switched from paddy to growing tea.Small tea growers have chosen to plant different crops in their fields, such as arecanut, khasi mandarin, agarwood (sasi), *etc*., in order to supplement their income during the lean tea-growing season and to make more efficient use of their property. Approximately 50% of the state's total output is currently produced by small tea producers in Assam.

The traditional rubber (*Hevea brasiliensis*) monoculture cultivation has many constraints like soil erosion, reduced biodiversity, nutrient wastage in soil and due to wide row spacing the growth of weeds is encouraged (Singh *et al*., 2019; Tondoh *et al*., 2019; Xiao *et al*., 2014; Wu *et al*., 2016). Zhou *et al.* (2016) mentioned that the aforementioned problems can be eradicated by using intercropping practices.

Intercropping rubber and tea has been advised to rubber farmers as a way to increase production and profitability during the early pre-tapping phase of rubber growth (Iqbal *et al.*, 2006). Considering the suitability of agroclimatic condition of North-East India for rubber cultivation, there is need to explore suitability of this crop for growing as an intercrop in tea plantation.

Economic life of rubber plant is 25-30 years which can be further extended by upward tapping. Growing of rubber as an intercrop in tea has already been reported in Sri Lanka (Iqbal *et al.*, 2006).

Zhang *et al*. (2007) reported growing of rubber as an intercrop in tea cultivation in China. Presently Chinese government advised local growers to adapt to tea-rubber based plating system which would increase soil management practices (Feng ,2007; Liu *et al*., 2016). South-east Asian mainland is seeing rapid increase in rubber plantation (Xu, 2011). Even in India Kerala, Tamil Nadu, Karnataka, Tripura, Nagaland has rubber-based agroforestry system. India is the world's fourth-largest producer of natural rubber, accounting for 0.4% of the gross cultivated area and 0.19 percent of the GDP.

With time, the cultivated soil's fertility state decreases, which affects crop productivity. Soil’s organic matter rapidly diminishes in a span of 20-30years. Recycling of nutrients through fallen leaves and pruning litter therefore has great importance in maintaining fertility status of the soil. The vertical space above the tea plants can be utilized by growing rubber plant as an intercrop following suitable agronomic practices. It is anticipated that the rubber plant will shade the tea plants and increase the growers' income.

Although total nutrient's content in soil may exceed a crop's requirement, its availability may be a limiting factor. Nutrient availability in soil depends mostly on nutrient concentration in soil, soil moisture, microbial activity in soil. The physico -chemical properties of tea soil should be well maintained so that tea plant show quite a good growth of tea shoots and the yield is maximum. It has been demonstrated that intercropping raises soil pH, enzyme activity, organic matter, and the amounts of nitrogen, phosphate, and potassium (Brooker *et al*., 2015)

The tea flush generally contains 5% nitrogen, 1% phosphorus, 2% potassium. When the level is depleted in soil the major 3 nutrients may affect the crop productivity. Therefore, it is necessary to research if growing rubber in Assam alongside tea is feasible. Although Assam has a long tradition of growing tea as a monoculture, the intercropping of various rubbers needs significant consideration in light of the current environment.

These studies show how intercropping has the capacity to change the physical and chemical characteristics of soil in tea fields. A scientific inquiry was carried out with the following objectives in light of the aforementioned facts and realising the significance of such investigations:

- To study the effect of tea- rubber cropping system on growth and yield of tea plants.
- To study the effect of tea- rubber cropping system on soil nutrient availability.

CHAPTER- II

REVIEW OF LITERATURE

A relatively recent idea that is gaining popularity in several tea-growing regions is the growing of tea with rubber. Although Assam has quite a few intercropping systems with tea, including those with arecanut, pepper, coconut, and several vegetables. Studies on intercropping tea with rubber are essentially non-existent. Till date very few places in Assam has adopted this tea-rubber intercropping system. There are numerous reports of intercropping arecanut, coffee, and coconut with various crops in various regions of India. Higher income, better use of scarce land resources, and the creation of additional jobs are the main goals of such intercropping. Initial growth of rubber at a spacing of 12x2.4 m was greater in the tea intercropping system in the northern districts of West Bengal (Gohain *et al*., 2002). (Baruah *et al.,* 2005) has practiced intercropping in young tea with various vegetables like chilli, tomato, cucumber, pea at Jorhat. In Kerala, an intercropping experiment involving coffee and rubber was carried out. In rubber plantations, coffee has been observed to flourish because it can tolerate shade (Punnose *et al*.,2000). Arecanut planting is more economical, when it is intercropped with different crops *viz.,* tea, black-peeper and it is profitable in terms of gross return (Abraham, 1974; Deka, 1999). Reports about Tinsukia district's small tea farmers where they were benefited from combining tea and orange as a multi-cropping system (Saikia, 2012).

Intercropping with tea was previously restricted to export agricultural products like pepper, coffee, and cloves. But now a days different nations has accepted and proved various economical and social benefits through different intercropping practices (Ekanayake,2003). Most tea producing countries has been studying on eco-physiological parameters on tea for multi-cropping (Shanqing *et al*., 2001).

2.1 Feasibility of mixed cropping in tea and their effect on growth, yield and soil nutrients

In a study conducted at West Bengal’s Nagarakata, it was reported that after intercropping rubber with tea there was maximum growth and productivity during first 3 years. This experiment was conducted in the year 1999 where rubber was planted at a spacing of 12m×2.4m and tea had a spacing of 100cm×60cm (Gohain *et al.,* 2002).

Intercropping is a green and sustainable planting pattern which is beneficial for tea growth as it can enhance above and below ground environment. It maximizes productivity and also tea yield was enhanced. Microclimate, soil nutrients, and microbes all have an impact on the metabolism of tea plants. The soil nutrients, microclimate and physico-chemical properties of soil is enhanced due to intercropping. The soil temperature, water and light condition in tea plantation becomes better and it promotes metabolism of tea quality components (amino acid, catechins, caffeine and aroma components) (Lei *et al.*, 2022).

Farooq *et al.* (2021) made a comparison by intercropping peanut with tea and between the monocropping of tea and peanut. Within different depths of the soil *viz.,* (0–10 cm, 10–20 cm, 20–30 cm, and 30–40 cm) and the considerable impact on the soil health and soil fertility was examined. There was an increase in total phosphorus, total potassium, available potassium and available phosphorus in intercropping than the monoculture operation in the different depths of the soil. Moreover the available nitrogen is lower in intercropping than in monocropping system of peanut in some layers of soil. Improved enzyme activity in the soil during intercropping speed up the process by which organic matter breaks down and release nutrients into the soil environment

Bai *et al.* (2022) reported positive relation in intercropping walnut in tea plantation. Walnut a perennial angiosperm which is deciduous in nature when intercropped with tea is likely to give some profit to the farmers as walnut has good economic importance in market. Also the additional benefit of low weed infestation, improves land use efficiency, provides shade to the tea and also increase humidity in spring.

Ma *et al.* (2017) conducted a research study at China on chestnut (*Castanea bungeana Blume)* and tea intercropping. This is a very common practice. This practice reduces soil erosion and improves tea quality. After many years of research, it was found out that intercropping chestnut trees in tea plantation increases soil carbon and also nutrient availability. Soil enzyme activity increases and the overall status of the soil gradually increases.

Baruah *et al.* (2005) did an effort to make use of the spaces between rows, other vegetable crops were tried to be planted alongside young tea plants. Main intention is to give the farmers an extra or an added source of income through vegetables. Twelve vegetables were grown in total *viz.*, tomato, french bean, pea, capsicum, chilli, cucumber, bitter gourd, brinjal, okra, cowpea, amaranth. The highest benefit was found in tea-tomato and tea cucumber intercropping.

Ma *et al.* (2022) reported that an increase in amino acid, which is one of the important biochemical components to evaluate tea quality when pea – tea intercropping system was experimented. Also it enhances the umami taste.

Duan *et al.* (2019) experimented on the intercropping practices of soyabean and tea. This intercropping encouraged plant growth and development which eventually improve plant quality and yield. In addition to reducing cold damage, soybean-tea intercropping influenced the growth of tea plants. Furthermore, due to intercropping manner the soil ammonium nitrogen (N) rose during the soybean flowering and mature periods, peaking during the soybean flowering and podding phase.

Bore (2005) reported benefits of intercropping in young tea plantation. The vegetables like peas, cabbage and finger millet was adopted in the system where it ended up concluding that it has advantages which provide generous amount of financial help during initial years of tea establishment. Even during subsequent years the yield of tea is not affected.

Buragohain (2015) investigated about different intercrops suitable for tea plantation. He examined on sasi, arecanut and coconut as an intercrop with tea plant. This study was extensively done for seeing the income generation through intercropping and better living for the farmers of Assam. Mostly tea with sasi was practiced as an intercrop and had beneficial effect on tea.

2.2 Efficiency of crop mixing in plantation crops and their advantages

Crop mixing has many potential advantages both in tropical and temperate agriculture. Crop mixing has diversity in plantation and it adds perennial as well as annual crops. It is practiced in different parts of India as well as World. It has advantages which has higher overall productivity, better control of pests and diseases, enhanced ecological services and greater economic profitability.

Multispecies crop mixing is sometimes being viewed as more difficult to manage but they have potential benefits in terms of productivity, output stability, disruption resistance, and ecological sustainability. Many farmers have adopted the crop mixing with different crops in one piece of land and these have become an income source. Biodiversity remains a important parameter in many poor farmers in many developing countries as it also provides food. It reduces soil erosion and enhances conservation agriculture (Malezieux *et al.,* 2009).

For consecutive years experiment was done on effectiveness of flower crops in adult coconut at Horticulture Research Station, Kahikuchi, Assam. Five flower crops used for the study viz., Gladiolus, Gerbera, Tuberose, Bird of Paradise, Marigold. There is a significant yield in gerbera-coconut garden (Nath *et al.,*2019).

Dissanayake *et al.* (2019) experimented on intercropping in immature oil palms at Sri Lanka. During the young stage of the oil palm there was no adverse growth effect on the oil palm as well as on the intercropped crop. A sustainable agriculture method practiced in India, mostly due to constraint in land holdings. During immature stage of the oil palms intercropping is suitable as there will be no yield from the oil palms. Most efficient crops grown as an intercrop with oil palm are banana, groundnut, maize, amaranthus.

Ahirwal *et al.* (2022) reported a study on oil palm with maize, turmeric, pineapple and made a comparison with monoculture oil palm. Oil palm immature phase is best for intercropping and it gives proper yield and feasibility.

Sen *et al.* (2012) experimented on intercropping rubber-tea in Tripura, which was successfully a goal programming approach towards higher income generation by the farmers. It would increase productivity of the land and hence a feasible way to adopt it.

Bhat *et al.* (1999) has examined the arecanut based on multispecies cropping system conducted at Central Plantations Crops Research Institute (CPCRI), Regional Science, Vittal. It had no negative impact on yield on intercropping practices. Mostly intercropped crop in arecanutare banana, peeper, cocoa. All has good returns and economical to many years.

Coconut based cropping system (CBCS) includes different crops as a mixed cropping which are compatible and efficient in utilizing land, water, soil and labour. Mostly had socio economic factor like greater stability, economics, human nutrition and biological aspects. Tuber crops like cassava, sweet potato, ginger, turmeric, potato and also cereals, pulses, oil seeds, vegetable crops, fruit crops, fodder crops, medicinal crops are grown. Coconut based mix cropping is diversified and conserve natural resources (Maheswarappa *et al.,* 2010).

Okigbo *et al.* (1976) conducted a survey in Tropical Africa about mixed cropping system which would be beneficial for farmers and also increase soil factors.

Newman (1975) in Sri Lanka conducted an experiment for finding the suitability and justification of growing plantation crops as mixtures. Crop diversification, generation of fuel and fodder, soil conservation are some advantages generated through mixed cropping along with microclimate enhancement and pest disease reduction.

Nimbolkar *et al.* (2016) concluded that intensification of agriculture and new technology has brought a new way of cropping system which is multi-storied cropping system. It has crops of different heights and canopy spread. Nutritional security, ecological restoration and economized productivity are the major components along with reducing flood, landslides and drought. It is particularly effective at increasing sustainable productivity and realising higher income per unit area, especially in plantation crops like coconut, areca nut, coffee, and cashew.

Suja and Nedunchezhiyan (2018) experimented on tropical tuber crops with different plantation crops. In mix cropping perennial crops at immature and mature phase with tuber crops is a good source of income. This will help the farmers to augment the employment opportunity and this crop will serve as an insurance crop at the time of disasters.

Hedge and Yusuf, 1993 investigated on soyabean as an intercrop in coconut plantation which had the potential to enhance the soil fertility by rhizobium present on the root nodules of the leguminous crops through nitrogen fixation.

Cardamom, black peeper, mandarins can be planted as an intercrop with robust coffee to increase the production per unit area. Cardamom has a low gestation period and is a potential crop with the coffee (Korikanthimath *et al.*, 1999).

Cropping systems with multiple species are useful system which enhances yield often higher than in monocultures and also mixed cropping is an effective alternative to pesticides. Moreover water and energy is saved, soil quality is preserved. In fact, the combination of crops, ranging from the most basic types to sophisticated multi-stage associations like agroforests, has allowed many communities to sustain their production circumstances while also overcoming major shocks like droughts, epidemics, or changes in market prices.

2.3 Feasibility of mixed cropping in rubber plantation

It was recorded that during the young or immature phase of rubber its radiation availability is almost around 90 percent in the first years and it gradually reduces once it grows old. The planting system most suitable in Indian condition is 6.7×3.4m (Joseph, 1999).

This effectively allows variety of intercropping in the rubber holdings for efficient utilization of the land and resources.

Rubber trees cannot be tapped in wet weather, however in such conditions, tea will flush well and produce well. The tea yield will also be lower when drought conditions are prevalent. But it will be feasible to harvest the rubber trees, bringing in more money. This would be beneficial for small holder farmers for income generation (De Zoysa ,1992).

Intercropping under rubber plantation with cinnamon was practiced with different spacing systems of rubber 8.4m to 18m. Spacing treatments between 13.2m and 18.0m included paired rows of rubber, while those between 8.4m and 13.2m had single rows. There was a considerable loss in rubber densities at 15.6m spacing but this loss were compensated by higher income through cinnamon (Pathiratna *et al.*, 2004).

Singh *et al.* (2019) studied about the rubber-tea intercropping in West Bengal area. Study proved that the yield of tea was better in monoculture than in intercropping and in the inter row spaces provided by the rubber trees. The rubber plants were grown which is a source of income for the small holder farmers. And the tea mosquito infestation decreases and the rubber plant growth increases, its girth increased more than the monoculture.

Vijayakumari, (1993) investigated on betelvine intercropped with rubber. The growth was excellent when intercropped and the branching height of the rubber plants was found to be 15 feet when intercropped with betelvine and 10feet when its has no intercropping system. Also the soil analysis data showed that there is a minimum change in the soil when it is intercropped with betelvine.

Iqbal *et al.* (2006) conducted an analysis of a rubber-tea intercropping case study in Sri Lanka which aimed to identify the key variables that affect intercropping decisions and develop a model that forecasts the likelihood that traditional smallholder rubber growers will adopt it.

Sreenivasan *et al.* (1987) have reported the benefit cost for rubber plantation which is 0.83 for ginger, 1.52 for turmeric, 1.50 for banana. It depicts that banana cultivation as more profitable in intercropping with rubber.

Samsuri *et al.* (2022) researched on okra, corn as an intercrop in rubber holdings with treatments ratios 20% okra + 80% sweet corn (strip and strip relay intercropping) with sole okra and sweet corn as the control. The strip intercropping pattern produced the maximum yield of sweet corn, while the strip intercropping design produced the highest yield of okra. The strip intercropping, however, had the highest gross margin and cost-benefit ratio according to the economic analysis.

San *et al*. (1999) reported the key concerns for sustainability include productivity, efficiency, and income stabilisation of Indonesian smallholder rubber farmers. A successful diversified production system which emphasized on genetics and breeding, nutrition, animal health, and management in crops. The economic feasibility of integrating sheep and soyabean crop into smallholder rubber production plantations had positive impact on farmers. The integration of sheep alone results in a 20% rise in the net present value of future income. The net present value of future revenue is increased by 38% when smallholder rubber production is combined with sheep and soybeans.

Siju *et al.* (2012) conducted a research study showed that contract farming of pineapple as an intercrop in the early stages of natural rubber in central Kerala is becoming more and more common. This could generally bring profit to the farmers for a long run.

Rodrigo *et al.* (2005) experimented by intercropping banana in rubber plantation which is a profit based cultivation during long immature period of rubber. There is a great increase in growth and yield of rubber in intercropping than in sole crops till 6years of age of rubber plant. Even the girth and height has been increased during the intercropping period.

2.4 Crop competition in mixed cropping and effect on growth

Interaction between the components of the multispecies crop combinations may result in sharing of growth factors and cause changes in the physical and biological variables in the ecosystem. Plant interaction is referred as neighbouring effect or interaction effect. The required ecoclimate, maximum activity of microbes and higher efficiency of using nutrients are components of complementary interactions. Other interactions include annidation, allelopathy, plant parasites etc. In light of this, interactions between nearby plants in terms of growth factors are frequently characterised as types of competition through leaves, light, carbon dioxide, roots, water, nutrients, and oxygen. Also the yield increment and reduction of several intercropping practices is the result of interacting components. The interaction with perennials with different plant species are of peculiar nature and has a greater magnitude than in the sole crops (Nair,1978).

In the first three years of rubber planting, the rubber board approved intercropping. To prevent direct competition between the main crop and intercrop, it should be placed one metre apart from rubber plants (Anon,1980).

Pathiratna, (2006) conducted an extensive study on intercropping of cinnamon in rubber plantation. With narrow spacing the growth of both the crops are not great. Standard interrow spacing (8.1m × 2.4m) and slightly higher interrow spacings, such as 9.6m x 2.4m and 10.8m x 2.4m were examined and found to be inappropriate since cinnamon yields began to fall after around five years, or after the second harvest of cinnamon. Even after the seventh year, there was still excess amount of light available but still during a seven-year period under these systems, the density of rubber fine roots in the interrow space remained low. The suitability of these intercropping depends directly on the inter row spaces. Also a very large inter row spacing eventually reduces the density of the rubber crop which is a big loss for the farmers in long run. So paired rows cropping is best and efficient way to increase production and enhancing yield of both the crops.

Competition for a variety of components may be present in an intercropping system, but crops also have adaptation mechanisms to deal with competition for nutrients and light. Allelopathy is a harmful effect that one plant has on another. The percentage of interplant interactions that are between individuals of various components must determine the strength of the interaction between components in a combination (Trenbath ,1976).

A comparative study on an intercrop is done to see the general interaction between different plants. It is based on the time of peak nutrient demands of component crops which should not coincide with the main crop, the competition for the light should be minimised in case of the component crop and both should complement each other for growth and development (Siju *et al.*, 2012).

Ahlgren *et al.* (1939) experimented on harmful root interaction of some crop which may be fatal for the growth of the plant. Some legume and grass interaction was reported after field trial by collecting data after the responses on different parameters on light, temperature, moisture and management. Different species studied were kentucky bluegrass, timothy, redtop, red clover, alsike clover and white clover.

Yang *et al.* (2021) researched on intercropping two herbaceous plant namely Amomum villosum, Alpinia oxyphylla and one woody plant Coffea arabica on rubber plantation based on the water utilization. Both the intercrops and the rubber plant depends on water and they shows an interspecific competition for water. The water use efficiency of rubber is higher and coffee as an intercrop best suited with rubber.

Competition intensity of mixed based cropping in rubber based agroforestry was seen thoroughly by (Wu *et al.*, 2020). Rubber monoculture as well as rubber intercropped with tea, cocoa, coffee, Flemingia macrophylla was investigated based on competition pattern by examining on nutrients uptake and root behaviour, where they concluded that coffee and rubber has high competition then the rest of the intercrop. The less competition was seen in cocoa and medium competition was seen on the rest two intercrop. Maximum competition means totally negative impact on proper growth of the plant yield and also nutrients will be less translocated and the reserve in the roots will be less year after year.

2.5 Competition for nutrients in rubber based mix-cropping

Juan *et al.* (2019) researched on intercropping calla lily with rubber plant. The nutrient content in rhizophore and non rhizophoric soil decreased and the nitrogen and potassium taken up calla lily has significantly decreased but phosphorus content uptake is increased, which means intercropping strictly inhibits calla lily growth as there is an interspecific competition between the two plant.

Zao *et al.* (2023) examined the nutrient status of plants and soil through stable isotope technique in the intercropped plant (tea, orange) in rubber based agroforestry. The soil nutrient status decreases by increasing the number of intercrop. Mostly there is a serious depletion of phosphorus content. Too many intercrop in the rubber plantation is harmful for soil nutrient status in soil and plant.

Teeteh *et al.* (2019) conducted a study regarding increase in nitrogen (N) and soil organic carbon (SOC) by growing plantain as an intercrop in rubber plantation. By intercropping plantain the soil nutrient pool slowly enhances and potassium (K) get accumulated in the plant biomass.

Zhang *et al.* (2007) conducted a study about the soil organic carbon content in pure rubber and tea- rubber intercropping system where it was found that there is considerable loss of total organic carbon in 26year old rubber monoculture but it increased in tea – rubber intercropping, which sums up that tea- rubber intercropping sequester more carbon in the soil than the monoculture rubber cultivation.

2.6 Soil moisture content in mixed cropping

Wu *et al.* (2006) reported that rubber when cultivated as a monoculture as rubber shows highly wasteful water behaviour unless it is intercropped with tea, cocoa and coffee. Tea based intercropping has moderate competition for water and increases water use efficiency. Mostly the crop selected for rubber intercropping should have fixed water use pattern.

Yun *et al.* (2012) examined soil moisture content after intercropping soyabean and peanut in walnut based plantation. As compared to monoculture both the intercropping has reduction in soil moisture content.

Wu *et al.* (2019) conducted the research on intercropping sharp leaf galangal with rubber by measuring the competition effects. The monoculture rubber tree and intercrop galangal tree absorb water mostly from surface soil and the rubber tree in agroforestry absorb mostly the shallow water.

2.7 Solar radiation interception in rubber based cropping system

Jalloh *et al.* (2003) experimented on solar radiation interception in an intercropping system of rubber with banana and pineapple. For daily solar radiation interception (SR) and the growth of the rubber- banana- pineapple intercropping a computer model was developed SURHIS (Sharing and Utilisation of Radiation intercepted in a Hedgerow-Intercropping System). Through this it was easily examined and it was found that positive growth of girth of the rubber plant, increase in LAI (Leaf Area Index).

Experiment was done to improve fractional interception and radiation use efficiency of immature rubber by growing banana as an intercrop. There was an increase in biomass per unit land area due to high radiation use efficiency. Shade has no impact on photosynthesis and there was growth of the component crops even when the density is being increased (Rodrigo *et al.*, 2001).

Solar radiation is an important factor for plant growth and it was seen on coffee intercropped in rubber plantation. Coffee plant was exposed to different solar radiation from 25 to 100%. Till 50% solar radiation the coffee growth was good and the LAI was increasing and further reduction in solar radiation gradually decreases the growth and LAI (Righi *et al.*, 2007).

2.8 Growth of tea bush as influenced by N, P,K and organic matter in soil

Ruan *et al*. (1997) revealed a close interrelationship between soil moisture and potassium availability on tea yields. The effect of potassium on yield of tea was greatly affected. Under drought stress area the potassium application is necessary for proper growth and yield of tea.

Venkatesan *et al*. (2004) researched on long-term impact of nitrogen and potassium fertilizers on yield, soil nutrients and biochemical parameters of tea. They have found that yield increases even the polyphenol, amino acid increases. It also states that in the absence of fertilizers the tea plants might start absorbing nutrients by the mineralization of organic matter in the soil for their survival. This would result in ultimate decline in organic matter.

Ruan *et al*. (2013) researched on Potassium management in tea plantations: Its uptake by field plants, status in soils, and efficacy on yields and quality of teas in China. The quality of harvested shoots was improved by potassium fertilizer application as revealed.

Ruan *et al*. (1999) studied about effects of potassium and magnesium nutrition on the quality components of different types of tea and growth. They examined at how the nutrients potassium and magnesium affected the qualitative elements of several tea varieties, such as black tea, oolong tea, and green tea. The findings demonstrated that applying K fertilizer enhanced the amount of free amino acids and caffeine present in different types of tea, with the treatment containing both nutrients showing the greatest rise. The application of K also boosted the amount of polyphenols in tea leaves.

Lin *et al.* (2012) studied about effects of phosphorus supply on the quality of green tea. Leaf Phosphorus concentration increased as Phosphorus supply increased. This resulted showed that P-deficiency decreased the concentration of total amino acids.

Pramanik *et al*. (2017) studied about humic substrates application in diluted form that enhances availability of phosphorus (P) and its uptake by tea bushes in the tea-growing soil of Northeast India. Application of humic substrate enhanced Phosphorus availability mainly by facilitating growth of phosphate-solubilizing bacteria (PSB) and enhancing phosphatase activity in soil and growth.

Nath, (2013) studied the macronutrients status of long term tea cultivated soils in Dibrugarh and Sivasagar Districts of Assam.The samples were analyzed for texture, pH, total organic matter, nitrogen, phosphorous, and potassium. Chemical fertilizers applied for long term to the soil can provide crops specific ingredient elements, but not with all essential elements they needed. The long-term application of chemical fertilizer might cause some plant nutrients to be depleted and other to be deposited in excess in the soil, and consequently the acidity of the soil is increased.

Islam *et al*. (2017) studied about the effects of phosphorus on growth and yield of tea and results showed that the application of phosphorus significantly increased plant height, number of leaves/plant, leaf length, number of branches /plant.

Tang *et al*. (2023) studied about the effects of combined application of nitrogen, phosphorus, and potassium fertilizers on tea growth and fungal community. By altering the microbial community in the soil, which is essential for regulating nutrient cycling and soil multiplication, it had an indirect impact on tea yield and quality. The findings stretched about how combined fertilization affects tea growth and soil quality, thereby guiding optimal fertilization strategies toward maximization of tea yield and quality and minimization of environmental risks.

Sitienei *et al*. (2012) researched on nitrogen and potassium dynamics in tea cultivation as influenced by fertilizer type and application rates. Nutrient loss was defined as nutrients that accumulated in plants and were lost during harvest, whereas fertiliser was defined as nutrient inputs that were gained by the soil. However, there was a positive relationship between N applied and the yield of the tea and a negative relationship between K applied and the yield of made tea.

Bhuyan *et al*. (2020) researched on effect of nitrogen in the soil, which reveals that nitrogen gives great contribution for quality and yield of tea. Also tea plants shows positive results while suppling NH_4^+ as compared to NO_3^-.

Rebello *et al*. (2022) experimented on identifying sustainable nitrogen management practices for tea plantations and it reveals that N is frequently given in excess of what crops actually need, which has serious negative effects on the ecosystem. N must be added during tea production in order to make up for the N lost during the harvesting of tea leaves. Green leaf tea quality and production can both improve with more N. However, using N fertilisers carelessly and excessively to boost tea yields has had detrimental effects on the environment, including soil acidification and eutrophication from N seeping into surface and groundwater.

CHAPTER -III

MATERIALS AND METHODS

A genuine understanding about the research methodology employed in the experimental study provides a systematic approach to solve the research problems. The present study was made to see how tea-rubber cropping system influence the growth and yield of tea along with nutrient availability in the soil. The details of the materials used and methodology adopted to carry out the study are briefly discussed hereunder.

3.1 Experimental site

The study along with the soil sample collection was conducted at Experimental Garden for Plantations Crops (EGPC), Section number 13, Department of Tea Husbandry and Technology, Assam Agricultural University, Jorhat with geographical coordinates 26º43´03´´N & 94º11´58´´E and 99.97m from the mean sea level during the period 2022-2023.Tea bushes were planted in the year 2013 at the spacing of 105 cm×60 cm and the rubber plant were also planted in the year 2013 at different spacing which will be discussed later in this chapter. The permanent shade tree planted were *Albizzia chinensis*

Fig.3.1. Satellite view of the tea garden (E.G.P.C), section- 13, Assam Agricultural University, Jorhat, Assam, India

3.2 Weather and climatic condition

The predominant climatic pattern of Jorhat is sub- tropical humid. It has wet summer and dry winter seasons. During the experimental period May 2022 to December 2022 the observations of various weather parameters recorded at the meteorological observatory of the department of Agricultural meteorology, Assam Agricultural University, Jorhat are shown in Table 3.1.

Table 3.1. Meteorological data of Experimental Garden of Plantation Crop, AAU, Jorhat from May, 2022 to December, 2022

Month	Maximum Temp (ºC)	Minimum Temp (ºC)	Relative Humidity (%) Morning	Relative Humidity (%) Evening	Total Rainfall (mm)	No. of Rainy Days	BSH
May'22	30.5	22.0	94	74	202.9	13	4.3
June'22	31.2	24.0	93	80	321.8	19	2.0
July'22	33.4	24.9	93	73	243.7	13	5.6
August'22	33.8	25.1	93	72	166.5	12	6.2
September'22	32.4	24.0	94	72	300.1	13	4.4
October'22	30.4	21.2	97	74	235.8	11	4.9
November'22	28.9	14.1	98	56	0.000	0	8.6
December'22	25.8	11.4	99	58	0.900	0	6.4

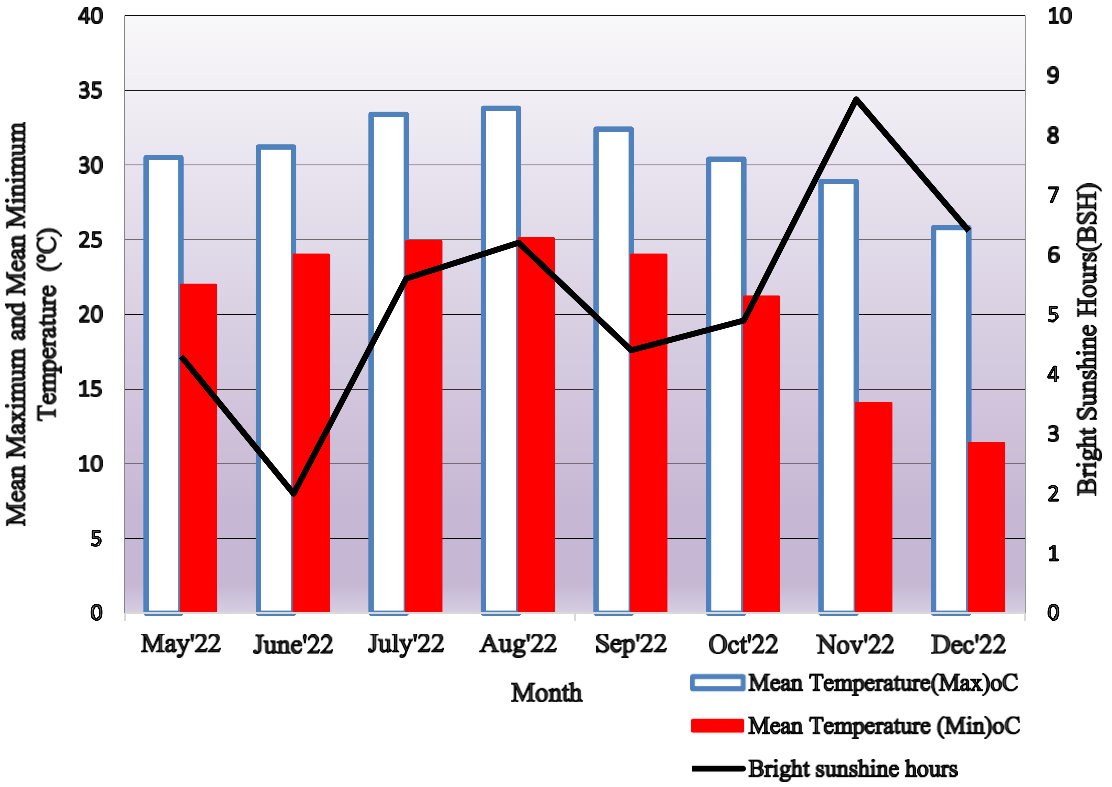

Fig. 3.2. (a). Mean maximum and minimum temperature (°C) and bright sunshine hours

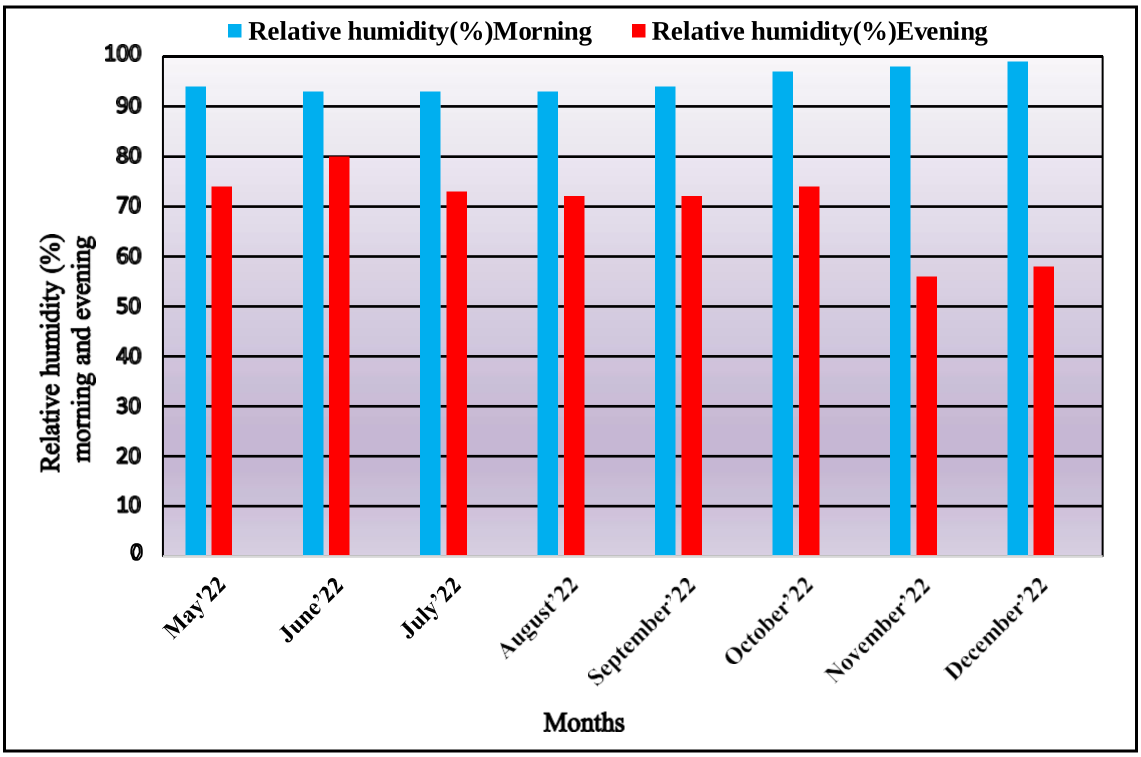

Fig. 3.2. (b). Relative Humidity (%) morning and evening

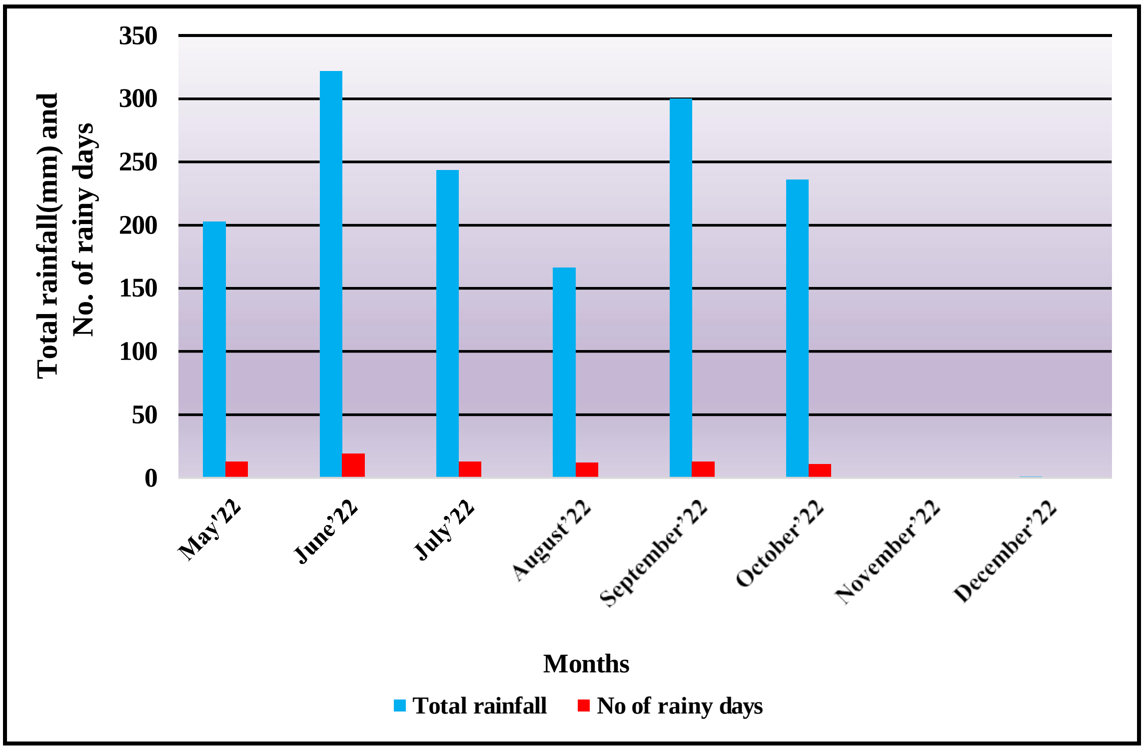

Fig. 3.2. (c). Total rainfall (mm) and no. of rainy days

Table 3.2 Meteorological data of soil temperature (°C) at 5 cm depth

Months	Soil temperature (°C) at 5cm (Morning)	Soil temperature (°C) at 5cm (Evening)
May'22	26.3	31.5
June'22	28.2	32.2
July'22	29.8	35.1
August'22	29.9	36.7
September'22	28.8	35.2
October'22	26.3	32.7
November'22	20.2	30.6
December'22	17.2	26.3

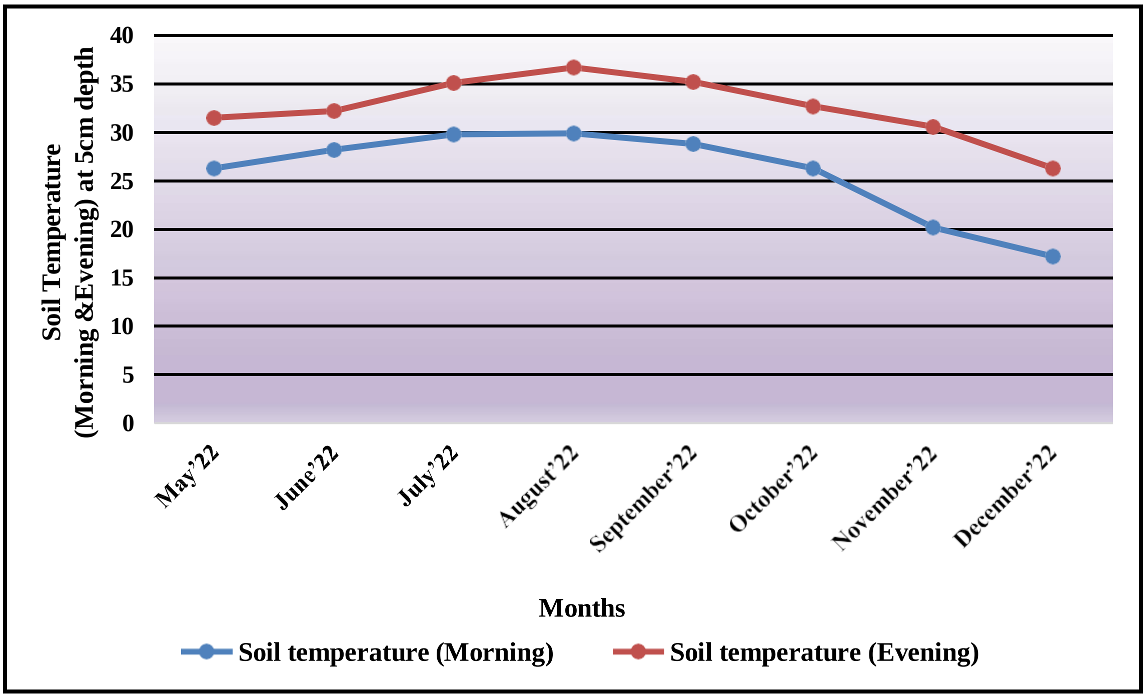

Fig. 3.3. Soil temperature (°C) at 5 cm depth

3.3 Collection of soil sample and plant sample

The sampling of the soils was carried out in two months *viz.*, June and December. In each month, soil was collected from the experimental site with the help of soil auger. Samples were collected from 4 different treatments in zig zag manner randomly in each replication. For one month, a total of 16 samples were collected from the site. A total of 32 samples of both top soil and sub-soil collected and properly carried in polythene bags with proper label.

For the tea leaf samples pluckable shoots were collected from different treatments in each replication and was carried in polythene bags. For one month, 16 samples were collected. So a total of 32 samples were collected from the site.

3.4 Cleaning and sterilization of glassware

For conducting the laboratory works different glassware were used for appropriate analysis viz., beakers, measuring cylinder, volumetric flask, pipettes, petri plates, test tubes etc. The glass wares were washed properly with tap water then followed by distilled water thoroughly. Then the glass wares were exposed to dry heat sterilization by keeping them in the hot air oven for about 60min at 160°C. The glass wares were wrapped properly with aluminium foil to prevent contamination during cooling. In order to accomplish an extensive sterilisation effect, the dry heat can permeate dense items thoroughly.

3.5 Experimental design

The detail of the experimental layout in each treatment is shown in Table 3.3.

Table 3.3. Experimental design in detail

Period of Experiment	:	May 2022- December 2022
Design of experiment	:	Randomized Block Design (RBD)
Number of tea plants per plot	:	60
Treatment	:	4
Replication	:	4
Year of planting of tea	:	2013
Year of planting of rubber	:	2013
Spacing of tea	:	105 cm×60 cm
Planting material	:	a). Tea– TV23 b). Rubber- RRIM600 c). Shade- *Albizzia chinensis*

3.6 Pruning Program

The detail of the pruning program is shown in Table 3.4.

Table 3.4. Pruning program detail

2016	2017	2018	2019	2020	2021	2022
FFP-I	UP	UP	FFP-II	LS	DS	UP

The treatment details are given below:

a) T1: Tea + shade tree (*Albizzia sinensis* at a spacing of 10 m×10 m)

b) T2: Tea + Rubber (Rubber planted at a spacing of 8.5 m×5.5 m)

c) T3: Tea + Rubber (Rubber planted at a spacing of 9.5 m × 5.5 m)

d) T4: Tea + Rubber (Rubber planted at a spacing of 12 m × 5.5 m)

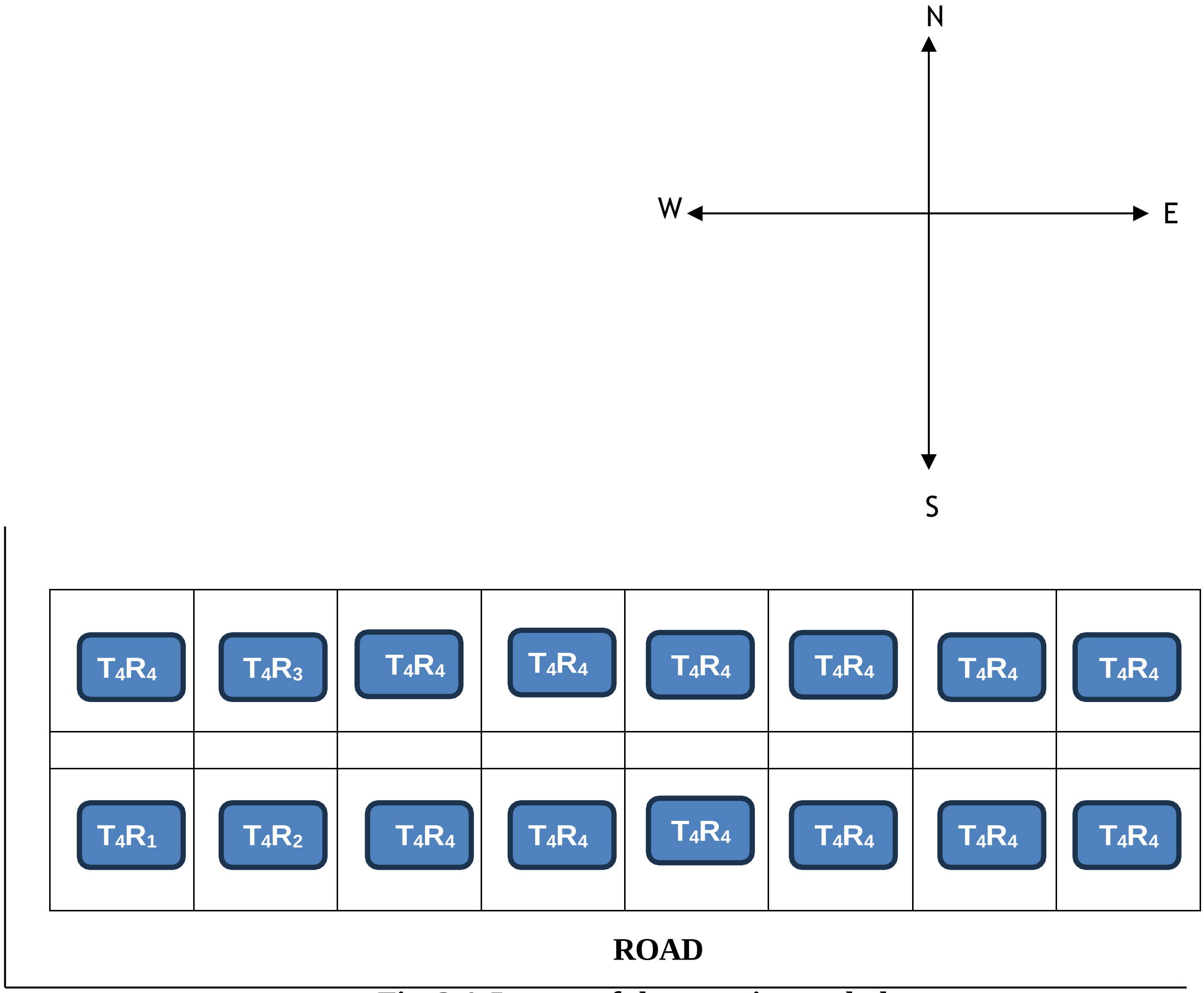

Fig. 3.4. Layout of the experimental plot

3.7 Methods

3.7.1 Growth parameters of Tea

3.7.1.1 Thickness of stem

For taking thickness of stem randomly five bushes were selected from each replication and thickness was taken with the help of vernier calliper at 15cm, 30cm,45cm from the ground. The data collected was then computed treatment wise which were recorded during May, August and December.

3.7.1.2 Bush spread

Randomly five bushes were selected from each replication and the spread was measured with help of the quadrant. Recorded during May, August and December.

3.7.1.3 Shoot weight

After each plucking round from each treatment, 100 shoots are being collected in a clean polythene treatment wise and then they are carefully taken weight in a weighing balance. Then 100 shoots collected were measured by taking the fresh weight (g) of the plucked shoots during each plucking round (Sano *et al.*,2018).

3.7.1.4 Plucking point density

It was determined by counting number of shoots plucked in each plucking round. At each plucking round the plucking point density was calculated by the method described by (Baruah and Dutta,1971). A bamboo grid of 40×40 cm^2 which is divided into 8 cm sides was placed in the top of the tea bushes and the number of the plucking points was counted from where the shoots were plucked.

3.7.1.5 Green leaf yield of tea

Weekly green leaf yield per plot throughout the whole cropping year was recorded using weighing balance. Total yield/plot was calculated per month and gross yield at the end.

3.7.2 Available nutrients present in plucked shoot

3.7.2.1 Leaf Available N

For estimating the leaf nitrogen the freshly plucked standard (2L+B) leaves were collected in a polythene bag and subsequently dried in a hot air oven. The samples were grounded nicely with the help of a mortar. Then 1gm of dried sample was taken in Kjeldahl flask with 25ml conc. H_2SO_4, 20ml of distilled water, 1g of digestion mixture and 1gm of K_2SO_4 and kept in digestion chamber. The content becomes clear and coloured pale green or blue. After this the distillation process is done and ammonium tetraborate is formed. Then this is back titrated with 0.1N H_2SO_4, releasing boric acid with formation of $(NH_4)_2$ SO_4.The disappearance of blue colour indicates the end point of the titration. The estimated nitrogen was shown as percentage of dried leaf sample (Anon, 1995).

3.7.2.2 Leaf available P_2O_5

For estimation of phosphorus in leaf the freshly plucked standard (2L+B) leaves were collected in a polythene and dried in hot air oven. The samples were grounded with the help of mortar. The process entails the oxidative destruction of the plant matter using several digestion mixture. In order to produce a colourless solution, digestion must continue until acid liquid has entirely volatilized.

To measure leaf phosphorus, 5ml of filtered solution were placed in 50ml volumetric flask together in 10m of nitric acid molybdate vanadate mixture. The volume was then filled and the mixture was thoroughly mixed. In about 30 minutes, the colour has fully developed. On a spectrophotometer, the measurement of yellow hue that was generated was measured.

3.7.2.3 Leaf available K_2O

To measure leaf potassium, put the solution straight into atomizer of the flame photometer, the 100 of which has been set with 40ppm K solution and record the reading to find out how much leaf potassium is present. The standard curve is measured which corresponds the extracts K concentration. The concentration measurement is then used for calculation of the K content of the plant sample.

3.7.3 Growth parameters of rubber

3.7.3.1 Stem girth of rubber at tapping height.

At the height of 125cm from the ground with the help of measuring tape, measurement of each rubber plant is being taken from treatment 2, 3 and 4. Treatment 1 is a control plot.

3.7.3.2 Canopy spread of rubber plant

For taking the canopy spread of the rubber plant we have used measuring tape. We have measured the diameter of the canopy spreading from north – south direction and on east – west direction.The spread of branches of rubber trees was determined by fixing a pole vertically touching the end of the branches at both the direction and taken as the shaded distance.

3.7.4 Soil parameters

3.7.4.1 Soil pH

The soil pH determines whether the soil is neutral, alkaline or acidic in nature. Measurement of pH in soil is very common as it affects the relative availability of soil nutrients. For determination of the soil pH a glass electrode pH meter is used to measure the correct pH within the acceptable range (Jackson ,1973).

3.7.4.2 Soil moisture

Water content in the land surfaces is soil moisture. It is generally expressed in weight or volume. Water affects soil formation, soil structure, stability and erosion but primarily it affects the plant growth. Water is essential element for the plant growth. For determination of moisture content in the soil, gravimetric method is used. It is determined by drying the soil to constant weight and measuring the soil sample mass after and before drying.The soil is oven dried at 105°C by using hot air oven.

3.7.4.3 Organic carbon content

Soil organic carbon is a very important for soil health, fertility and ecosystem services and including good growth and production of plant. The depletion of soil organic carbon (SOC) leads to poor health of the soil, loss in water holding capacity, enzymatic activities. For determination of the organic carbon titrimetric determination (Walkley and Black, 1934) process is being conducted and was expressed in percentage.

3.7.4.4 Available Nitrogen

Throughout a growing season, soils have an innate ability to provide crops with nitrogen that is available to plants. Plants available form of nitrogen are in the form of nitrate and nitrites. Nitrogen is one of the essential plant nutrients which helps for the crop production. For precise determination of the available nitrogen in soil Kjeldahl method is used (Jackson ,1973). This method of determination needs 3 phases:

Digestion
Distillation
Titration

3.7.4.5 Available Phosphorus

Phosphorous is one of the important macro elements for plant growth after nitrogen. Without adequate phosphorus the crop cannot reach a maximum economic yield level. Phosphorus content in each sample was determined by estimation of available phosphorous by Bray’s method as described by (Jackson ,1973) and was determined in kg ha^{-1}. On the basis of the reaction with ammonium molybdate and the development of the "Molybdenum Blue" hue, the extracted phosphorus is quantified calorimetrically. The amount of phosphorus removed from the soil can be determined by measuring the compound's absorbance in a spectrophotometer.

3.7.4.6 Available potassium

Potassium is second. major nutrient element for tea after nitrogen. It is considered to play a key role in activators of enzyme involve in carbohydrate and protein metabolism. Potassium is taken up by the plant in the ionic K^+ form in strongly acidic soil. Available potassium was estimated directly in neutral normal ammonium acetate in the soil solution ration, estimated through the help of flame photometer as outlined by (Jackson, 1973).

3.8 Statistical Analysis

The Randomized Block Design (RBD) analysis was done to analyse statistically all the parameters under the study. The critical difference (C.D) values were calculated at 5% level of significance.

CHAPTER IV
EXPERIMENTAL FINDINGS

The experimental findings of the present investigation on "Growth & Yield of tea and soil nutrient availability as influenced by tea- rubber cropping system" conducted in the Experimental Garden for plantation crops, AAU, Jorhat are presented below. Both field and laboratory studies were conducted to carry out the research work. The experimental findings are presented in this chapter under following headings.

4.1 GROWTH PARAMETERS

4.1.1 Growth parameters of tea

4.1.1.1 Thickness of the stem

From the present experiment, it was observed that thickness of the stem not varied significantly in all the treatment for all the months. At 15 cm height, for the month of May the highest thickness recorded was (6.47 cm) of T_1 and lowest was recorded in T_2 (6.33 cm). For the month of august the highest thickness recorded was on T_1 (6.50cm) and lowest was T_2 (6.35 cm). Similarly for December the highest thickness recorded was on T_1 (6.54 cm) and lowest was T_2 (6.38 cm). Data recorded for thickness of stem at 15 cm from ground are presented in Table 4.1.

For thickness of the stem at 30 cm height during the month of May the highest stem thickness was found in T_1 (2.46 cm) and lowest was (2.24 cm) of T_2. For the month of august the highest stem thickness was found in T_1 (2.50 cm) and lowest was (2.27 cm) of T_2. For the month of December the highest stem thickness was found in T_1 (2.56 cm)and lowest was (2.34 cm) of T_2. Data recorded for thickness of stem at 30 cm from ground are presented in Table 4.2.

For thickness of the stem at 45 cm height during the month of May the highest stem thickness was found in T_1 (1.78 cm) and lowest was (1.64 cm) of T_2. During the month of august the highest stem thickness was found in T_1 (1.80 cm) and lowest was (1.67 cm) of T_2.

During the month of December the highest stem thickness was found in T_1 (1.86cm) and lowest was (1.74cm) of T_2. Data recorded for thickness of stem at 45cm from ground are presented in Table 4.3.

Table 4.1. Thickness of stem (cm) at 15 cm height from the ground as influenced by tea rubber cropping system

Treatment	**May**	**August**	**December**
T1	6.47	6.50	6.54
T2	6.33	6.35	6.38
T3	6.35	6.40	6.44
T4	6.38	6.43	6.50
$C.D_{0.05}$	N/A	N/A	N/A
Significance	NS	NS	NS

Table 4.2. Thickness of stem (cm) at 30 cm height from the ground as influenced by tea rubber cropping system

Treatment	May	August	December
T1	2.46	2.50	2.56
T2	2.24	2.27	2.34
T3	2.26	2.30	2.37
T4	2.32	2.35	2.38
$C.D_{0.05}$	N/A	N/A	N/A
Significance	NS	NS	NS

Table 4.3. Thickness of stem (cm) at 45 cm height from the ground as influenced by tea rubber cropping system

Treatment	May	August	December
T1	1.78	1.80	1.86
T2	1.64	1.67	1.74
T3	1.75	1.77	1.80
T4	1.75	1.79	1.84
$C.D_{0.05}$	N/A	N/A	N/A
Significance	NS	NS	NS

4.1.1.1 Bush spread of tea

From the present experiment, it was observed that bush spread of tea varied significantly in all the treatments and it was recorded for three months to compare the growth of the tea bush. During the month of May at T_1 it shows highest bush spread (2317cm^2) and lowest was recorded in T_2 (2140cm^2). In August the highest bush spread was recorded to be (2344 cm^2) at T_1 and lowest recorded was (2165cm^2) at T_2.

For the month December the highest bush spread recorded was from T_1 (2357cm^2) and lowest was to be 2167 cm^2 at T_2. Gradual increment was seen in all the treatments from May to December and data recorded for the bush spread are presented in Table 4.4. and Fig 4.1.

Table 4.4. Bush spread of tea as influenced by tea-rubber cropping system (cm^2)

Treatment	May	August	December
T1	2317	2344	2357
T2	2140	2165	2167
T3	2156	2172	2177
T4	2254	2281	2283
$C.D_{0.05}$	77.63	107.98	112.82
S.E(d)	33.84	47.07	49.18
S.E(m)	23.93	33.29	34.77
Significance	S	S	S

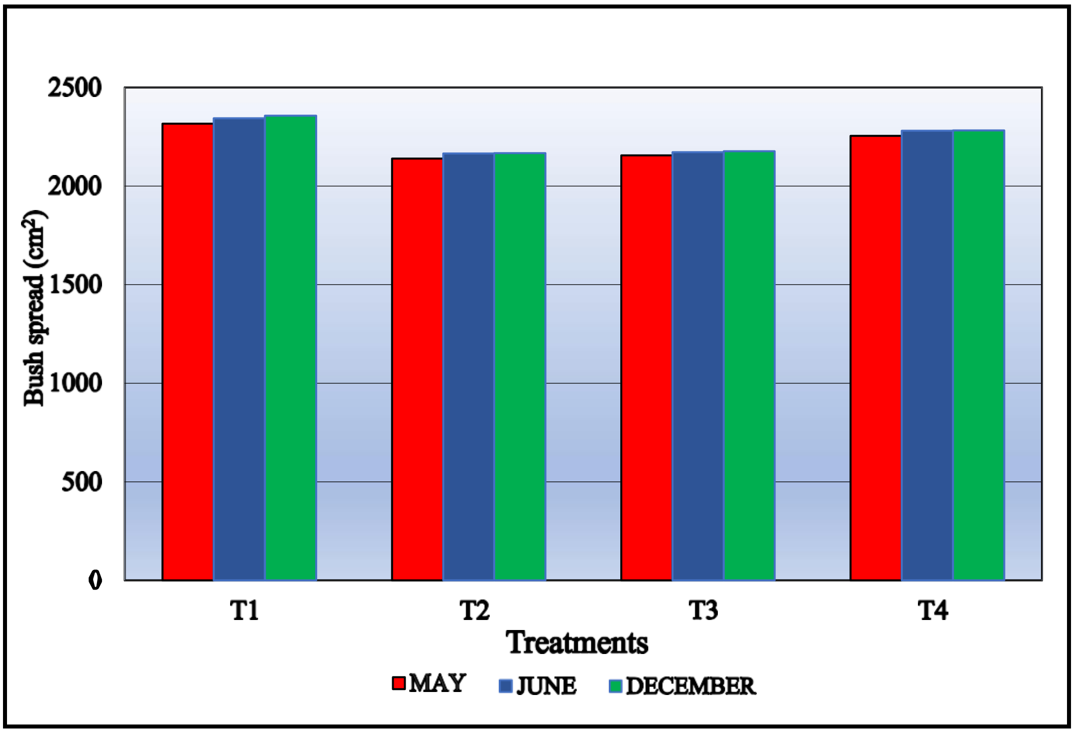

Fig. 4.1. Bush spread of the tea as influenced by tea- rubber cropping system

4.1.1.2 Shoot weight (g)

From the present experiment, it was observed that there is a significant variation in all the months and the highest weight for the 100 shoots was recorded in T_1 and lowest was at T_2 for all the months. Fresh weight data of 100 shoots was recorded under different treatments and are presented in Table 4.5.

From the present experiment, it was observed that there is a significant variation in all the months and the highest weight for the 100 shoots was recorded in T_1 and lowest was at T_2 for all the months. Fresh weight data of 100 shoots was recorded under different treatments and are presented in Table 4.5.

Table 4.5. Shoot weight (g) of tea as influenced by tea-rubber cropping system

Treatment	May	June	July	August	September	October	November
T1	55.34	56.10	58.37	54.02	53.90	51.42	48.67
T2	43.27	48.60	49.72	51.27	41.40	36.24	32.99
T3	51.31	53.36	50.05	55.89	46.15	43.32	40.57
T4	52.98	54.35	50.05	57.31	51.61	44.14	42.64
C.D0.05	5.08	3.20	1.80	3.74	4.76	3.73	3.30
S.E(d)	2.22	1.39	0.78	1.63	2.07	1.63	1.44
S.E(m)	1.57	0.99	0.55	1.15	1.47	1.51	1.01
Significance	S	S	S	S	S	S	S

4.1.1.3 Plucking Point Density (nos. /1600cm^2)

From the present experiment it was observed that plucking point density of tea plants varied significantly at different months from the different treatments. The highest plucking point density was recorded on T_1 for each month. The lowest plucking point density was recorded in T_2 for all the months. From September there was gradual reduction in plucking point density and in august the plucking point density was highest in all the treatments. The data recorded on plucking point density was shown in Table 4.6.

Table 4.6. Plucking point density of tea in different months (nos./1600cm^2) as influenced by tea – rubber cropping system

Treatment	May	June	July	August	September	October	November
T1	22	23	25	26	23	18	16
T2	14	15	16	20	15	12	9
T3	16	18	19	21	17	14	11
T4	18	19	20	23	20	15	12
$C.D_{0.05}$	1.83	2.13	2.62	2.84	4.70	2.56	3.20
S.E(d)	0.80	0.93	1.14	1.24	2.05	1.12	1.39
S,E(m)	0.56	0.66	0.81	0.87	1.45	0.79	0.99
Significance	S	S	S	S	S	S	S

4.1.1.4 Green leaf yield (kg/plot)

For the present experiment the green leaf yield of 60 tea plants/plot for different treatment is presented in Table 2. It was observed that the tea bushes with shade tree *Albizzia chinensis* recorded the highest total yield (T_1) 27.86 kg/plot. The lowest yield was recorded in bushes intercropped with the rubber tree planted with a spacing 8.5 m×5.5 m (T_2) 12.29 kg/plot. The total yield of (T_4) is 21.31 kg/plot which is higher than (T_3) 16.33 kg/plot and (T_2) 12.29 kg/plot. Data recorded for the yield of the green leaf showed significant variation in all the months and are presented in Table 4.7.

Table 4.7. Green leaf yield (kg/plot) as influenced by tea- rubber cropping system

Treatment	May	June	July	August	September	October	November	Total
T1	3.47	4.13	4.66	5.41	5.05	2.77	2.37	27.86
T2	1.52	1.67	1.97	2.35	2.29	1.58	0.91	12.29
T3	2.36	2.47	2.82	2.92	2.68	1.91	1.17	16.33
T4	2.70	2.92	3.77	4.60	3.23	2.10	1.99	21.31
$C.D_{0.05}$	0.70	0.49	0.43	0.48	0.39	0.38	0.46	
S.E(d)	0.30	0.21	0.19	0.21	0.17	0.16	0.20	
S.E(m)	0.21	0.15	0.13	0.15	0.12	0.12	0.14	
Significance	S	S	S	S	S	S	S	

4.1.2 Available nutrient in the plucked tea shoots

4.1.2.1 Leaf N (%) present in the plucked shoots

From the present experiment, it was observed that leaf nitrogen doesn't vary significantly for all the treatments during both the months. The leaf nitrogen was highest in T_1 (3.36%) and lowest recorded was (3.21%) at T_2 during June.

During December the highest leaf nitrogen was recorded in T_1 (3.26 %) and lowest was recorded in T_2 (3.16%). Data recorded on leaf nitrogen in the plucked shoots are presented in Table 4.8. and Fig. 4.2.

Table 4.8. Leaf N (%) present in the plucked shoot as influenced by tea- rubber cropping system

Treatment	June	December
T1	3.36	3.26
T2	3.21	3.16
T3	3.32	3.23
T4	3.35	3.24
$C.D_{0.05}$	N/A	N/A
Significance	NS	NS

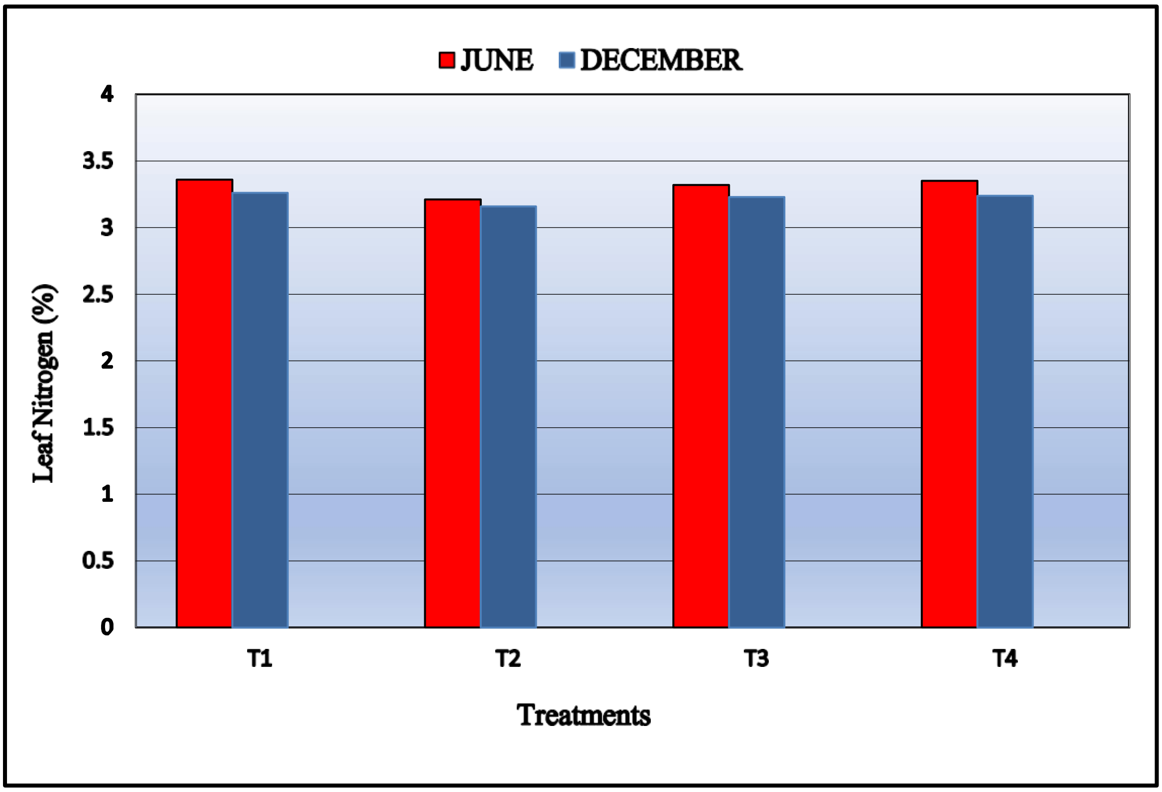

Fig. 4.2. Leaf N (%) present in the plucked shoots as influenced by tea-rubber cropping system

4.1.2.2 Leaf P_2O_5 (%) present in the plucked shoots

From the present experiment, it was observed that leaf phosphorus has no significance for both the months. The leaf phosphorus was highest in T_1 (0.29 %) and lowest recorded was (0.24%) at T_2 during June.

During December the highest leaf phosphorus was recorded in T_1 (0.28%) and lowest was recorded in T_2 (0.24%). Data recorded on leaf phosphorus are presented in Table 4.9. and Fig. 4.3.

Table 4.9. Leaf P_2O_5 (%) present in the plucked shoot as influenced by tea- rubber cropping system

Treatment	June	December
T1	0.29	0.28
T2	0.24	0.24
T3	0.25	0.24
T4	0.26	0.25
$C.D_{0.05}$	N/A	N/A
Significance	NS	NS

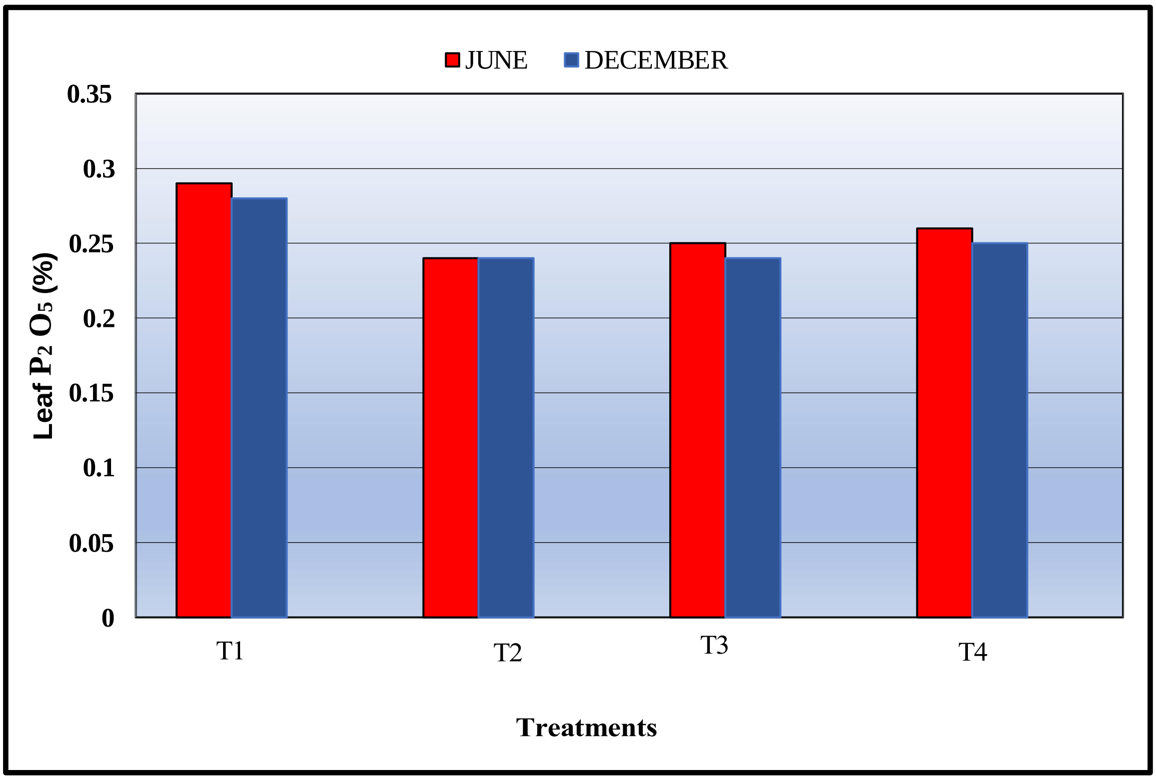

Fig. 4.3. Leaf P_2O_5 (%) present in the plucked shoot as influenced by tea- rubber cropping system

4.1.2.2 Leaf K_2O (%) present in the plucked shoot

From the present experiment, it was observed that no significant variation was showed in leaf potassium for both the months. The leaf potassium was highest in T_1 (1.69%) and lowest recorded was (1.58%) at T_2 during June.

During December the highest leaf potassium was recorded in T_1 (1.61%) and lowest was recorded in T_2 (1.56%). Data recorded on leaf potassium are presented in Table 4.10. and Fig. 4.4.

Table 4.10. Leaf K_2O (%) present in plucked shoot as influenced by tea- rubber cropping system

Treatment	June	December
T1	1.69	1.61
T2	1.58	1.56
T3	1.64	1.58
T4	1.67	1.59
$C.D_{0.05}$	N/A	N/A
Significance	NS	NS

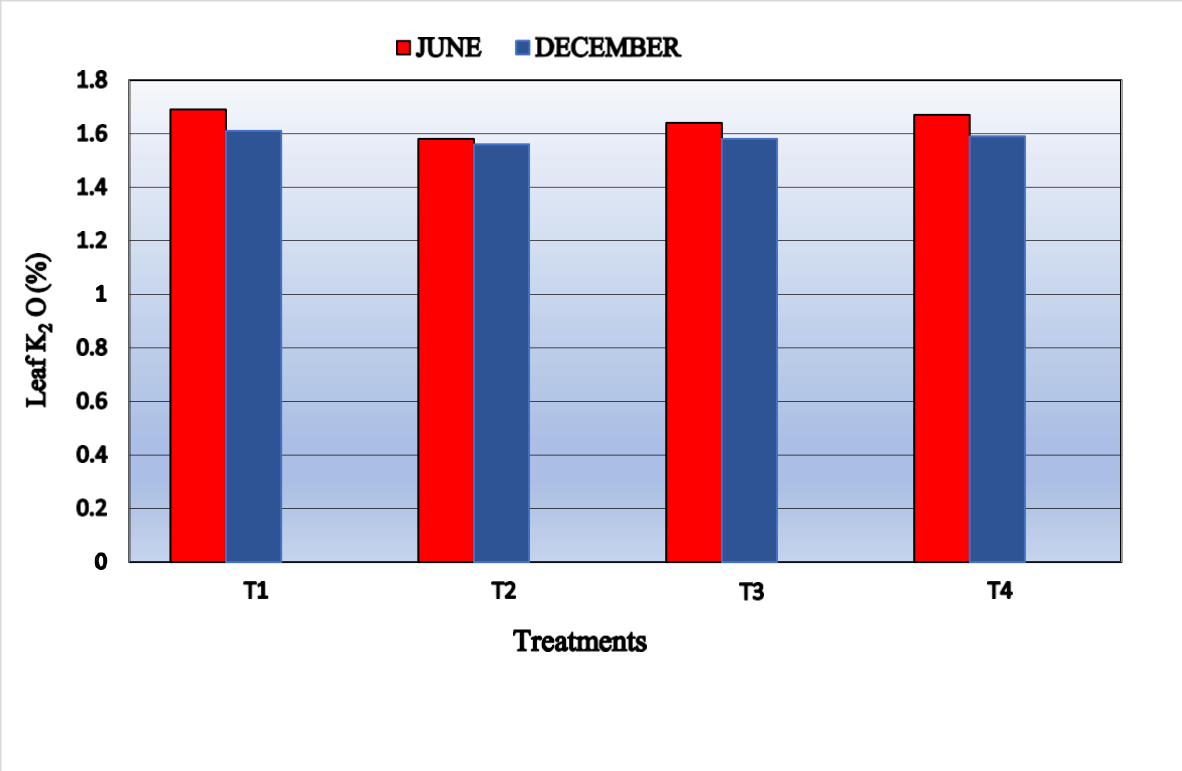

Fig. 4.4. Leaf K_2O (%) present in the plucked shoot as influenced by tea-rubber cropping system

4.1.2 Growth parameters of rubber plant

4.1.2.1 Stem girth (cm) at tapping height

From the present experiment, it was observed that the highest stem girth was recorded in T_4 in comparison to T_3 and T_2. For the month of September the highest stem girth of rubber plant was seen in T_4 (71.25 cm) and lowest was seen in T_2 (65.93 cm) T_1 is a control plot with conventional shade tree *Albizzia chinensis.*

During December the highest stem girth of rubber plant was seen in T_4 (72.17 cm) and lowest was seen in T_2 (66.44 cm). Increase in the girth of the rubber plant can be seen in different treatments. Data recorded on stem girth of the rubber plant are presented in Table 4.11

Table 4.11. Stem girth at tapping height (cm) as influenced by tea-rubber cropping system

Treatment	September	December
T1	-	-
T2	65.93	66.44
T3	69.06	69.88
T4	71.25	72.17

4.1.2.2 Canopy spread of rubber

From the present experiment, it was observed that the canopy spread of the rubber is being recorded at September and December from east -west direction as well as from north- south direction. In both the direction there was a little reduction in canopy diameter during December. Highest canopy diameter recorded was from T_4 (8.69m) and lowest was T_2 (8.25m) from east-west direction during September. For the month of December the highest canopy diameter recorded was (8.29cm) of T_4 and lowest recorded was T_2 (7.96m).

And for north- south direction the highest canopy diameter was (8.95m) of T_4 and lowest was T_2 (8.72m) for the month of June. During December the highest canopy spread recorded was (8.46cm) of T_4 and lowest recorded was T_2 (8.35m) The data recorded on canopy spread from east-west and north-south direction are presented in Table 4.12. and Table 4.13. respectively.

Table 4.12. Canopy Spread of Rubber plant at East -West direction (m) as influenced by tea-rubber cropping system

Treatment	September	December
T1 (control)	-	-
T2	8.25	7.96
T3	8.41	8.13
T4	8.69	8.29

Table 4.13. Canopy Spread of Rubber plant at North - South direction (m) as influenced by tea-rubber cropping system

Treatment	September	December
T1(control)	-	-
T2	8.72	8.35
T3	8.74	8.36
T4	8.95	8.46

4.2 SOIL PARAMETERS

4.2.1 pH of the soil

From the present experiment, it was observed that the soil pH had no significant variation at both the months in top soil as well as in sub-soil. Top soil pH was highest in T_4 (5.11) and lowest in T_1 (4.95) for the month of June. Top soil pH for the month of December revealed that the highest pH was from T_4 (4.97) and lowest was recorded in T_1(4.92). Data recorded on top soil pH were presented in Table 4.14. and Fig. 4.5.

Sub soil pH was highest in T_4 (5.12) and lowest in T_1 (4.96) for the month of June. Sub soil pH for the month of December revealed that the highest pH was from T_4 (5.09) and lowest was recorded in T_1 (4.93). Data recorded on sub-soil pH were presented in Table 4.15. and Fig.4.6.

Table 4.14. pH of the top soil as influenced by tea-rubber cropping system

Treatment	June	December
T1	4.95	4.92
T2	4.96	4.93
T3	4.99	4.96
T4	5.11	4.97
$C.D_{0.05}$	N/A	N/A
Significance	NS	NS

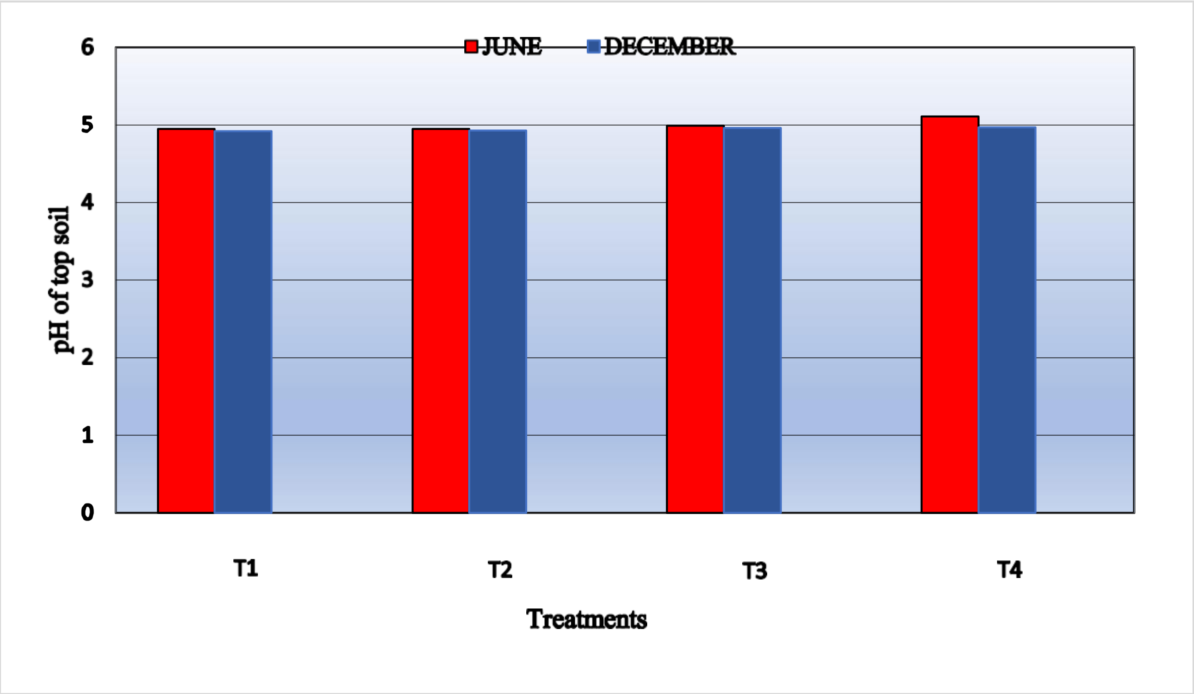

Fig. 4.5. pH of the top soil as influenced by tea-rubber cropping system

Table 4.15. pH of the sub soil as influenced by tea-rubber cropping system

Treatment	June	December
T1	4.96	4.93
T2	4.97	4.94
T3	5.09	5.00
T4	5.12	5.09
$C.D_{0.05}$	N/A	N/A
Significance	NS	NS

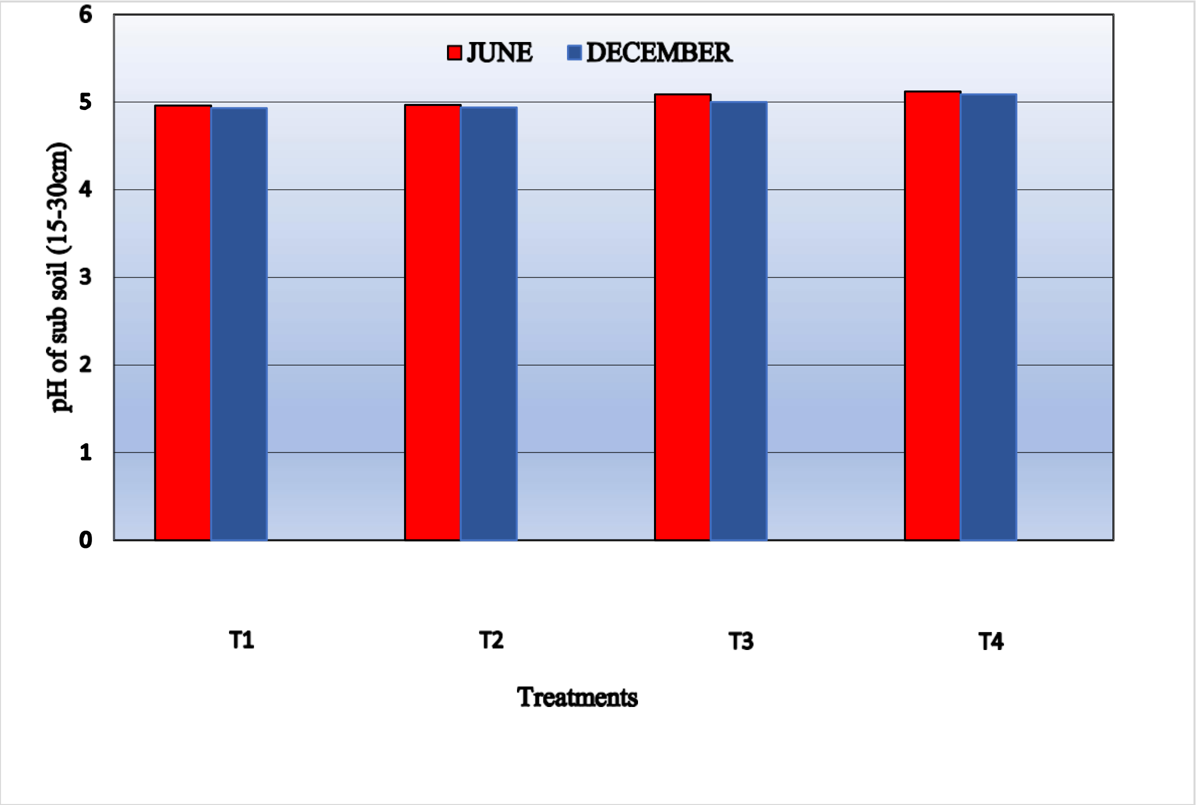

Fig. 4.6. pH of the sub-soil as influenced by tea-rubber cropping system

4.2.2 Soil Moisture (%)

From the present experiment, it was observed that the soil moisture shows no significance during June and December. In June the highest soil moisture for top soil was (22.51 %) of T_1 and lowest was (20.46 %) of T_2. Sub soil data for month of June reveals that highest was (22.89%) of T_1 and lowest was (21.75 %) of T_2. The data revealed that the moisture content in the top-soil are presented in Table 4.16. and Fig. 4.7.

During December the highest soil moisture was recorded in T_1 (17.05 %) for top soil and lowest (15.46 %). For lowest sub soil moisture content was seen in the intercropping plot T_2 i.e., (18.27 %) and highest was (19.17 %) of T_1. The data revealed that the moisture content in the sub-soil are presented in Table 4.17. and Fig. 4.8.

Table 4.16. Soil moisture (%) content of top soil as influenced by tea-rubber cropping system

Treatment	June	December
T1	22.51	17.05
T2	20.46	15.46
T3	21.31	16.30
T4	21.59	16.59
$C.D_{0.05}$	N/A	N/A
Significance	NS	NS

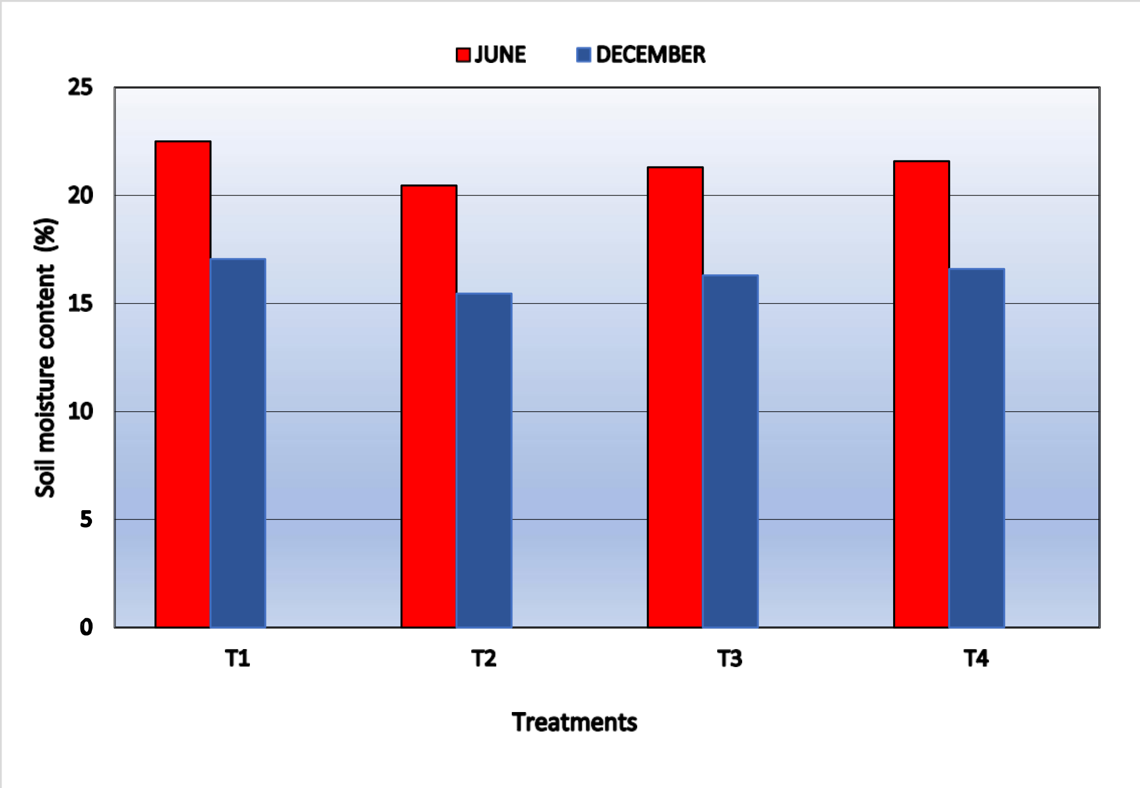

Fig 4.8. Soil moisture (%) content (top-soil) as influenced by tea – rubber cropping system

Table 4.17. Soil moisture (%) content of sub soil as influenced by tea-rubber cropping system

Treatment	June	December
T1	22.89	19.17
T2	21.75	18.27
T3	22.12	18.38
T4	22.28	18.57
$C.D_{0.05}$	N/A	N/A
Significance	NS	NS

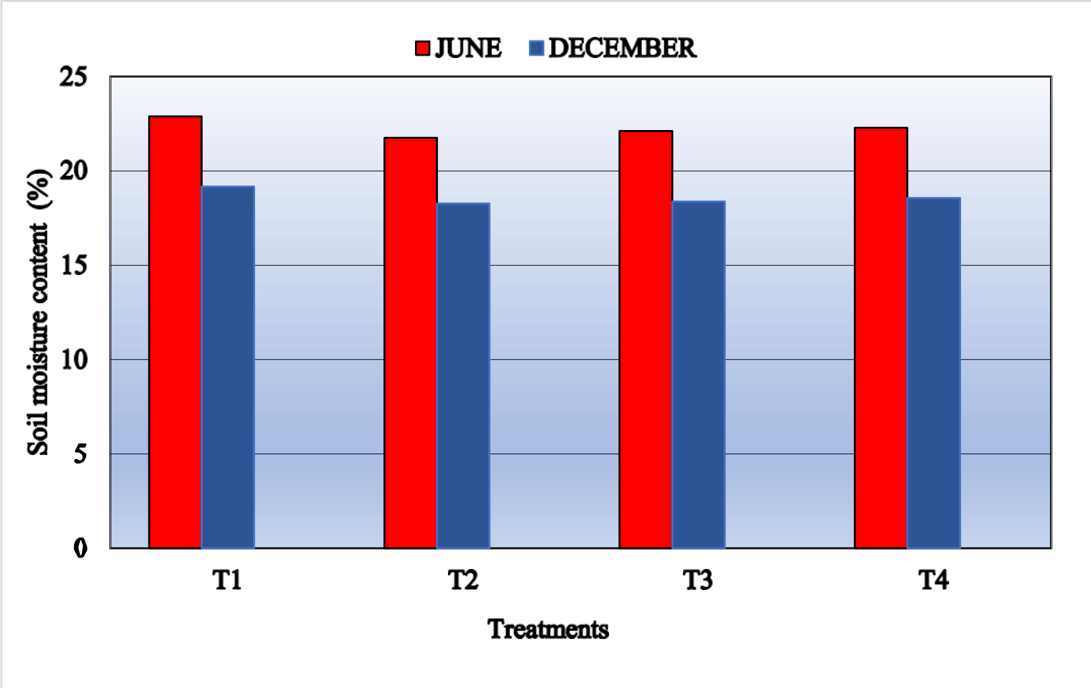

Fig 4.8. Soil moisture (%) content (sub-soil) as influenced by tea- rubber cropping system

4.2.3 Soil organic carbon (g/kg)

From the present experiment, it was observed that the organic carbon in soil varied significantly during the month of June and no significant variation was recorded in December. Soil organic carbon was highest in T_4 (8.5 g/kg) and lowest recorded was (8.0 g/kg) at T_1 during June.

During December the highest soil organic carbon was recorded in T_4 (8.3 g/kg) and lowest was recorded in T_2 (8.0 g/kg). Data recorded on soil organic carbon are presented in Table 4.18. and Fig 4.9.

Table 4.18. Soil Organic Carbon (g/kg) as influenced by tea -rubber cropping system

Treatment	June	December
T1	8.0	8.1
T2	8.1	8.0
T3	8.2	8.2
T4	8.5	8.3
$C.D_{0.05}$	0.13	N/A
S.E(d)	0.06	0.09
S.E(m)	0.04	0.06
Significance	S	NS

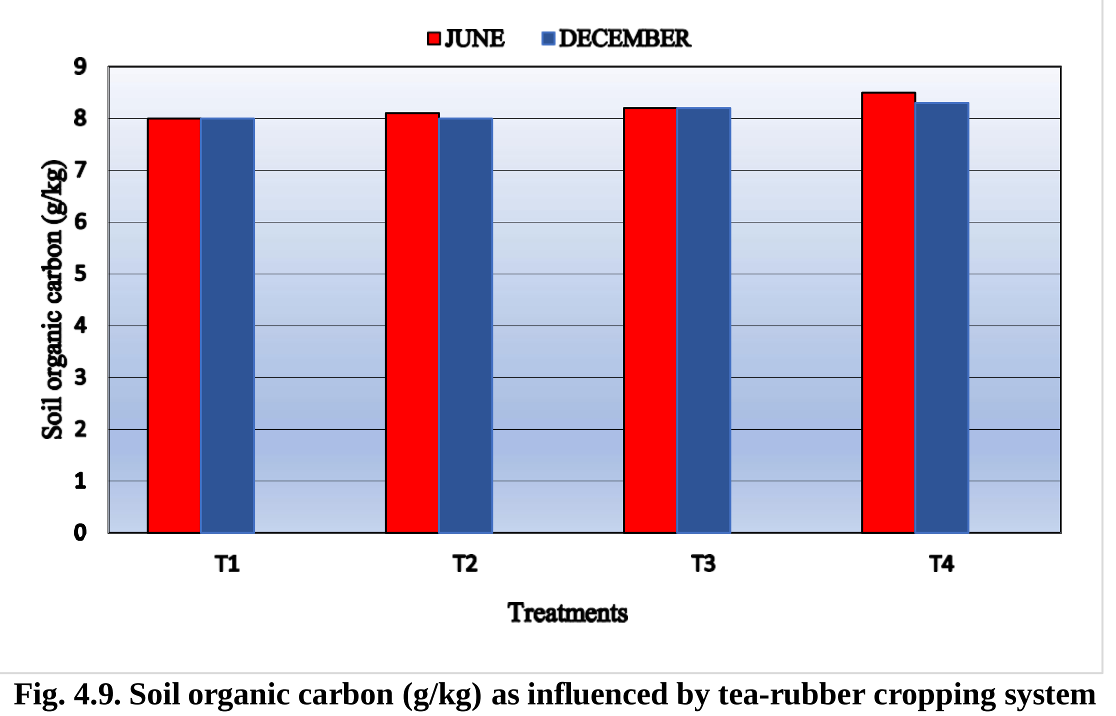

Fig. 4.9. Soil organic carbon (g/kg) as influenced by tea-rubber cropping system

4.2.4 Available Nitrogen in soil (kg/ha)

From the present experiment, it was observed that available nitrogen has no significant variation during both the month. Available nitrogen was highest in T_4 (327.64 kg/ha) and lowest recorded was (319.55 kg/ha) at T_1 during June.

During December the highest available nitrogen was recorded in T_4 (258.93 kg/ha) and lowest was recorded in T_1 (256.95 kg/ha). Data recorded on available nitrogen in soil are presented in Table 4.19. and Fig.4.10.

Table 4.19. Available nitrogen (kg/ha) in soil as influenced by tea-rubber cropping system

Treatment	June	December
T1	319.55	256.95
T2	320.11	257.19
T3	320.31	257.88
T4	327.64	258.93
$C.D_{0.05}$	N/A	N/A
Significance	NS	NS

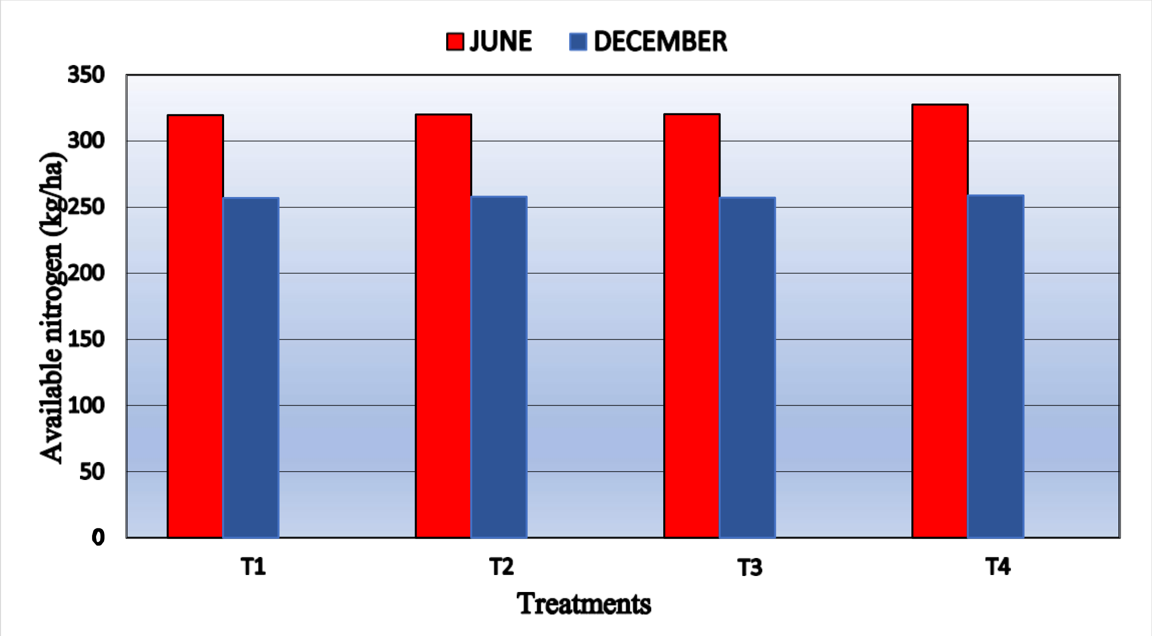

Fig. 4.10. Available N (kg/ha) present in the soil as influenced by tea- rubber cropping system

4.2.5 Available phosphorus (kg/ha) in soil

From the present experiment, it was observed that the available phosphorus in soil varied significantly at both the months. Available phosphorus was highest in T_4 (25.67 kg/ha) and lowest recorded was(24.70kg/ha) at T_1 during June.

During December the highest available phosphorus was recorded in T_4 (25.64kg/ha) and lowest was recorded in T_1 (24.69kg/ha). Data recorded on available phosphorus and in soil are presented in Table 4.20. and Fig.4.11.

Table 4.20. Available phosphorus (kg/ha) in the soil as influenced by tea-rubber cropping system

Treatment	June	December
T1	24.70	24.69
T2	24.94	24.87
T3	25.31	25.29
T4	25.67	25.64
$C.D_{0.05}$	0.68	0.69
S.E(d)	0.30	0.30
S.E(m)	0.21	0.21
Significance	S	S

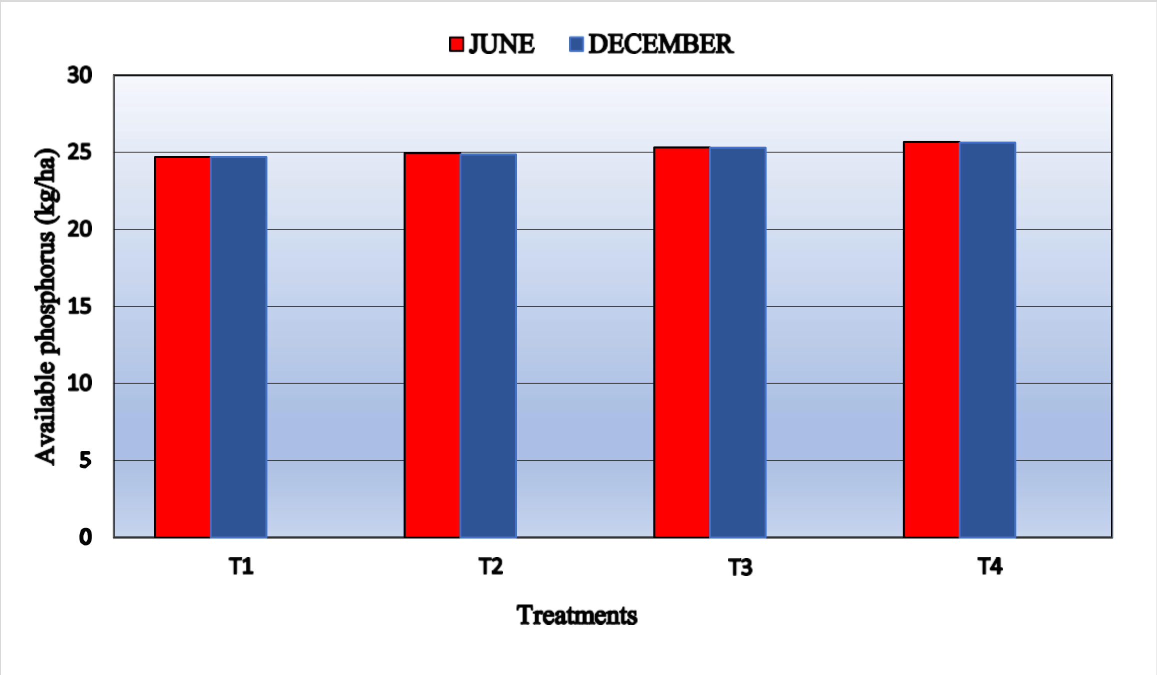

Fig. 4.11. Available P (kg/ha) present in the soil as influenced by tea- rubber cropping system

4.2.6 Available Potassium(K) (kg/ha) in the soil

From the present experiment, it was observed that the available potassium in soil not vary significantly during both the months. Available potassium was highest in T_4 (249.74 kg/ha) and lowest recorded was (240.55 kg/ha) at T_1 during June.

During December the highest available potassium was recorded in T_4 (245.26 kg/ha) and lowest was recorded in T_1 (233.47 kg/ha). Data recorded on available potassium and in soil are presented in Table 4.21. and Fig. 4.12.

Table 4.21. Available potassium (K) (kg/ha) present in the soil as influenced by tea-rubber cropping system

Treatment	June	December
T1	240.55	233.47
T2	244.64	240.78
T3	245.89	241.97
T4	249.74	245.26
$C.D_{0.05}$	N/A	N/A
Significance	NS	NS

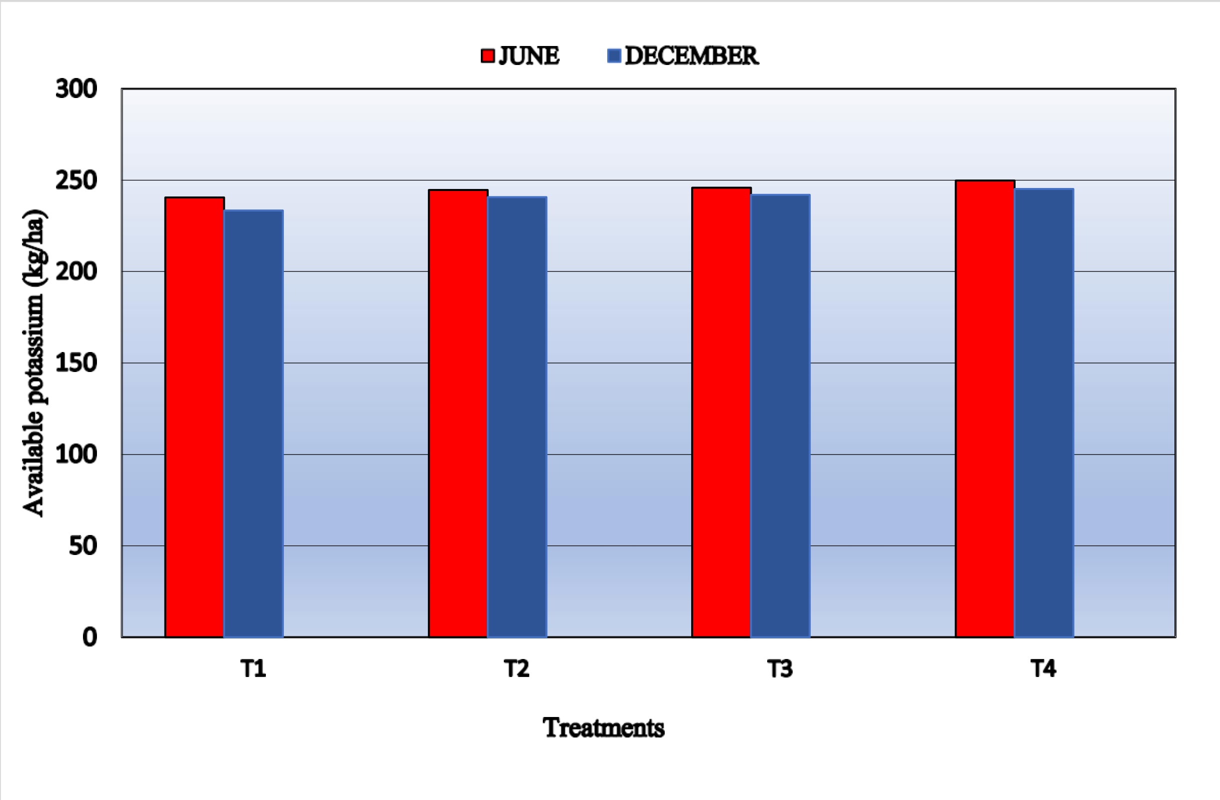

Fig. 4.12. Available K (kg/ha) present in the soil as influenced by tea-rubber cropping system

CHAPTER-V
DISCUSSION

In agriculture, intercropping of plantation crops is a complex cropping pattern which allows two or more crops to grow and attain harvest from the same land. In such a situation the target is to increase the efficiency of utilization of the land with varying architecture to take the advantages of moisture, nutrients etc. for maximum profitability. More focus has been placed on attaining yield sustainability, maintaining soil fertility, boosting farm income, production and effectively using the resources accessible through intensive farming in modern agriculture.

Assam's plantations have completed a full circle as thousands of small farmers have switched from paddy to growing tea. Large number of youth has adopted plantation of tea in recent years and the fallow high lands have gradually been brought under tea in many districts like Golaghat, Jorhat, Tinsukia, Sibsagar, Dibrugarh etc. Tea has been adopted mostly because of its adaptability under prevailing agroclimatic condition and high economic return from per unit area of land.

In Assam, mostly in upper assam area we can find tea plantation in small as well as in large scale. Tea is long established crop occupying the land for about hundred years. So, monocropping of tea can’t generate adequate income and employment to the small scale farmers. Small tea growers have chosen to plant different crops in their fields, such as arecanuts,agarwood (sasi), rubber etc., in order to supplement their income during the lean tea-growing season and to make more efficient use of their property. This emphasises the value of utilising tea holdings in an integrated manner to secure appropriate income and create new opportunities from small areas. Considering the suitability of agroclimatic condition of North-East India for rubber cultivation, there is need to explore suitability of this crop for growing as an intercrop in tea plantation and benefit the small tea growers of Assam and other north-eastern states. So, taking into consideration the above mentioned aspects, the present research work was conducted to study the growth and yield of tea and soil nutrient availability as influenced by tea-rubber cropping system.

The results revealed that yield of the green tea leaf and growth of the tea was found to be higher in tea with conventional shade than in the other treatments where tea was intercropped with rubber plant. But after determining soil physical character like soil moisture and soil chemical properties like pH, NPK, soil organic carbon content, this proved that intercropped plot with widest spacing in rubber plant shows better results in nutrient availability.

This chapter systematically presents the results of the study and its related discussion of the soil properties and plant parameters as influenced by tea-rubber cropping system.

For growth performance in tea plant in terms of thickness of stem from different height from the ground during different months it revealed that no significant variation was observed. The maximum thickness for 15 cm,30 cm and 45 cm from the ground was recorded in T_1 and the lowest was recorded in T_2 (Table 4.1, 4.2, 4.3). This implies that thickness of the tea in the control plot T_1 was highest might be because of the less competition and proper penetration of light. And also due to better utilization of nutrients present in the soil. This corroborates with the study of (Singh *et al*., 2019). He conducted an experiment on tea-rubber intercropping and concluded that highest thickness was recorded where tea was planted as a monocrop.

Significant difference was recorded in the bush spread. The highest bush spread was recorded at T_1 and the lowest was recorded in T_2. Gradual increment was seen in all the treatments from May to December (Table 4.4). The growth of the bush was high due to proper shade management and nutrient uptake in control plot with shade trees. Whereas the rubber plant canopy was dense and proper penetration of light was less so the area of tea bush was small as compared to control plot.

The shoot weight of 100 shoots was revealed that significant difference was observed in all the months. The highest fresh weight was recorded during $T_1$for all the months and lowest was recorded during T_2(Table 4.5). The increase in shoot weight was might be due to proper solar radiation in the control plot which helps in proper growth of the tea plants. This study corroborates with the study of (Chen *et al*.,2019). He revealed that increase in plant weight are strongly correlated with the amount of solar radiation that tea plants received. The intercropped plot has very low light interception and it remains shady. Even the weight of a shoot is also influenced by weather conditions, the smaller shoots are produced under dry weather conditions (Mwakha, 1985; Wijeratne, 1996).

Plucking point density of the tea shows significant difference in different months. The highest plucking point density was recorded in T_1 and lowest was recorded in the T_2. The plucking point density was highest due to proper growth of the tea in control plot as the uptake of the tea plants was more in control plot(Table 4.6). And also the penetration of the light was more in the control plot due to the presence of *Albizzia chinensis* which provides efficient shade to the tea plants.

Yield of the tea plants varied significantly in all the months. Tea under control plot produces highest yield as compared to in intercrop situation (Table 4.7). The total yield in T_1, under control plot is 27.86kg/plot. And the lowest yield was recorded in the T_2(12.30kg/plot). The most important point of consideration is that tea is economically viable crop in immature phases of rubber. This corroborates the study of (Yogaratnam and Iqbal, 1998). They recorded that intercropping tea and rubber generally resulted in higher yields up to eight years after planting. Also the present age of the tea and rubber is 9^{th} year and as the rubber plant age increases the canopy of rubber comes close slowly and the tea yield is affected adversely due to over-shading. The wider inter-space of intercrop increases crop growth rate and increases productivity of tea (Das *et al*., 2008).The planting spacings of shading trees must be optimum. It has been reported that 30-40% shading in rubber tree-tea interplanting system was profitable to dry matter accumulation and improve tea quality. Heavy shading (over 50% shading) caused an obvious decrease of tea yield (Shoubo *et al*.,1991).

Nitrogen content in leaf don't vary significantly in different treatments for both the month. For the month of june the highest leaf nitrogen was recorded in T1(3.36%) and lowest was recorded in T2(3.21%). For the month of december the highest leaf nitrogen was recorded in T1 (3.25%) and lowest was recorded in both T2 (3.16%)(Table 4.8). This might be due to the fact that rate of light intensity on the uptake of nitrogen by tea shoot was high. This study corroborates the findings of (Gensham and Renjum, 1986). Even (Burridge *et al*., 1964) found that positive effect on nitrogen uptake. The lowest leaf nitrogen was recorded in T_2 and T_3 might be due to rate of light intensity on the uptake of nitrogen by tea shoot was less as the spacing of rubber was congested and the area remains densely shady.

Phosphorus content in leaf have no significant difference for both the months. It was observed that leaf phosphorus was highest in T_1 and lowest in T_2 (Table 4.9). This might be due to the fact that rate of light intensity on the uptake of phosphorus by tea shoot was high.This study corroborates the findings of(Gensham and Renjum, 1986). The lowest leaf phosphorus was recorded in T_2 and T_3 might be due to rate of light intensity on the uptake of phosphorus by tea shoot was less as the spacing of rubber was congested and the area remains densely shady.

Potassium content in leaf don't vary significantly in different treatments for both the months. It was observed that leaf potassium was highest in T_1 and lowest in T_2 (Table4.10). This might be due to the fact that rate of light intensity on the uptake of potassium by tea shoot was high.This study corroborates the findings of(Gensham and Renjum, 1986). The lowest leaf potassium was recorded in T_2 and T_3 might be due to rate of light intensity on the uptake of potassium by tea shoot was less as the spacing of rubber was congested and the area remains densely shady.

In growth performance in rubber plant in terms of girth, the highest measurement in girth was seen in T_4 in September (71.25cm) and minimum girth was attained in T_2 (65.93cm). Similarly, the girth of the rubber plant during December revealed that highest was T_4 (72.17cm) and minimum was T_2 (66.44cm). There was an increment in rubber's girth from September to December period (Table 4.11). Maximum girth attained might be due to the result of more readily available growth elements from both below and above the soil surface, as well as because there is less competition. This corroborates the study of (Kakaty *et al.*, 2002). He revealed that due to the presence of adequate amount of growth elements in the soil, the girth increment might be maximum. This precisely indicates that effect of intercropping rubber with tea has no adverse impact on rubber growth.

In growth performance of the rubber plant in terms of the rubber canopy the highest spread of the canopy from east-west direction was recorded in T_4 and the lowest was recorded in T_2 for both the months. Even in the north-south direction the highest was recorded in T_4 and lowest was recorded in T_2(Table 4.12,4.13). It was recorded that in wider spacing of the rubber plant, the canopy spread was highest. This corroborates with the study of the (Brar *et al.*,2012). He had made an extensive study about the guava plants canopy spread and he revealed that wider spacing resulted in increase in canopy, whereas the lowest canopy was recorded in the narrow space guava plants.

In this study, the pH of soil was recorded for both top and sub soil and it was revealed that no significant variation was seen in both the depth of the soil. For the month of June and December the highest pH recorded in both the depth of the soil was T_4 and lowest was recorded in T_1(Table 4.14,4.15). The pH of the soil was higher in intercropping plots than control plots because the plant residues which could improve soil structure and soil quality status. This corroborates the findings of (Wen *et al.*, 2020). They reported that while intercropping tea with loquat, waxberry and citrus, it was revealed that pH was highest in intercropping plots than in monocropping plot of tea for both autumn and spring seasons.

The soil moisture status during the month of June and december shows no significant variation in both the depth of the soil. The study revealed that the highest soil moisture content was recorded in the control plot T_1 whereas the lowest was recorded in T_2 for both the month and in both the depths of the soil (Table 4.16, 4.17).Intercropping plots with tea-rubber revealed lower soil moisture content than T_1whichmight be because of the high rate of transpiration from leaf canopy of rubber and due to narrow spacing of rubber in those plots. This study corroborates the findings of (Dutta, 2016). He studied on tea and arecanut intercropping where he revealed that high rate of transpiration from leaf canopy of arecanut and tea causes depletion of soil moisture in intercropping. Further depletion of soil moisture was mostly seen in the top soil for all the treatments because of presence of feeder roots of tea which might accelerate the moisture uptake. This study corroborates the findings of Wu *et al.*, (2016). They reported that tea trees take water from the top layers of the soil whereas the rubber trees uptake water from deeper layers of the soil and this suggest that rubber trees and tea trees have different but complementary water use patterns.

Soil organic carbon varied significantly at different treatments during the month of June. In both the month of June and December the highest organic carbon content was seen in T_4, whereas the lowest soil organic carbon content was recorded in T_1(Table 4.18). The soil organic carbon status was more in the intercropping plots which might be due to rate of decomposition of the plant residues were highest in the shaded condition than in area where it is less shaded. This study corroborates the findings of (Ma *et al.*, 2017). They experimented the decomposition of leaf litter at different light intensity, where he had revealed that 40%, 30% light intensity decomposes the litter faster than 50-70% light intensity as shading supported more stable environment and temperature which is favourable for the activities of decomposing organisms to promote foliar litter decomposition. Also the higher crop residues from both rubber and tea plants in that area increases organic content. This study corroborates the findings of (Jessy *et al.*, 2017). In the experiment they reported that the soil organic carbon was more in soils where intercrop were present. Even (Liu *et al.*, 2023) compared with the impact of monoculture cultivation over intercropping and the effects of rubber intercropping mainly increased the soil carbon pool.

Crops under mixed cropping system exerted influence on the nutrient status of the soil. Available nitrogen in soil has no significant variation in different treatments for both the month. It was observed that soil nutrient status particularly in respect to the nitrogen was highest in the intercropped plot (T_4) 327.64kg/ha and lowest in control plot (T_1) 319.80kg/ha for the month of June and during December the highest available nitrogen was also recorded in T_4 (258.93kg/ha) and lowest in T_1 (256.95kg/ha) (Table 4.19). There might be high quantity of soil microbial community and the soil organic carbon content was high. This corroborates the findings of (Tang *et al*., 2020). And also there may be adequate supply of nutrients in the soil in the intercropped plots. This corroborates the study of (Bai *et al*., 2022). In their experiment they observed that the available nitrogen content was high in intercropped plot of tea and walnut rather than in the monocropping plot.

Available phosphorus in soil varied significantly in different treatments for both the month. It was observed that soil nutrient status particularly in respect to the phosphorus was highest in the intercropped plot (T_4) 25.67kg/ha and lowest in control plot (T_1) 24.70 kg/ha for the month of June and during December the highest available phosphorus was also recorded in T_4 (25.64 kg/ha) and lowest in T_1 (24.69 kg/ha) (Table 4.20). The available phosphorus content in soil was highest in intercropped condition might be due to maximum abundance of associated microbial taxa involved in soil nutrient cycling, including rhizobia and phosphate solubilizing bacteria. This corroborates the study of (Bai *et al*., 2022). He revealed that due to the presence of soil microbes it helps in nutrient cycling of the soil and it increases the soil nutrient status. Another reason for this might be the releasing of nutrients by the trees to meet crop demands and the organic carbon in content was high. This corroborates the study of (Palm, 1995). He revealed that different tree releases nutrients to the soil which helps in enhancement of soil quality and meet crop demands.

Available potassium in soil varied significantly in different treatments for both the month. It was observed that soil nutrient status particularly in respect to the potassium was highest in the intercropped plot (T_4) 249.74 kg/ha and lowest in control plot (T_1) 240.55kg/ha for the month of June and during December the highest available potassium was also recorded in T_4 (245.26 kg/ha) and lowest in T_1 (233.47 kg/ha) (Table 4.21). The available potassium content in soil was highest in intercropped condition might be due to maximum abundance of associated microbial taxa involved in soil nutrient cycling, including rhizobia and potassium solubilizing bacteria. This corroborates the study of (Bai *et al*., 2022). He revealed that due to the presence of soil microbes it helps in nutrient cycling of the soil and it increases the soil nutrient status. Another reason for this might be the releasing of nutrients by the trees to meet crop demands. This corroborates the study of (Palm, 1995). He revealed that different tree releases nutrients to the soil which helps in enhancement of soil quality and meet crop demands.

CHAPTER VI

SUMMARY AND CONCLUSION

Intercropping system is a traditional agricultural method practised from many decades which aims at increasing the efficiency of utilization of the land for maximum profitability. A complex ecological situation might arise if the geometry of the planting and the crop combinations are not appropriated. The geometry should be such that both the crops planted should have less competition for soil moisture, nutrients and solar radiation for growth of the plants.

Keeping this in view, the present investigation was carried out with two cropping systems- one the tea under conventional shade tree and the other tea under rubber plantation, to find out the growth parameters of the tea and its influence in rubber trees and also to record the soil nutrient status of both the systems.

Study on the thickness of stems at different heights from the ground revealed that thickness was highest under control plot with *Albizzia chinensis*. As the growth of the tea plants and the bush vigour was highest in the tea under conventional shade trees.

Even the bush spread was highest in the control plot and it shows significant variation in the months. From may to august the increment was higher than august to december. The highest bush spread was recorded in tea with *Albizzia chinensis* plot as the penetration of light through the canopy of the shade tree is optimum to enhance the growth of the tea plants, whereas the area under tea with rubber tree intercropped had very dense shaded environment as the canopy of the rubber is very dense than *Albizzia chinensis*.

The fresh weight of shoots was highest in control plot and it shows significant variation in all the months. From September the fresh weight of the shoots have decreased. The fresh weight of the shoots were highest in the conventional shade tree plot than the tea-rubber intercropped plot. The increase in shoot weight is correlated with amount of solar radiation the plant received.

Plucking point density had significant variation in all the months and it was highest in control plot. For the month of August the plucking point density was found to be highest in all the treatments which was even reflected in the yield. Pluckable shoots under

conventional shade tree was highest when compared to intercrop. From the month of September the plucking point density started decreasing slowly due less sunshine hour.

The ability of the photosynthetic system to convert solar energy into dry matter and distribute it to the portion of the plant that produces the commercial output is what mostly determines how well crops can be harvested. The total yield was highest in the conventional shade tree plot with tea as compared to tea-rubber intercropped plot. The increase in yield was might be due to increase in partitioning of photosynthates towards harvestable shoots in the control plot. The lowest yield might be due to low partitioning rates or lower production of the photosynthates and due to heavy shading from the rubber plants canopy. Once the age of the rubber increases the canopy comes closer and the light penetration through the canopy decreases which directly effects the growth and yield of tea.

The NPK content in the plant shoot is one of the important factor which maximizes plant growth. The components of a tea shoot and how they are converted into other compounds impact the quality of the final product. There was no significant variation between different treatments but the highest NPK content in the shoots were recorded in the control plot. This might be due to the rate of light intensity has effect on the uptake of nitrogen by tea shoot from the soil.

The rubber girth showed increment from September to December and highest girth was recorded in the plot where rubber was interplanted widely. And the lowest was recorded where the rubber interplanted with narrow spacing. The girth was increased might be due to the result of more readily available growth elements from both below and above the soil surface, as well as because there is less competition in-between both the plants. And also the rubber canopy spread was highest in the plot where rubber was interplanted with wide spacing. This might be due to as the horizontal growth was more where there was more space between the two rubbers and its not congested.

The soil pH showed no significant variation among all the treatments in both the depths of the soil. The highest pH was recorded in the intercropped plot with rubber spaced at wider spacing. All the intercropped plot showed highest pH as compared to control plot.

Depletion of the soil moisture content in both top and sub-soil was highest under intercrop condition. Further depletion of soil moisture was mostly seen in the top 0-15cm soil (Table 4.16) for all the treatments because of presence of feeder roots of tea which might accelerate the moisture uptake. Moreover due to the high rate of transpiration from leaf canopy of rubber and tea it caused depletion of soil moisture in intercropping.

Soil organic carbon had no significant variation in both the months and the highest was recorded in the intercropped plot in comparison to the control plot. The rate of decomposition of the plant residues were highest in the shaded condition than the area exposed to light condition. The rubber intercropped plots had very dense canopy and its shady in comparison to the conventional shade tree plot.

The soil available NPK was highest in the intercropped condition in comparison to control plot might be due to high soil organic content, soil microbial taxa was high in the plots and also adequate supply of nutrients in the soil. Improved enzymic activity in the soil during intercropping speed up the process by which organic matter breaks down and releases nutrients into the soil environment.

To sum up, intercropping of tea with rubber indicated that in present condition the growth parameters was revealed to be better in the control plot. Whereas the soil nutrient availability showed no significant variation among all the treatments except for the available phosphorus content in the soil which showed significant variation in both the months. The rubber plant had no adverse effect on the soil status but due to the dense canopy spread of the rubber interplanted with narrow spacing the light transmission is quite low which eventually effects the yield and growth of the tea plants. The yield was recorded to be highest in the control plot might be due to the aforementioned reason. Also the nutrient content in the plucked shoots were highest in the tea – *Albizzia chinensis* plot might be due to proper uptake of the nutrient from the soil, which is also reflected in the plucking point density and yield. The increase in the yield might be due to more proper partitioning of photosynthates towards harvestable shoots under tea- *Albizzia chinensis* plot. The yield recorded in the present study was much lower than the state or district average which might be due to overshaded condition of the area.

If the planting geometry is improper when mixed crops are grown, a complex ecological situation could develop. Planting geometry should be chosen such that the plant receives sufficient space and sunlight for proper growth. The economic return achieved under various conditions demonstrated that intercrop plots did not yield as much as regular shade did. Also the present research work was inconclusive about the root study, tea quality and rubber's yield. So to get a conclusive evidence to confirm the viability of widespread adoption of this cropping system, a long-term study with broader rubber spacing and large plot sizes is needed.

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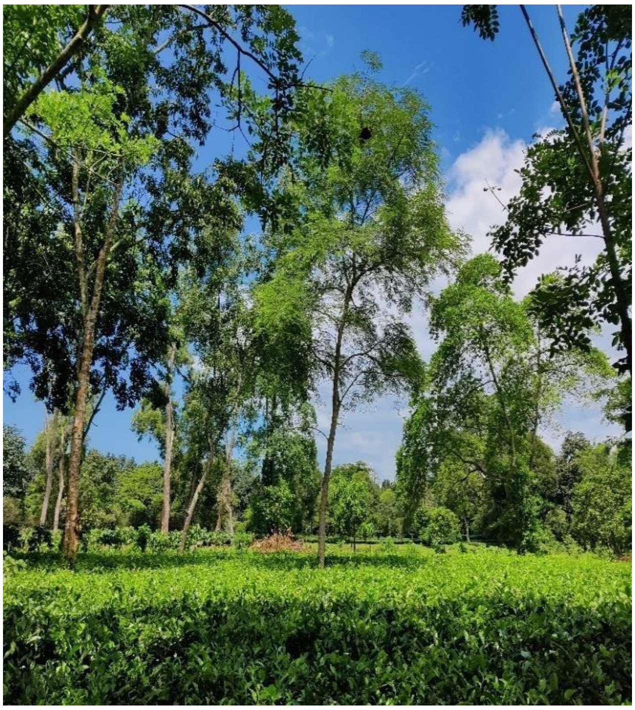

Plate 1. Tea - *Albizzia chinensis* plot

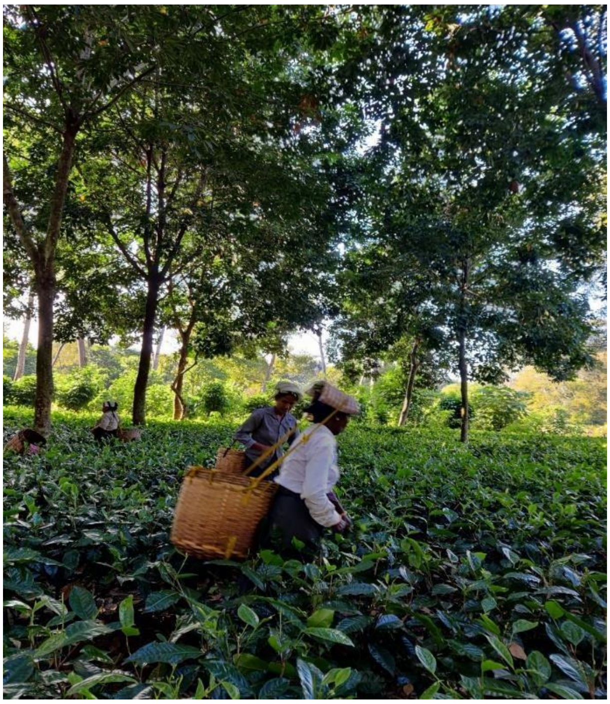

Plate 2. Tea- Rubber plot

Plate 3. Preparation for plant samples for laboratory analysis

Plate 4. Preparation for soil samples for laboratory analysis

Plate 5. Rubber canopy spread measurement

Plate 6. Thickness of tea stem by vernier caliper

Plate 7. Analysis of soil organic carbon

Plate 8. Analysis of leaf K_2o

Plate 8. pH estimation in rotatory shaker

Plate9.Titration for Available N in soil

APPENDIX – I

Calculation for thickness of stem at 15cm, 30cm, 45cm from the ground

Thickness of stem at 15cm from the ground

i. May

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.273			
Treatment	3	0.047	0.016	2.801	0.10087
Error	9	0.05	0.006		
Total	15	0.37			

ii. August

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.089			
Treatment	3	0.049	0.016	0.961	0.45229
Error	9	0.152	0.017		
Total	15	0.29			

iii. December

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.22			
Treatment	3	0.057	0.019	0.638	0.60932
Error	9	0.269	0.03		
Total	15	0.547			

Thickness of stem at 30cm from the ground

i. May

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.037			
Treatment	3	0.122	0.041	1.556	0.26652
Error	9	0.236	0.026		
Total	15	0.396			

ii. August

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.062			
Treatment	3	0.12	0.04	1.858	0.2071
Error	9	0.194	0.022		
Total	15	0.376			

iii. December

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.055			
Treatment	3	0.122	0.041	2.308	0.14506
Error	9	0.159	0.018		
Total	15	0.335			

Thickness of stem at 45cm from the ground

i. May

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.047			
Treatment	3	0.043	0.014	1.067	0.41034
Error	9	0.122	0.014		
Total	15	0.212			

ii. August

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.053			
Treatment	3	0.043	0.014	1.184	0.36927
Error	9	0.11	0.012		
Total	15	0.207			

iii. December

Source of Variation	**DF**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Significance**
Replication	3	0.042			
Treatment	3	0.03	0.01	3.077	0.08317
Error	9	0.029	0.003		
Total	15	0.101			

APPENDIX-II

Calculation of bush spread of tea

i. May

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	41,956.750			
Treatment	3	83,832.750	27,944.250	12.203	0.00160
Error	9	20,610.250	2,290.028		
Total	15	1,46,399.750			

ii. August

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	31,362.50			
Treatment	3	98,897.00	32,965.67	6.815	0.0108
Error	9	43,533.50	4,837.06		
Total	15	1,73,793.00			

iii. December

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	30,364.50			
Treatment	3	90,994.50	30,331.50	6.844	0.01067
Error	9	39,886.00	4,431.78		
Total	15	1,61,245.00			

APPENDIX-III

Calculation of shoot weight i.May

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	14.224			
Treatment	3	329.294	109.765	11.174	0.00217
Error	9	88.407	9.823		
Total	15	431.925			

ii. June

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	8.132			
Treatment	3	123.442	41.147	10.584	0.00262
Error	9	34.99	3.888		
Total	15	166.563			

i. July

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	1.118			
Treatment	3	155.804	51.935	42.311	0.00001
Error	9	11.047	1.227		
Total	15	167.969			

ii. August

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	5.019			
Treatment	3	333.82	111.273	20.903	0.00022
Error	9	47.909	5.323		
Total	15	386.748			

iii. September

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	11.748			
Treatment	3	378.26	126.087	14.656	0.00082
Error	9	77.427	8.603		
Total	15	467.435			

iv. October

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	35.003			
Treatment	3	462.104	154.035	29.064	0.00006
Error	9	47.699	5.3		
Total	15	544.805			

v. November

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.602			
Treatment	3	502.594	167.531	40.542	0.00001
Error	9	37.19	4.132		
Total	15	540.386			

APPENDIX-IV

Calculation of plucking point density

i. May

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.5			
Treatment	3	140	46.667	36.522	0.00002
Error	9	11.5	1.278		
Total	15	152			

ii. June

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.5			
Treatment	3	131	43.667	25.355	0.0001
Error	9	15.5	1.722		
Total	15	147			

iii. July

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	16.5			
Treatment	3	168	56	21.447	0.00019
Error	9	23.5	2.611		
Total	15	208			

iv. August

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	20.5			
Treatment	3	84	28	9.164	0.00425
Error	9	27.5	3.056		
Total	15	132			

v. September

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	44.5			
Treatment	3	147	49	5.841	0.01697
Error	9	75.5	8.389		
Total	15	267			

vi. October

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	3.5			
Treatment	3	75	25	10	0.00317
Error	9	22.5	2.5		
Total	15	101			

vii. November

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	6.5			
Treatment	3	104	34.667	9.905	0.00328
Error	9	31.5	3.5		
Total	15	142			

APPENDIX-V

Calculation of yield

i. May

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.163			
Treatment	3	7.823	2.608	14.06	0.00096
Error	9	1.669	0.185		
Total	15	9.655			

ii. June

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.175			
Treatment	3	12.663	4.221	45.463	0.00001
Error	9	0.836	0.093		
Total	15	13.674			

iii. July

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.257			
Treatment	3	16.269	5.423	78.295	0
Error	9	0.623	0.069		
Total	15	17.149			

iv. August

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.153			
Treatment	3	24.403	8.134	90.954	0
Error	9	0.805	0.089		
Total	15	25.361			

v. September

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.084			
Treatment	3	17.914	5.971	104.982	0
Error	9	0.512	0.057		
Total	15	18.51			

vi. October

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.053			
Treatment	3	2.997	0.999	18.346	0.00036
Error	9	0.49	0.054		
Total	15	3.54			

vii. November

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.354			
Treatment	3	5.598	1.866	23.479	0.00014
Error	9	0.715	0.079		
Total	15	6.667			

APPENDIX- VI

Calculation for Leaf N

i. June

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.277			
Treatment	3	0.059	0.02	0.207	0.88917
Error	9	0.851	0.095		
Total	15	1.187			

ii. December

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.138			
Treatment	3	0.019	0.006	0.154	0.92441
Error	9	0.364	0.04		
Total	15	0.521			

APPENDIX-VII

Calculation for Leaf P_2O_5

i. June

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.001			
Treatment	3	0.007	0.002	0.835	0.50798
Error	9	0.024	0.003		
Total	15	0.032			

ii. December

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.001			
Treatment	3	0.007	0.002	0.835	0.50798
Error	9	0.024	0.003		
Total	15	0.032			

APPENDIX- VIII

Calculation of Leaf K_2O

i. June

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	1.606			
Treatment	3	0.028	0.009	0.037	0.98972
Error	9	2.216	0.246		
Total	15	3.85			

ii. December

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	1.08			
Treatment	3	0.006	0.002	0.026	0.99389
Error	9	0.72	0.08		
Total	15	1.806			

APPENDIX- IX

Calculation of pH of top soil

i. June

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.032			
Treatment	3	0.067	0.022	3.296	0.07178
Error	9	0.061	0.007		
Total	15	0.159			

ii. December

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.907			
Treatment	3	0.008	0.003	0.030	0.99266
Error	9	0.800	0.089		
Total	15	1.715			

Calculation of pH of sub-soil

i. June

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.009			
Treatment	3	0.076	0.025	3.817	0.05143
Error	9	0.060	0.007		
Total	15	0.145			

ii. December

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.067			
Treatment	3	0.069	0.023	3.051	0.08470
Error	9	0.068	0.008		
Total	15	0.204			

APPENDIX-X

Calculation of soil moisture content

i. June

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	4.910			
Treatment	3	8.551	2.850	0.963	0.45130
Error	9	26.638	2.960		
Total	15	40.100			

ii. December

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.150			
Treatment	3	5.349	1.783	2.934	0.09185
Error	9	5.470	0.608		
Total	15	10.969			

Calculation of soil moisture content (sub-soil)

i. June

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	8.017			
Treatment	3	2.693	0.898	0.886	0.48434
Error	9	9.115	1.013		
Total	15	19.824			

ii. December

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	10.983			
Treatment	3	1.930	0.643	0.459	0.71795
Error	9	12.628	1.403		
Total	15	25.541			

APPENDIX-XI

Calculation of soil organic

i. June

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.018			
Treatment	3	0.486	0.162	23.797	0.00013
Error	9	0.061	0.007		
Total	15	0.566			

ii. December

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.007			
Treatment	3	0.145	0.048	3.066	0.08384
Error	9	0.142	0.016		
Total	15	0.293			

APPENDIX-XII

Calculation of available N

i. June

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	1,354.314			
Treatment	3	176.960	58.987	0.487	0.69942
Error	9	1,089.026	121.003		
Total	15	2,620.301			

ii. December

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	35.094			
Treatment	3	9.601	3.200	0.996	0.43804
Error	9	28.929	3.214		
Total	15	73.623			

APPENDIX- XIII

Calculation for available P

i. June

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.380			
Treatment	3	2.202	0.734	4.165	0.04168
Error	9	1.586	0.176		
Total	15	4.168			

ii. December

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.353			
Treatment	3	2.204	0.735	4.089	0.04360
Error	9	1.617	0.180		
Total	15	4.174			

APPENDIX- XIV

Calculation for available K

i. May

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	588.673			
Treatment	3	171.857	57.286	0.412	0.74852
Error	9	1,251.72	139.08		
Total	15	2,012.25			

ii. December

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	897.275			
Treatment	3	297.238	99.079	0.234	0.87076
Error	9	3,817.76	424.196		
Total	15	5,012.28			