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PRODUCTIVITY OF TREE FODDER BANKS IN SELECTED HOMEGARDENS OF CENTRAL KERALA

By

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(2017-17-008)

THESIS

Submitted in partial fulfillment of the requirement for the degree of

MASTER OF SCIENCE IN FORESTRY

Faculty of Forestry

Kerala Agricultural University

DEPARTMENT OF SILVICULTURE AND AGROFORESTRY

COLLEGE OF FORESTRY

VELLANIKKARA, THRISSUR- 680 656

KERALA, INDIA

2019

DECLARATION

I, hereby declare that this thesis entitled **"Productivity of tree fodder banks in selected homegardens of central Kerala"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society

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Dedicated to my dear
Parents and Brother

ACKNOWLEDGEMENT

It is with utmost and great devotion, I place on record my deep sense of gratitude and indebtedness to my project advisor Dr. Asha K. Raj, Assistant Professor, Dept. of Silviculture and Agroforestry, College of Forestry, whose valuable guidance, timely help and moral support, friendly co-operation and warm concern throughout the study period made my thesis work an easy task.

I owe my sincere thanks to Dr. K. Vidyasagaran, Dean, College of Forestry for his immense help in a way of extending the facilities available in the college and Arimboor Grama Panchayat for conducting the present study and valuable suggestions he has provided throughout the course of my research. I express my heartfelt gratitude to Kerala agricultural University for extending financial and technical support for pursuance of my study and research.

I am deeply indebted to my advisory committee members Dr. T. K. Kunhamu, Professor and Head, Dept. of Silviculture and Agroforestry, College of Forestry, Dr. V. Jamaludheen, Professor, Dept. of Silviculture and Agroforestry, College of Forestry and Dr. A.V. Santhoshkumar, Dept. of Forest Biology and Tree Improvement, College of Forestry for their constant encouragement and constructive suggestions throughout the study period and for providing all the required infrastructure and moral support for me during the execution of the work.

I express my heartful thanks to Kearla Agricultural University for providing me KAU fellowship during my course period and also I owe my sincere thanks to All India Coordinated Research Project on Agroforestry for the partial funding in completion of my Research work.

I take this opportunity to render my sincere gratitude to farmers of Arimboor gram Panchayat Mr. Varghese Chirayath, Mr. Varghese A. and Mr. Praveen Panamukath for all their extreme support and coordination for carrying out this research in their fields. Special thanks to Mrs. Chandrika and Mrs. Shayla for their help during the field work.

I would like to acknowledge the academic and technical support provided by all the faculty members of the Kerala Agricultural University and my esteemed institution, the college of Forestry in the successful completion of my studies and thesis work.

I express my heartful thanks to Mrs. Jithila, Mrs. Divya, Mrs. Reshma, Mrs. Acsah , Mrs. Vijayalakshmi, Mr. Binu, Mr. Tojimon, Mr. Eldose and the workers of Tree nursery, college of forestry for their valuable guidance and timely help during various stages of my work.

Words cannot really express the true friendship that I realized from Mr. Jobin Kuriakose, Mr. Sachinkrishna, Mr. Harilal K, Mr. Abhi Jamtia, Mr. Vishnu Narayana, Ms. Gayathri Mukundan, Ms. Wahiba, Ms. Sharmista V, Ms. Meghana and my dear juniors Mr. Shifin, Mr. Athul E.S, Mr. Adarsh V, Mr. Naveen Unnimenon, Mr. Prasad P.S, Mr. Akhil A, Mr. Vayshak Mr.Arjun M.S, Mr.Sreehari K, Mr. Arshad, Mr. Akash, Ms. Subashmitha, Ms. Swathi, Ms. Anjali. For their valuable mental and physical support during the course of the study. Also the co-operation and help extended by Mr. Niyas sir and Mr. Shine sir are remembered with gratitude.

At this juncture, I express my deep love to my parents and brother without whose moral support, blessings and affection this would not have been a success.

Above all I bow my head before GOD ALMIGHTY whose blessings and care enabled me to undertake this venture successfully.

Anush Patric

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SYMBOLS AND ABBREVATIONS

ANOVA	Analysis of variance
BD	Bulk density
Cm	Centimeter
CF	Crude Fibre
CP	Crude Protein
DM	Dry Matter
DMRT	Duncan's Multiple Range Test
et al	And others
Fig.	Figure
g pl^{-1}	Gram per plant
Ha	Hectare
K	Potassium
Kg	Kilogram
Mg	Mega gram
N	Nitrogen
Ns	Non-significant
P	Phosphorus
Ph	Soil reaction
SOC	Soil Organic Carbon
SPSS	Statistical Package for the Social Sciences
PAR	Photosynthetically Active Radiation

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INTRODUCTION

1. INTRODUCTION

Homegardens are considered as a resource system of multiple functions and an important wheel of vehicle for food and nutritional security, environmental and ecological benefits, biodiversity and soil conservation, socio-cultural benefits and job creation as well as mitigation of the impact of climate change in both developing and under developed countries. Homegardens are recognized worldwide as an epitome of a sustainable agroforestry system (Torquebiau, 1992; Kumar and Nair, 2004). Homegardens constitute the prominent land use system in Kerala that addresses the livelihood security and nutritional demands of small and marginal farmers. The homegardens in Kerala is very often said to combine crops with livestock rearing which ensures productivity, enhance nutritional status, augment farm income, help to reduce dependence on inorganic chemical fertilizers and help to maintain soil health through organic recycling (Jaslam *et al.*, 2017). Furthermore, the biophysical aspects of home gardens such as soil conservation effects and potential for carbon sequestration are ecological benefits to both the farmer and to the community.

However, increasing human population, urbanization and other socio-economical changes have resulted in the breakdown of these traditional agroforestry systems of Kerala, accompanied by increasing economic, cultural, nutritional, and environmental problems. Unless concerted efforts are made to improve the economic prospects of the traditional homegardens, farmers will deter from the practice of homegardening and shift to other profitable land use activities. In this context, suitable interventions through an effective blend of tree/crop/animal components of demand in an integrated farming system mode are the need of the hour for the successful revitalization of existing homesteads. Since livestock plays a very pertinent role in maintaining soil health and sustainability of homesteads, in addition to nutritional benefits, revival of livestock population in homesteads needs urgent attention.

However, scarcity of quality fodder and high cost of purchased concentrate feeds are the major hindrance to successful livestock production in Kerala (Ajith *et al.*, 2012). Earlier the fodder materials available within the homesteads and from paddy fields were sufficient to meet the feed requirements of livestock. However, the change in cropping pattern of homesteads coupled with decline of paddy fields led to acute shortage of fodder. Hence, to meet the high nutrient demand of high yielding crossbred cattle, the homestead farmers had to depend entirely on expensive commercial concentrate feeds, which drastically reduced their net returns. In this context, cultivation of quality fodder on farm itself is highly warranted for promoting profitable livestock production in homesteads.

Fodder trees, with their nutrient rich leaves, constitute a potential source of quality green fodder to livestock especially during lean periods. Introducing fodder trees in homegardens is one of the promising ways for enhancing production of protein rich fodder on farm itself, thereby saving farmer's expenses on purchased feeds. *Morus indica* (Mulberry), *Calliandra calothyrsus* (Calliandra), *Sesbania grandiflora* (Agathi), *Gliricidia sepium* (Gliricidia), and *Moringa oleifera* (Moringa) are promising fodder trees by virtue of their nutritive foliage, fast growing nature, ability to withstand heavy pruning, good coppicing ability and higher biomass production (Raj *et al.,*2016; Joy ,2017; Sagaran, 2017). These trees have good shade tolerance and are found to be suitable components in agroforestry systems. Since the agro-climatic requirement of these trees suits well to that of Kerala, there is a good possibility of utilizing these trees as nutrient rich fodder source in our state.

However, due to intensive multi-tier cropping in homesteads, the scope for large scale tree fodder cultivation is limited. Hedgerow planting of fodder trees with higher tree densities in the available interspaces is a possible option for enhancing productivity from limited land area. Maintaining fodder trees as hedges also regulate the possible competition between the component crops in homesteads and facilitate easy harvesting of fodder. In addition to fodder supply, trees also offer numerous ecological services that help to maintain better soil properties and overall productivity of the system.

However, in spite of vast potential, fodder tree cultivation is not popular among farmers mainly because of the insufficient knowledge on suitable fodder trees and their nutritive aspects, as well as on the standard management practices to derive optimal productivity of quality forage from a limited land area. Information exists on the performance of various tree species as fodder banks under open conditions and partially shaded coconut gardens. On-station trials conducted in Kerala Agricultural University revealed the productivity of 9.91 and 11.73 Mg ha^{-1} yr^{-1} of dry fodder from Mulberry and Calliandra fodder banks intercropped in coconut gardens of Kerala (Raj *et al.*, 2016; Sagaran, 2017). However, there is paucity of research on their yield and nutrient outputs under homesteads with constraints in light and space availability. Hence, it is important to validate this research along with some other promising fodder tree species on farmer's homesteads in Kerala for popularizing fodder tree cultivation. With this background, a field study has been envisaged with the following objectives:

- To assess the forage yield and nutritive value of selected fodder tree species under hedgerow planting in selected homegardens of Central Kerala.
- The study will also probe short term changes in soil nutrient status of selected homegardens with tree fodder integration.

REVIEW OF LITERATURE

2. Review of Literature

Homegardens constitute the prominent land use system in Kerala that addresses the livelihood security and nutritional demands of small and marginal farmers. Despite the multidimensional benefits this unique land use system is fading out in Kerala at alarming pace. Since livestock plays a very pertinent role in maintaining soil health and sustainability of homesteads, decline in livestock population owing to acute feed shortage and consequent economic loss, is one among the reasons for deterioration of these systems in Kerala. Introducing fodder trees in homegardens is one of the promising ways for improving production of protein rich fodder for feeding livestock. In this context a field study has been envisaged to assess growth, forage yield and nutritive parameters of selected tree fodders as hedge rows under high density planting and intensive harvest management in small, medium, and large scale homesteads of Central Kerala. Relevant literature pertaining to the above aspects is reviewed hereunder.

2.1 HOMEGARDENS OF KERALA - THE CURRENT SCENARIO

Homegardens or homestead cultivation in general is the cultivation around the immediate vicinity of a house. Though numerous definitions are available, John (1997) comprehensively defined homestead/ home garden as a functional/operative and self-sustaining farm unit which consists of a collection of crops and multipurpose trees, planted randomly, with or without animals, owned and primarily managed by the dwelling farm family, with the objectives of satisfying the basic family needs (food, fuel, timber) and producing marketable surplus for the purchase of non-producible items. In the realm of agroforestry, homesteads and other multistrata, multispecies associations occupy an odd place. They are the most elegant manmade, tree-crop-animal associations, resembling a natural ecosystem and offer valuable ecosystem functions with human interference (Kumar and Tiwari, 2017). Against a backdrop of reduced cultivable land availability, increasing population pressure, food crises, climate change, and the fact that conventional intensification of agriculture has now reached its limitations, agroforestry practices offer interesting prospects. Improving management of such systems and ensuring their environmental, technical and social sustainability is a major issue for research and development (Nair, 1993).

Kerala has a wide land use and cropping patterns. Among these homegarden is a prominent traditional land use practice in Kerala. Round-the-year availability of diverse agricultural products ensures the food and nutritional security of the family in addition to economic benefits (Nair, 1989). Despite the manifold virtues as a promising land use system, homegardens in Kerala are undergoing massive transformation that wear down their inherent characteristics. Population pressure on the land and associated fragmentation, high cost of land, alternative options of land use are potential threats to retaining homegardens in the tropics. The multi species structure of homegardens are shifting to cash crops-based monocultures such as rubber and coconut, inflicting serious drain in plant diversity. The shift in farming pattern in homesteads has seriously affected the resource base in terms of soil and water conservation, poor drainage, massive soil erosion and associated loss of soil fertility (Kumar and Nair, 2004; Kunhamu, 2013). Hence, the homesteads of Kerala, which once considered the self-sustainable mini-production models is at the verge of extinction and unless concerted efforts are made to revitalize these systems, farmers will deter from the practice of homegardening and will shift to other profitable land use activities. In the wake of increasing population and low per capita availability of lands, proper management of micro-development models like homesteads is the key to success in a populous country like India (Jaslam *et al.*, 2017).

2.2 LAND HOLDING SIZES AND FLORISTIC DIVERSITY OF HOMESTEADS IN ARIMBOOR PANCHAYATH, THRISSUR

In Kerala, homestead agroforestry system forms a major land use pattern (Nair and Sreedharan, 1986; Jose, 1992). Size of holdings of homesteads in Kerala are generally classified as small (below 0.4 ha), medium (0.4 to 2 ha) and large (> 2.0 ha) (Kumar *et al.,* 1994).

Arimboor Grama Panchayat is situated in Anthikkad Block, Thrissur Taluk, in Thrissur district. The panchayat has an area of 22.65 sq. kms. The average size of land holdings in Thrissur district is 0.12 ha during 2010-11 (District Credit Plan, 2013).

As per the government classification the farmers are classified in to five sections based on their land holdings (Farm Guide, 2012). They are Marginal (< 1 ha), Small (1-2 ha), Semi medium (2-4 ha), Medium (4-10 ha), Large (> 10 ha). Households who possess holdings above 10 hectares are classified as large farms. In Arimboor panchayat, there are no householdings belonging to this category. In the present situation, this class of households are found only in the plantation sector. Majority of the land holdings fall within the size of less than 1 hectare. (Hand book of Arimboor Grama Panchayat, 2010-2011). Hence, for effective study and analysis, the homesteads with livestock component are classified into small with < 0.25 ha, medium with 0.25 ha -0.50 ha and large with 0.50 ha -1.0 ha (AICRPAF, 2017).

Survey conducted in 17 selected taluks of Kerala in small (below 0.4 ha), medium (0.4 to 2 ha) and large (> 2.0 ha) holding size categories shown profound unevenness in the number and abundance of trees (Kumar *et al.,* 1994). Floristic diversity was higher in the smaller homesteads. It decreased with increasing the size of holdings. Jose (1992) calculated Simpson's diversity indexes for different homegarden size-class categories and components. In general, tree density is higher in smaller holdings.

Survey conducted in Arimboor panchayath revealed significant variation in the functional diversity of varying size class of homesteads. Livestock component was comparatively higher in medium and small homesteads than large homesteads. Among the tree species multipurpose trees and fruit trees dominated in all the three size class of homegardens whereas timber species was relatively less. Vegetables, spices and medicinal plants were relatively higher in small and medium homegardens. In general species diversity was found to be higher in small and medium homegarden when compared to the larger one (AICRPAF, 2017).

2.3 LIVESTOCK COMPONENT IN HOMESTEADS

The rural economy and livelihood is greatly supported by the livestock sector. According to reports, the livestock sector employs eight percent of the labour force of India. Contribution of livestock to the national economy in terms of Gross Domestic Product (GDP) is 4.1 percent respectively. India continues to be the largest milk producing nation in the world. At the national level, the milk production is estimated to be 176 million tonnes in 2017-18 (GoK, 2018). Estimates by the Planning Commission of India indicate that the demand for milk will rise to 182 million tons by the year 2021–22.

Among the milk producing states in the country, Kerala ranks 14th, with a share of just 1.5 per cent of the total milk production in the country. The production of milk in Kerala has increased from 25.20 lakh MT to 25.76 lakh MT in 2017-18. However, the per capita availability of milk in Kerala has been declining during the 12th Five-Year Plan period. It decreased from 202 gm per day in 2016-17 to 192 gm per day in 2017-18 (GoK, 2018). Moreover, nearly 65 per cent of the meat required is met from animals of neighboring states. Hence, there is good scope for the development of livestock sector in Kerala.

In Kerala as per 2003 census nearly 94 % of the livestock population is concentrated in the rural area, 80% of the livestock farmers are marginal farmers and agricultural farmers. Most of the cattle holdings are one cow farms. Women constitute 60% of the workers (Envis centre, 2018). The homestaeds in Kerala is very often said to combine crops with livestock rearing which ensures productivity, nutrition and income to the family (Salam *et al.,* 1995). The organic manures from livestock uphold and sustain the soil nutrients which are vital for the production of other crops under homegardens (Andrews and Kannan, 2016).

However, the livestock population in Kerala is diminishing. There is a decrease in livestock population over 2007 to 2012 from 3.58 million to 2.73 million registering a negative growth of 23.76 % in the total number of animals of various species. Marginal farmers in Kerala rear nearly 87.7 per cent of the total cattle in the State, followed by small farmers in their homesteads (8.4 per cent) (GoK, 2017). There was a drastic reduction in the livestock population over a period of 15 years in all the three size classes of homegarden in arimboor panchayath. Livestock was prominent component in almost all the large homegardens of arimboor panchayath during 2000 which declined to 75% in large homegarden during 2016. Similar was with the case with other size categories as well (AICRPAF, 2017). Hence decline of livestock in homesteads have seriously affected the sustainability of homesteads itself. Combining crop cultivation with livestock activities has positive influence on the betterment of homesteads. Moreover, livestock represents an important capital asset and a source of income to the farmer (Jaslam *et al.,* 2017). Similar views on crop and livestock combination were expressed by Maydell (1987) and Helen and Smitha (2013). The livestock component, besides providing financial support at times of distress, supports the farmer by providing draught power, milk, meat, and organic manure. Hence, revival of livestock component in homesteads demands urgent intervention.

2.4 MAJOR CONSTRAINTS IN LIVESTOCK FARMING

Insufficient quantity and quality nutrition is one of the major limitations for livestock production in Kerala (Ajith *et al.*, 2012). Kerala produces only 60 per cent of the roughage requirement for livestock (Kerala State Planning Board, 2011). Regarding the cattle feed concentrate, state is not producing even half of the requirement. Average milk yield per day of cross bred cows remains low at 6 litres compared to its potential of 8-10 litres, mainly due to insufficient nutrition. Earlier, the feed materials available within the homesteads as well as from other cropping systems like paddy was sufficient to meet the feed requirement of livestock. However, with the changing cropping pattern of homesteads and the decline in paddy cultivation there is severe shortage of feed thereby forcing farmers to depend on highly expensive purchased feeds. Thus, cattle rearing is not at all remunerative and farmers are avoiding this enterprise due to difficulty in maintaining them. In this context, production of quality fodder within the homesteads is the only alternative to overcome the deficit. One of the strategies to revive the fodder availability in homegardens is to promote understorey productivity through judicious intercropping of compatible, shade tolerant fodder crops in the interspaces available. Moreover, the agro climatic condition of Kerala provides an ideal habitat for cultivation of fodder yielding species under homegarden (Kunhamu *et al.*, 2015).

2.5 RELEVANCE OF FODDER TREES IN ANIMAL NUTRITION

The common practice of dairy farming in humid tropics of Kerala is homestead based, where one or two high yielding crossbred cows are reared mainly for milk production, under cut and carry forage feeding system. The major cattle feeds are natural grass and back yard planted fodder, mainly hybrid napier grass. Owing to the poor dry matter, crude protein content (6-12 %) and dry season scarcity, these grasses are insufficient for meeting all feed requirements, affecting the productivity of animals. Utilization of fodder trees has long been known to be one of the most effective means of improving both the supply and the quality of forage in tropical smallholder livestock systems, especially during the dry season (Gutteridge and Shelton, 1993). Fodder trees are increasingly recognized as important components of animal feeding, especially as suppliers of protein. Moreover, tree fodders are long living and require low maintanence, which provide sustainable feed to livestock. Introduction of fodder trees like Mulberry, Leucaena and Calliandra in small holder farms in African countries like Uganda and Kenya has improved livestock diets, milk production and income of small scale dairy farmers (Franzel *et al.,* 2014). Tree leaves are a rich source of supplementary protein, vitamins and minerals and their use in ruminant help to enhance microbial growth and digestion (Cheema *et al.,* 2011). Jamala *et al.* (2013) claimed that leguminous species contain 25 to 50 % more crude protein than non-leguminous plants.

Nitrogen fixing fodder trees have higher crude protein content and a large portion of the nitrogen fixed is probably released into the rhizosphere and is utilized by the associated field crops (Mathew *et al.*, 1992). Fodder trees can also be grown on boundaries where regular crops cannot be able to grow. These trees are capable of extracting water through their deep and extensive root system and need no additional irrigation.

2.6 INTEGRATION OF FODDER TREES IN HOMESTEADS/SMALL HOLDER FARMS

Severe land scarcity in small holder homesteads will not permit large scale fodder tree cultivation. A more practical option for farmers is to establish tree fodder banks with very higher plant density in the available interspaces, which ensures higher forage yields from small land area. The fodder tree selection should be based on its rapid establishment and fast growth, easy regeneration and coppicing ability, nitrogen fixing ability, palatable leaves with high nutritive value and less toxic substances, and tolerance to shading and drought (ICAR, 2012). However, while intercropping in homesteads, fodder trees should be grown as hedge rows at lower heights and managed intensively to regulate the possible competition between the component crops in homestead and to facilitate easy harvesting of fodder (Sagaran, 2017).

Fodder trees are particularly important in Eastern Africa, where over 2 lakh smallholders plant them, mainly to feed dairy cows, especially during droughts (Hemme and Otte, 2010). African farmers have fed tree foliage to their livestock for centuries, using wild browse or trees that grow naturally on their farms, or in hedges along field boundaries or along the contours as a soil conservation measure (Franzel *et al.*, 2014).

Calliandra seedlings in Kenya reported higher survival rates than direct seeding. Calliandra yields 1.5 kg dry matter per tree per year when grown in hedges pruned at 0.6 m to 1 m height, five times per year (Badege *et al.*, 2013). For adaptation, they are deep rooted, resistant to drought and they maintain high protein levels during the dry season, when high-quality feed is scarce (Franzel *et al.*, 2014). In Ethiopia, *Sesbania sesban* is the most widely cultivated fodder tree and is generally grown in homesteads.

2.7 GROWTH, YIELD AND QUALITY ATTRIBUTES OF TREE FODDER BANKS

2.7.1 Mulberry

Among various fodder trees, Mulberry (*Morus indica*) is a fast growing, deciduous, medium-sized tree and it is one of a promising species by virtue of its nutritive foliage with high crude protein content, higher biomass yield, amenable to severe pruning and good coppicing ability (Raj *et al.*, 2016). Mulberry leaf supplementation can improve the efficiency of the whole diet. In countries such as India, where Mulberry is primarily grown for sericulture, excess leaves and leftovers are fed to cattle, sheep and goats and is reported to be of good quality and can be profitably utilized as supplement to poor quality roughage (Yao *et al.*, 2000).

Mulberry fodder is considered to be of good quality (Majumdar *et al.*, 1967). On dry basis, leaves contain an average of 20-23% crude protein. Akbulut and Ozcan (2009) studied on the chemical composition of Mulberry and reported that Mulberry contain highest amount of calcium, potassium, magnesium, sodium, phosphorous and sulphur. Saddul *et al.* (2004) studied on the chemical composition of Mulberry and found that Mulberry is a good protein source and mineral resource. Mulberry was found to be a suitable intercrop in coconut plantations of Kerala. Mulberry fodder banks with a stand density of 49,382 plants ha^{-1} yielded 9.91 Mg ha^{-1} yr^{-1} dry fodder underneath coconut plantation of Kerala, in the initial year of establishment (Raj *et al.*, 2016). A three-fold increment in forage yield was obtained from the 3-year old stands (John, 2018).

2.7.2 Agathi

Sesbania grandiflora is a fast-growing perennial legume tree and it is valued fodder for ruminants. These trees can be planted at high densities (up to 3,000 stems/ha) to produce pole timber, or sparsely planted to produce dry-season forage and fuel wood (Singh and Sharma, 2012). *Sesbania grandiflora* is notable for its rapid early growth (up to 2 m height within 100 days after seedling). *Sesbania grandiflora* is valued as a good fodder in many regions (Rajasekaran *et al.*, 1994).

The leaves contain as much as 25-30 percent crude protein. Leaves and pods are valued for fodder (Karmakar *et al.*, 2016). In Java homegardens an annual yield of 27 kg of green leaf/tree was achieved by harvesting side branches every 3-4 months (Cook *et al.*, 2005). If the trees are cut back to a suitable height, a large supply of fresh fodder can be obtained for most of the dry season (Gohl, 1982). In Cuba, forage yield was high as 10 and 12 tons DM/ha/year (Martin *et al.*, 2014). In Uganda, leaf yield was nearly 19 tons DM/ha/year for foliage cut at 2 months intervals. The nutritive value was the highest at short cutting intervals (Kabi and Breeba, 2008).

2.7.3 Moringa

Moringa oleifera is a small to medium tree popularly grown for fodder in humid forest zone of Nigeria (Fadiyimu *et al.*, 2011). Moringa has an outstanding growth rate and can be harvested for fodder in less than 2.5 months. Ideal cutting intervals range from 15 to 75 days, depending on local conditions (Sultana *et al.*, 2014; Nouman *et al.*, 2014). Fresh fodder yields may range from 27 to 120 t ha^{-1} at the first cutting (Amaglo *et al.*, 2007). Up to 9 cuttings/year can be attained. Highest growth and forage yield are obtained under warm, dry conditions, with some supplementary fertilizer and irrigation (Radovich, 2009). Pollarding and coppicing promote leafy regrowth and enhance leaf yield (Orwa *et al.*, 2009).

Nouman *et al.* (2013) reported 15.31 per cent protein content in *Moringa oleifera*. The higher fodder yield from Moringa at closer spacing has been reported in north-central Nigeria (Abdullahi *et al.*, 2012). Also, the dense population of 83,330 plants ha^{-1} attained with 30cm x 40 cm spacing produced highest Moringa fodder yield compared to wider spacing in South-Western Nigeria due to higher yield per unit area of land (Adegun and Ayodele, 2015).

The biomass production of Moringa is affected by climatic condition, spacing, cutting height, planting pattern, geometry and cutting frequencies. Moringa can be harvested at 4 to 6 weeks interval during rainy season and 12 weeks interval during summer. Cutting height ranges from 100-150 cm. On an average 4.2 to 8.3 t ha^{-1} dry matter yield can be obtained. Moringa being rich source of nutrients and metabolizable energy, can be considered as alternative fodder for livestock (Sultana *et al.*, 2015).

2.7.4 Gliricidia

Gliricidia sepium is one of the most important tropical fodder trees due to its protein-rich forage and high nutritive importance. It is a perennial, medium-sized (2-15 m high) legume tree. Gliricidia can be able to produce profuse branching and fresh growth after every cutting. Wilting of the leaves is recommended to improve storage, increase dry matter intake and reduce potential toxicity (Heuze *et al.*, 2016).

The major factor contributing to the low yield in *Gliricidia sepium* is believed to be the inability of this species to withstand regular cutting, resulting in plant death. It was observed that the low yield of this species, once cutting commenced was contrasted by a high yield during the establishment phase. Similar results were observed by Horne *et al.* (1986) in Indonesia. Gliricidia leaves contain between 25 to 30 % crude protein and are highly digestible buffalos, cows and goat. Gliricidia is used as a supplemental fodder because of its high protein content. So, it would be a good idea to plant Gliricidia on the farms bunds.

2.7.5 Calliandra

Calliandra calothyrsus is an evergreen small legume tree having high quality foliage and is a high yielding fodder shrub suitable to humid tropical conditions of Kerala. Calliandra is valued for its multipurpose attributes and used in agroforestry systems. Savory and Breen (1979) reported the highest forage yield from the high density stands of 60,000 plants ha^{-1} compared to lower densities (10,000 and 30,000 plants ha). The annual dry forage yields of 11.73 Mg ha^{-1} was obtained from Calliandra fodder banks with density of 27,777 plants ha^{-1} when intercropped in coconut garden Sagaran (2017). Usually, low density planting patterns are followed for fodder trees in semi-arid and arid regions due to the constraints in soil nutrients and moisture. But, species like Calliandra permit high density intensive cultivation in close hedgerows in humid high rainfall tropical condition like Kerala which is well evident from the various studies conducted earlier (Joy, 2017).

Jayaprakash *et al.* (2016) reported that, Calliandra had relatively high protein (18.45%), minerals, ether extract and energy content and thus have the potential to be a good alternate feed source for ruminant animals. Sagaran (2017) reported 18 – 19 per cent crude protein, 28 per cent crude fibre, 3.3 per cent ash content and 28.75 per cent DM content in Calliandra fodder under coconut garden. Calliandra, being a leguminous species, has root nodules that fix nitrogen from the air. This fixation process helps in improving soil fertility because nitrogen is one of the most significant nutrients for plant growth. Calliandra is often used as a companion legume in alley cropping systems. It must be pruned regularly so that it does not over-shade other crops (Wiersum and Rika, 1997).

2.8 UNDERSTOREY LIGHT AVAILABILITY AND INTERCROP GROWTH IN HOMESTEADS

The homegardens vary in size influencing the species diversity and composition. It is expected that with variation in size, density and compositional pattern, the light availability and soil condition also varies and requires different management practices for improving the overall sustainability of these important land-use systems (Vibhuti and Bargali, 2018). Understorey productivity is a function of the shade tolerance/compatibility of the species. In short, the tree species, age, spacing, foliage type, density and shade tolerance of the forage species determine the understorey biomass yield and an optimal combination shall include a reasonably fast growing nitrogen fixing tree with light crown and a shade tolerant forage crop (Mathew *et al.*, 1992). Light performs to be one of the most important limiting factors deciding the productivity of crops in any intercropping system, (Oswald *et al., 2002*). Variation in understorey productivity has been observed for many plantation crops such as coconut and arecanut. Shade loving species, requiring low light intensities are likely to perform better under high-density multistoried cropping system.

Productivity and income from Mulberry was higher in open than from the partially shaded coconut garden (Meerabai, 1997). Poor shade tolerance of Agathi has been reported by (Gutteridge and Shelton, 1994). Seedling growth of Moringa is more affected by shade intensity. The seedling of *Moringa oleifera* under medium shade level produced significantly the highest biomass accumulation and partition (Ahmed *et al.*, 2014). Sagaran (2017) and Joy ,(2017) reported better establishment, growth, yield and survival of Calliandra fodder banks in partially shaded coconut garden thereby indicating the shade tolerant nature of Calliandra. Gliricidia grows well even under high shade and is recommended as a good green manure crop for shady conditions in Kerala (KAU, 2016).

The use of fodder shrubs and trees has been more widely practised in Java homegardens where population pressure on land makes it imperative that every available feed resource is fully utilized. It has been a traditional practice in many parts of West Java to use fodder shrubs and trees as protein supplements fed with a basal feed of rice straw (Rangkuti *et al.*, 1990).

A specific concept in incorporating fodder shrubs and trees into farming systems producing annual crops has been developed by the International Institute of Tropical Agriculture (IITA). Shrubs and fodder trees are grown as hedgerows in cropped land. These serve as windbreaks and provide green manure fertilizer for the crops. During the productive period, the cut material from the hedgerow species often provides fodder in excess of the amount needed from green manure for animals (Chen *et al.*, 1991).

As always, homegardens are less intensely managed systems. Scientific management of these traditional systems poses serious limits on account of intertwined nature of various components in time and space. The understorey space utilization for intercropping depends entirely on the tree density and light availability. A legitimate approach is to manipulate the tree environment rather than the tree itself. Hence practices such as branch pruning for improving understorey light conditions are a common management practice in homesteads. For instance, branch pruning of taller trees such as *Tectona grandis*, *Terminalia paniculata*, *Sweitenia macrophylla* is a common practice in homegardens of Kerala. Other conventional practices such as weeding, fertilization, crop density regulation are also in practice in the various parts of the tropics (Raj *et al.,* 2016).

2.9 SOIL NUTRIENT STATUS CHANGES ASSOCIATED WITH FODDER TREE INTEGRATION IN HOMESTEADS

The integration of trees in cropping systems increases soil fertility, productivity, improves soil structure, and reduces soil erosion. As compared to pure agricultural systems, agroforestry systems contribute towards improved nutrient cycling and sustainability through greater mineralization of nutrients from unavailable reserves, addition of nutrients in plant litter/ tree residues, more closed nutrient cycles as a result of greater uptake by plant roots and less leaching losses and achieving a balanced supply of nutrients including micronutrients (Szott and Kass, 1993). The two yearlong field investigation on the dynamics of home gardens revealed that the tree components contributed considerable amounts of nutrients by way of litterfall, stemflow and throughfall. Nutrient addition took place mainly through organic manures. Harvested biomass accounted for removal of large quantities of nutrients from the systems (Young *et al.,* 2016)

Integration of fodder trees in homesteads can bring positive changes in soil fertility status. Calliandra is an N-fixing legume that roots profusely and nodulates readily with Rhizobium bacteria. It yields high amounts of biomass and has been recommended for green manure in areas of low fertility (Palmer *et al.,* 1994). Roots of the Moringa can penetrate deep into soil to search for water and nutrients, which enables Moringa trees to tolerate severe conditions. Moringa is a drought tolerant plant that can be grown in diverse soils, except those that are waterlogged. Slightly alkaline clay and sandy loam soils are considered the best media for this species due to their good drainage (Ramchandran *et al.* 1980; Abdul ,2007). Gliricidia is a legume and able to fix N. It produces a lot of litter and the half-life of Gliricidia leaves is about 20 days. The plant is thus considered as a good soil improver. Because of its deep roots and quick growth, it is used as a windbreak. It thrives on steep slopes and may be used to reclaim denuded land. *Gliricidia sepium* is also often used as shade for perennials (coffee, tea, cocoa) or as nurse-tree since it produces light shade and reduces soil temperatures (Orwa *et al*., 2009). *Sesbania grandiflora* has several environmental benefits. As a fast-growing, N-fixing legume, it is used for the reforestation of eroded areas and to improve soil fertility. It is often planted to make fence lines or as shade tree, windbreak and support for other crops (Duke, 1983; Heering and Gutteridge, 1992).

Several research indicates that by adding trees in grassland or pasture systems the soil organic carbon (SOC) content can be augmented considerably (Reyes-Reyes *et al.,* 2002). Raj *et al.,* (2016) reported improved soil SOC and NPK content by intercropping Mulberry and subabul fodder banks in coconut garden. Soil enrichment was found to be higher in case of subabul than that of Mulberry. However high density cultivation of a non-legume tree like Mulberry can deplete soil nutrients if adequate nutrition is not given (John, 2018). Sagaran (2017) also reported improvement in soil properties due to an integration of Calliandra fodder banks in coconut garden. Similar findings were also observed by Joy (2017) who also reported a favorable impact on coconut yield due to Calliandra intercropping.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present study entitled "Productivity of tree fodder banks in selected homegardens of Central Kerala" was carried out as three separate experiments in selected small, medium, and large scale homegarden with livestock component in Arimboor panchayat, Thrissur district, Kerala during the year 2018-2019. The main objective of the study was to assess the forage yield and nutritive value of selected fodder tree species under hedgerow planting in selected home gardens of Central Kerala. The study also examined short term changes in soil nutrient status of selected homegardens with tree fodder integration. The materials used and the methods adopted for the study is discussed in this chapter.

3.1 Location

The proposed study was conducted in in selected small, medium, and large scale homegarden with livestock component in Arimboor panchayat, Thrissur district, Kerala, which is the mid land area lying within the geographical extremes of 10^0 29′ 0″N and $70^0$80′0″E, spanning an area of about 22.65 sq. km.

Small homegarden (SHG)

The selected small scale homegraden was a multitier system owned by Varghese Cheriyath with an area of 17 cents (0.17 acre) comprising of 8 livestock (8 cows). The dominant arboreal components and their abundance in the homegarden include trees such as *Cocos nucifera* (5), *Swietenia mahagoni* (2), *Gliricidia indica* (4), *Trema orientalis* (1), *Ficus hispida* (1), *Artocarpus heterophyllus* (2), Banana (3) and *Adenanthera pavonina* (1). Other components include *Costus speciosus*, *Macaranga peltata*, colocasia and tapioca.

Medium homegarden (MHG)

The selected medium scale homegraden was a multitier system owned by Varghese A, with an area of 32 cents (0.32 acre) comprising of 7 livestock (7 cows). The dominant arboreal components and their abundance in the homegarden include trees such as *Cocos nucifera* (6), *Artocarpus heterophyllus* (3), *Mangifera indica* (3), *Glyricidia indica* (4), *Trema orientalis* (1), *Bridelia retusa* (1), *Ficus hipsida* (2), *Ficus exasperate* (1). Other components include *Macaranga peltata*, *Costus speciosus*, colocasia, tapioca, hibiscus.

Large homegarden (LHG)

The selected large scale homegraden was a multitier system owned by Praveen Panamukath with an area of 65 cents (0.65 acre), comprising of 3 livestock (3 cows). The dominant arboreal components and their abundance in the homegarden include trees such as *Cocos nucifera* (13), *Gliricidia indica* (12), *Trema orientalis* (2), *Ficus hispida* (3), Arecanut (4), Banana (17), *Artocarpus heterophyllus* (6), *Mangifera indica* (4). Other components include *Zizipus trinervia*, *Tespesia populnea*, *Lawsonia inermis*, *Costus speciosus*, *Sreblus asper* and colocasia. The field was heavily infested with weed species eupatorium.

3.2 Climate and Soil

Arimboor has a humid climate. The maximum average temperature of the area in the summer season is 36^0 C while the minimum temperature recorded is 22^0C. The average annual rainfall is 3752 mm. The dry season is from December to May. The South-west monsoon generally sets in during the last week of May. On an average there are 130 rainy days in a year. Kerala experienced 53% above normal rainfall during the monsoon season (till August 21^{st}) of 2018 and created massive floods in various areas including Arimboor. The mean relative humidity ranged from 47 per cent during February to 89 percent during June. Data on weather conditions such as temperature, rainfall and relative humidity obtained from the Department of Agricultural Meterology, College of Horticulture, Vellanikkara are given in Appendix I and graphically depicted in Fig. 1.

The soil of the small homegarden was lateritic in nature with acidic pH (5.6), medium level of organic carbon (0.98%), low level of available nitrogen (210 Kg ha^{-1}), exchangeable potassium (135 Kg ha^{-1}) and high level of phosphorous (32 Kg ha^{-1}). The soil of the medium homegarden was sandy loam in nature with acidic pH (5.4), low level of organic carbon (0.65%), low available nitrogen (220 Kg ha^{-1}), high level of exchangeable potassium (235 Kg ha^{-1}) and phosphorous (62 Kg ha^{-1}). The soil of the large homegarden was sandy in nature with acidic pH (5.3), very low level of organic carbon (0.21%) and available nitrogen (230 Kg ha^{-1}), and with high level of exchangeable potassium (220 Kg ha^{-1}) and phosphorous (30Kg ha^{-1}).

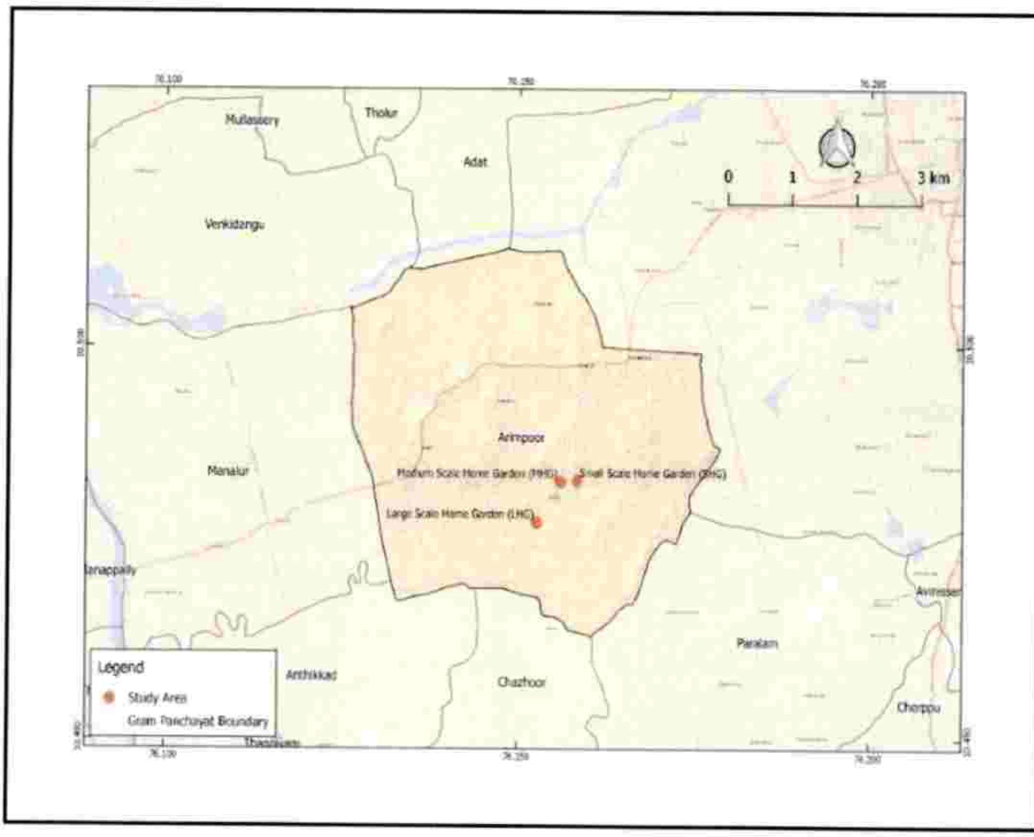


Plate 1. Study area map of Arimboor Panchayath, Thrissur District

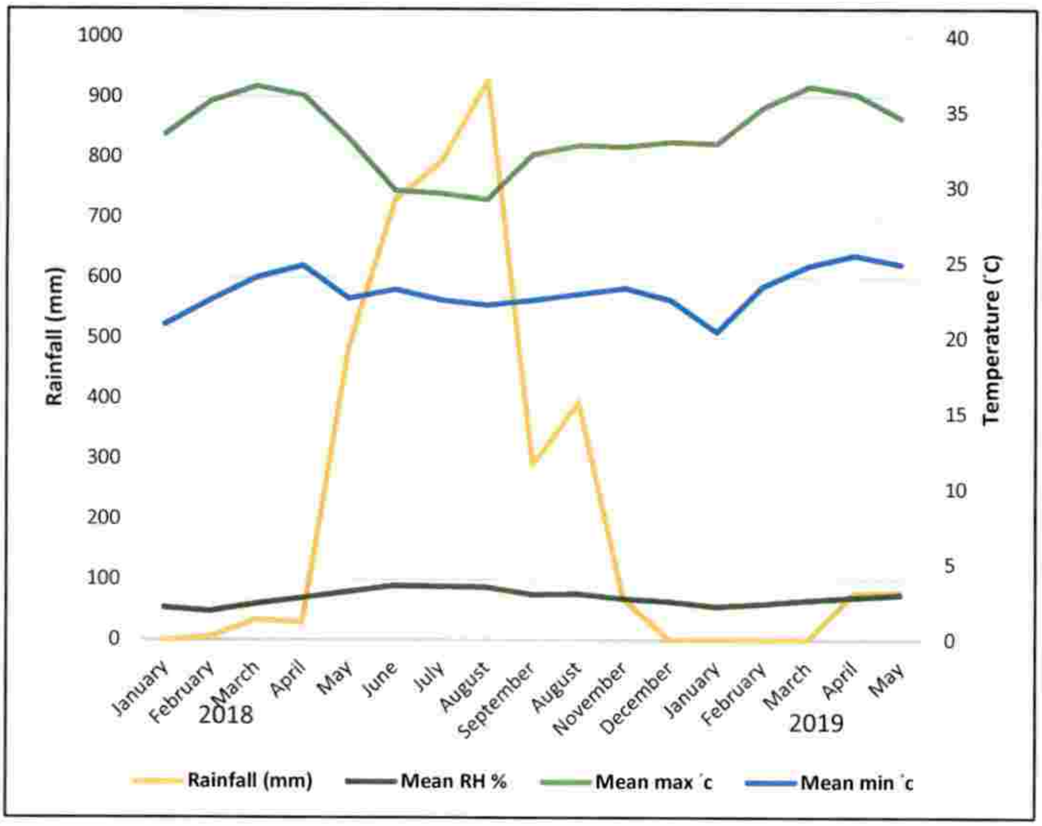


Fig 1. Mean monthly rainfall, temperature and relative humidity data from June 2017 to May 2019 at Arimboor, Thrissur

3.3 Materials

3.3.1. Fodder tree species

Mulberry, Aagthi, Moringa, Gliricidia and Calliandra were the fodder tree species selected for the study.

3.3.1.1 Mulberry

The leaves of the multipurpose perennial shrub, Mulberry (*Morus indica*), traditionally used for silkworm feed rearing, is known for its high protein content with high digestibility, high mineral content, low fiber content and very good palatability (Saddul *et al.*, 2004). Being a potential fodder tree suited to the agro climatic conditions of Kerala, Mulberry variety V1 (Victoria 1, a cross of S-30 and Berc 776 Mulberry cultivars), released from Central Sericulture Research and Training Institute, Mysore, Karnataka was selected for this study. This variety has given higher forage yields when grown as fodder banks in partially shaded coconut plantations (Raj *et al.*, 2016; John, 2018).

3.3.1.2 Aagthi

Aagthi (*Sesbania grandiflora)* is a fast-growing perennial, legume tree growing up to 10-15 m height. Leaves contain 36 per cent crude protein content. Aagthi is also recommended as an ideal fodder tree for growing as hedgerow planting as fodder banks in humid tropical conditions of Kerala (KAU, 2016). Its roots are heavily nodulated and some floating roots may develop in waterlogged conditions. The outstanding feature is its extremely fast growth rate, especially during the first three to four years. It is easy to propagate by direct seeding. After cutting, shoots re-sprout with vigor. It is not toxic to cattle. It can be planted very densely @ 3000 stems per ha. It is adapted to the moist tropics with annual rainfall in excess of 1000 mm.

3.3.1.3 Moringa

Moringa oleifera Lam. belonging to the family Moringaceae is a softwood tree, native of India, and now grown worldwide in the tropics and sub-tropics. It is a small to medium sized tree that can grow to a height of 10-12 m. The roots are deep. Moringa comes up well in a wide range of soil. A deep sandy loam soil with a pH of 6.5 – 8 is ideal for cultivating this crop. Moringa leaves are a valuable source of protein for ruminants but they have a moderate palatability. It is fast-growing with drought-tolerant nature and well adapted to agro climatic conditions of Kerala. Moringa variety PKM 1 released from Tamil Nadu Agricultural University, Periyakulam, Coimbatore, Tamil Nadu was selected for this study. It has higher foliage yield compared to other varieties. Green fodder of Moringa crop harvested at 2 to 3 months' interval contains dry matter (16.63 %), crude protein (15.82 %), ether extract (2.35 %), crude fibre (35.54 %), and total ash (7.61 %). Moringa gives green fodder yield of around 100-120 ton/ha/year (Mahima *et al.*, 2014).

3.3.1.4 Gliricidia

Gliricidia sepium is a perennial, medium-sized (2-15 m high) legume tree. *Gliricidia sepium* is one of the most important tropical fodder trees due to its protein-rich forage and high nutritive value. *Gliricidia sepium* yields 9 to 16 t $ha^{-1}$of dry matter in fodder plots, It can be lopped around 7 months after establishment on plants grown from cuttings and 14 months for seedlings. Thereafter lopping can be done every 2 to 3 months during the rainy season and every 3 to 4 months during the dry season, provided regrowth reaches 1-2 m height before harvest (Wiersum and Nitis, 1992). *Gliricidia sepium* is a legume and able to fix N. The plant is thus considered as a good soil improver. Because of its deep roots and rapid growth, it is used as a windbreak. It thrives on steep slopes and may be used to regain denuded land. *Gliricidia sepium* is also often used as shade for perennials (Coffee, Tea, Cocoa) or as nurse-tree since it produces light shade and reduces soil temperatures (Orwa *et al.*, 2009).

3.3.1.5 Calliandra

Calliandra calothyrsus is an evergreen, small legume tree native to Central America and Mexico. It has been introduced to many tropical regions where it is used in agroforestry systems as forage for livestock, fuelwood, plantation shade etc., and grown as an intercrop as hedgerows. Calliandra has a fast growing, vigorous root system that develops down to a depth of 1.5-2 m within 4-5 months (Orwa *et al.*, 2009). Calliandra is an N-fixing legume that roots abundantly and nodulates readily with *Rhizobium* bacteria. Calliandra fodder banks have shown good survival, growth, forage yield and quality as an understorey component in partially shaded coconut gardens of Kerala (Sagaran, 2017; Joy, 2017).

3.3.2. Manures and fertilizers

Farm yard manure (FYM) @ 20 t ha^{-1} and $N{\cdot}P_2O_5{\cdot}K_2O$ each @ 50 Kg ha^{-1} were applied uniformly for all treatments. Fertilizers were applied through N: P: K mixture (18: 18:18). FYM was applied as basal and fertilizer in two split doses before south west and north east monsoons.

3.4. Methods

The field study was conducted as three separate experiments in selected small, medium, and large scale homegardens with livestock component in Arimboor Panchayath, Thrissur district, Kerala. The homegardens were selected based on diagnostic and design survey conducted in Arimboor Panchayath under All India Coordinated Research Project on Agroforestry (AICRP). Scarcity of quality fodder and acute crude protein deficit were the major constraints for livestock rearing in these homesteads. Hence protein rich fodder trees like Mulberry, Aagthi, Moringa, Gliricidia and Calliandra were intercropped in the homesteads to assess their forage yield and nutritive value under hedgerow planting as fodder banks. The experimental details are given below.

3.4.1 Design and layout of the experiment

Design : Randomized Block Design

Treatments : 5

Replication : 4

Plot size : 3 m x 2 m

Spacing of trees : 45 cm x 45 cm

3.4.2 Treatment details

The treatments consisted of five fodder tree species, planted as fodder banks in the available interspaces of selected homesteads, the details of which are given below.

a. Mulberry - *Morus indica* (T1)
b. Aagthi - *Sesbania grandiflora* (T2)
c. Moringa - *Moringa oleifera* (T3)
d. Gliricidia - *Gliricidia sepium* (T4)
e. Calliandra - *Calliandra calothyrsus* (T5)

The layout of the trial is given in Fig. 2, 3 and 4

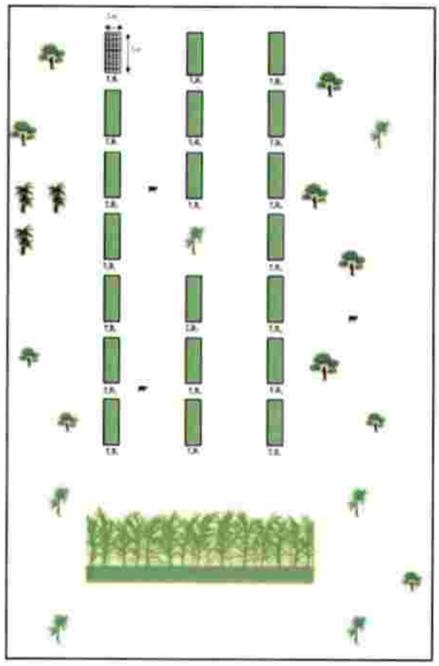


Fig 2.

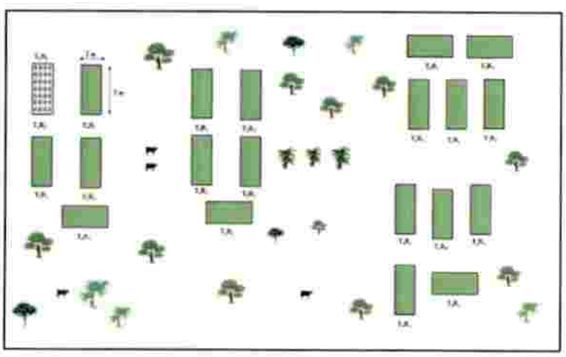


Fig 3.

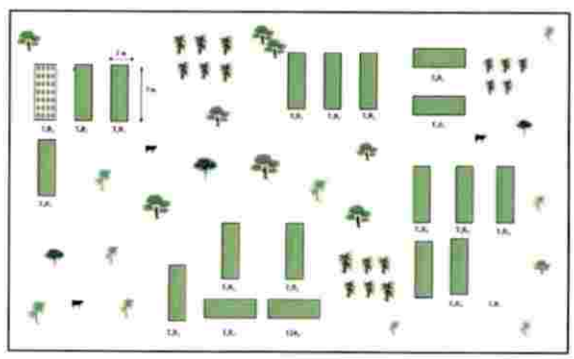


Fig 4.

Layout plan of the field trial – Fig 2. Small homegarden (SHG)

Fig 3. Medium homegarden (MHG) Fig 4. Large homegarden

3.4.3 Raising of tree seedlings/saplings

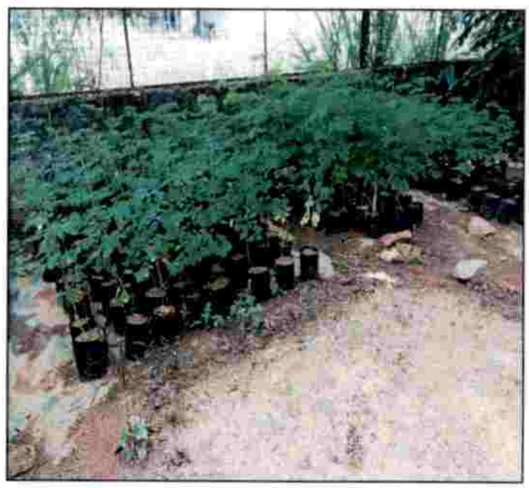
Seeds of Calliandra were brought from Kerala Livestock Development Board, Dhoni Fram, Palakkad District ; Moringa seeds (PKM variety) from Department of Seed Science and Technology, TNAU, Coimbatore; Agathi seeds from Suresh seed network, Bangalore, was brought and were raised in nursery in beds of standard size (12 m x 1.2 m). Healthy and uniform seedlings was transplanted to polythene bags after one month and later transplanted to the selected homestead on attaining 20-30cm height. Mulberry (variety V1) was raised from uniform stem cuttings of 6-8 months maturity, 20 cm length, having three nodes and of pencil thickness diameter, and Gliricidia was raised using mature stem cuttings of 50 cm length and 3-3.5 cm diameter in polybags and transplanted to homestead at 3 months stage.

3.4.4 Field culture

The available field area within the homesteads were cleared during April-May and the weeds, stubbles and roots were removed. Land was prepared by ploughing twice to bring the soil to fine tilth. A crop free zone of 1-1.5 m radius was maintained around the existing trees in the homesteads. The layout was done allocating a plot size of 3 m x 2 m (6 sq. m) for each treatment. Pits were taken at prescribed spacing of 45 cm x 45 cm within each plot. Seedlings/ saplings of Mulberry, Agathi, Moringa, Gliricidia and Calliandra were transplanted to the main field with the onset of pre-monsoon showers. Manures and fertilizers were applied as detailed in 3.3.2. Plants were weeded as and when required.

Standard Nursery Beds

Germination Stage



Cuttings of Mulberry

Seedlings of Moringa

Plate 2. Raising fodder tree seedlings/saplings in nursery

Calliandra

Gliricida

Cuttings of Gliricidia

Mulberry

Plate 3. Transplanting stage of tree seedlings/saplings in nursery

Plate 4. Field culture and planting in homestead

Small scale homesteads (0 – 25 cents)

Medium scale homesteads (25 – 50 cents)

Large scale homesteads (50 cents – 1 ha)

Plate 5. Fodder banks under homestead

3.4.5 Harvest of trees

The first harvesting was done three months after planting, when the trees attained more than 1m height. Subsequent harvests were taken at 2 months interval during rainy season and 3 months interval during summer season. A pruning height of 1m from the ground was maintained for all the harvests. Altogether 5 harvest was taken in a year.

3.5. Observations

Five trees/plot were selected at random avoiding border plants and the following observations were recoded

3.5.1 Growth parameters of fodder trees

3.5.1.1 Plant height of fodder trees three months after planting

The plant height was measured from ground level to the growing tip of the shoot and expressed in cm.

3.5.2 Coppice parameters after first harvest

3.5.2 .1 Number of coppices per plant

Number of coppices per plant for each treatment was counted and expressed as mean values over the period of study

3.5.2.2 Coppice length

Length of the coppices were measured from the base to the tip of the apical meristem and expressed in cm

3.5.2.3 Coppice weight:

Weight of the coppices per plant was measured for each treatment and expressed as mean values

3.5.3 Survival percentage of trees for various treatments.

Number of trees in each treatment plot was counted after the experimental period and expressed as survival percentage.

3.5.4 Green fodder yield from trees

For each cut, biomass from 5 trees/ plot avoiding border plants was separated into leaf and stem and their individual fresh weights and total biomass determined. Thereafter, yield from all harvests in a year was pooled to get annual gross yields. Using the net harvested area and fresh weight, annual gross fodder yield was scaled up to a hectare basis and adjusted with survival percentage. The small, medium and large scale homegarden had unutilized net areas of 7645 sq. m, 8253 sq. m and 8198 sq. m when extrapolated on hectare basis.

All the harvested fodder was edible with leaf and green stem. The proportion of brown stem was negligible.

3.5.5 Dry fodder yield from trees.

After harvesting, the biomass from each plot was weighted fresh. Biomass from trees was separated into leaf and stem and their fresh weights determined. Subsamples (200 g) of the two components were oven dried at 70^0C for 48 hours for dry matter (DM) determination AOAC (1995). The fresh fodder yields from each harvest were multiplies with the DM content, summed up to get annual dry fodder yield and was expressed on hectare basis.

3.5.6 Leaf –stem ratio

The annual dry leaf yield was divided with annual dry stem yield for various treatments and expressed as leaf-stem ratio.

3.5.7 Incidence of pest and diseases.

No serious disease and pest incidence were noticed during the experimental period. However, a minor attack of stem borer was noticed in agathi plots during rainy season.

3.5.8 Plant nutrient analysis.

Subsamples (200 g) of the leaf and stem fractions were oven dried and subjected to dry matter (at 70°C) analysis following standard procedures (Jackson, 1973). Nitrogen content in the dry matter was estimated by modified microkjeldahl method. Phosphorus content was determined calorimetrically by vanado-molybdo phosphoric yellow colour method and potassium was determined by flame photometry (Jackson, 1973). All nutrient concentrations were expressed on dry matter basis.

3.5.9 Quality aspects of fodder biomass

3.5.9.1 Crude protein yield

Total nitrogen (N) of oven dried fodder (leaf and stem) samples from ach harvest was determined by micro Kjeldahl procedure and crude protein (CP) calculated from N content (CP= Nx6.25) according to the official methods of AOAC (1995). CP content was multiplied with DM yield from each harvest and summed up to get annual crude protein yields per hectare.

3.5.9.2 Crude fiber content

Oven–dried leaf and stem samples were refluxed first with 1.25% H_2SO_4 and subsequently with 1.25% NaOH for 30 minutes each to dissolve acid and alkali soluble component present in it. The residue containing CF was dried to a constant weight and the dried residue was ignited in muffle furnace, loss of weight on ignition was calculated to express it as CF in percentage (AOAC, 1995).

3.5.9.3 Ash content

Oven dried samples were ignited in muffle furnace at 550°C to burn all the organic matter and left over was weighed as ash (AOAC, 1995).

Plate 6. Harvest and feeding of tree fodder

Plate 7. Quality analysis of green biomass and soil

Plate 8. Soil nutrient analysis

3.5.9.4 Understorey Photosynthetically Active Radiation (PAR) measurements

PAR measurement was carried out using Line Quantum Sensor (LQI 2404, K131). A battery powered data logger integrated the mean PAR at hourly intervals from 8 a.m to 5 p.m from each plot. PAR above the canopy of homegardens was documented from the nearby open area. PAR below the canopy was recorded from the center of each fodder tree plot. PAR was then converted to canopy transmittance, which is the light available beneath the canopy.

PAR transmittance (%) = $\frac{PARi}{PARt} X\ 100$

3.6. Soil analysis

To study the changes in soil nutrient status on account of intercropping fodder trees in homegarden, representative soil samples (in triplicates) from all treatment plots and also from open contiguous plots were collected (top 0-15cm layer), and analyzed for organic C, available N, P, K content following standard methods.

3.6.1. Soil organic carbon

Soil organic carbon was analysed by using Walkely and Black's permanganate oxidation method (Walkely and Black, 1934).

3.6.2. Available nitrogen

Available nitrogen in soil was determined by alkaline permanganate method (Subbiah and Asija, 1956).

3.6.3. Available phosphorus

Available phosphorus was extracted using Bray-I extractant (Bray and Kurtz, 1945) and the P content was colorimetrically assayed (Chloromolybdic acid blue colour method). The reducing agent was ascorbic acid (Jackson, 1973).

3.6.4. Available potassium

Available potassium was determined by flame photometry using neutral normal ammonium acetate solution as the extractant (Jackson, 1973).

3.7. Economics

Cost of cultivation of various systems and the economical yield obtained was used for calculating the B: C ratio of various fodder production systems.

3.8. Statistical analysis

The data were subjected to statistical analysis by analysis of variance (ANOVA) using general linear model procedure in SPSS version 21.0 (SPSS Inc., USA) to ascertain the significance of various parameters. The Duncan's Multiple Range Test (DMRT) was used to test the differences among treatment means at 5 per cent significance level. Comparison of the performance of fodder trees in each homestead was done separately using RBD design. Comparison of the fodder productivity of three homegardens as well as the productivity of tree species in general was evaluated in two factorial RBD design (three size class of homesteads *viz.* small, medium and large; and five fodder tree species).

RESULT

4. RESULTS

The salient findings of the study, "Productivity of tree fodder banks in homesteads of Central Kerala", are presented hereunder.

4.1 GROWTH AND YIELD OBSERVATIONS OF TREE FODDER BANKS IN HOMEGARDENS OF VARYING SIZE CLASSES AT INITIAL UNIFORM CUT

All the fodder trees were given an initial uniform cut at 1m height at the stage of three months after transplanting to the field. Growth and yield parameters of fodder trees at the initial cut are given below.

4.1.1 Plant height

The data given in Table 1 shows the height of different fodder tree species grown as fodder banks in small, medium and large scale homegardens. Plant height of different fodder trees varied significantly in small and medium homegardens. In SHG, Agathi-T2 (1.64 m) was found to be taller than other tree species, followed by T5 (1.41 m), T3 (1.31 m), T1 (1.26 m) and T4 (1.2 2m). Similar trend was observed in medium sized homegarden (MHG). However, in large sized homegarden (LHG) plant height showed no significant difference between the treatments. A marginal increment in height was observed in Agathi and Gliricidia compared to other tree species.

Comparing plant height in different homesteads, LHG and MHG showed significantly higher plant growth when compared to SHG. In general, Agathi-T2 was found to be significantly taller than other tree species in all the homesteads (Table 2).

4.1.2. Coppice parameters

4.1.2.1 Number of coppices

Fodder tree species showed sign [illegible]erence on the number of coppices (Table 1) after harvest in small, medium and large scale homegardens. Number of coppices was higher for Agathi-T2 (3.5) when compared to other tree species in small sized homegarden (SHG). Similar trend was observed in medium sized homegarden (MHG), whereas fodder tree species of large sized homegarden (LHG) showed significantly higher number of coppices in Gliricidia- T4 (3.75) compared with other tree species.

Coppice number did not show any significant variation in different size class of homesteads. However coppice number showed considerable variation in different fodder tree species. Gliricidia (3.08) and Agathi (3.00) showed better coppicing and was on par with Calliandra (2.67). Mulberry showed medium coppicing, whereas, coppice number was significantly lower in Moringa (Table 2).

4.1.2.2 Length of coppices

Coppice length of different tree species in different homesteads are given in Table1. Coppice length of different tree species showed no noticeable variation in SHG. But in medium sized homegarden (MHG) coppice length was significantly higher in Agathi- T2 (96.73 cm) followed by T3 (80.85 cm), T5 (64.51 cm), T4 (58.52 cm) and T1 (44.43 cm). Large sized homegarden (LHG) also showed similar trend with the highest coppice length in Agathi -T2 (101.50 cm), followed by other tree species Gliricidia- T4 (94.35 cm), T5 (75.10 cm), T3 (59.53cm) and T1 (44.67 cm).

As indicated in Table 2, coppice length showed no significant variation among SHG, MHG, or LHG. However, a general comparison of fodder trees indicated higher coppice length in Agathi (91.87 cm) and Gliricidia (80.48 cm) compared to other tree species (50.93 to 70.25 cm) irrespective of homegardens (Table 2).

4.1.2.3 Weight of coppices

The data given in Table 1. indicate the significant variation in coppice weight of tree species in different homegardens. Coppice weight was significantly higher for Gliricidia- T4 (286.50 g pl^{-1}) when compared to other fodder tree species in small and large size classes. But in medium sized homegarden (MHG) coppice weight was more in Gliricidia (175.33 g pl^{-1}) and was on par with all other fodder tree species except Mulberry.

As indicated in Table 2. Coppice weight of trees as in different size class of homesteads followed the trend LHG>SHG>MHG. Coppice weight also showed significant difference between tree species. Weight of coppices was significantly highest for Gliricidia-T4 (274.04 g pl^{-1}) followed by Agathi (193.58 g pl^{-1}) and Calliandra (130.53 g pl^{-1}). Moringa (107.76 g pl^{-1}) showed intermediate values whereas Mulberry (81.73 g pl^{-1}) had the least coppice weight.

Table 1. Plant height and coppice parameters of tree fodder banks at the stage of initial cut in small, medium and large scale homegardens

Treatments	Plant height (m)	Coppice parameters		
		Number of coppices	Coppice length (cm)	Coppice weight (g pl^{-1})
Small homegarden (SHG)				
Mulberry (T1)	1.26^{c}	2.25^{b}	63.68	120.75^{b}
Agathi (T2)	1.64^{a}	3.5^{a}	77.36	158.75^{b}
Moringa (T3)	1.31^{bc}	2.0^{b}	70.35	98.80^{bc}
Gliricidia (T4)	1.22^{c}	2.25^{b}	88.55	286.50^{a}
Calliandra (T5)	1.41^{b}	2.5^{b}	65.08	152.05^{b}
P value	0.000^{***}	0.008^{**}	0.484^{ns}	0.000^{***}
Medium homegarden (MHG)				
Mulberry (T1)	1.34^{b}	2.00^{bc}	44.43^{d}	57.13^{b}
Agathi (T2)	1.87^{a}	2.75^{ab}	96.73^{a}	150.00^{a}
Moringa (T3)	1.38^{b}	1.50^{c}	80.85^{ab}	130.86^{a}
Gliricidia (T4)	1.30^{b}	3.25^{a}	58.51^{cd}	175.33^{a}
Calliandra (T5)	1.41^{b}	3.00^{a}	64.51^{bc}	124.66^{a}
P value	0.000^{***}	0.007^{**}	0.000^{***}	0.002^{**}
Large homegarden (LHG)				
Mulberry (T1)	1.38	2.50^{b}	44.67^{d}	67.30^{e}
Agathi (T2)	1.64	2.75^{b}	101.50^{a}	272.00^{b}
Moringa (T3)	1.39	2.00^{b}	59.53^{cd}	93.60^{d}
Gliricidia (T4)	1.62	3.75^{a}	94.35^{ab}	360.27^{a}
Calliandra (T5)	1.45	2.50^{b}	75.10^{bc}	114.87^{c}
P value	0.145^{ns}	0.002^{**}	0.000^{***}	0.000^{***}

*** significant at $p<0.001$. ** significant at $p<0.01$, * significant at $p<0.05$, ns= not significant at $p>0.05$. Values with the same superscripts in column do not differ significantly

Table 2. Comparative plant height and coppice parameters as influenced by varying size of homestead and different fodder tree species

Treatment	Plant height (m)	Coppice number	Coppice length (cm)	Coppice weight (g pl^{-1})
Fodder tree species				
Mulberry (T1)	1.33^{d}	2.25^{bc}	50.93^{c}	81.73^{e}
Agathi (T2)	1.72^{a}	3.00^{a}	91.87^{a}	193.58^{b}
Moringa (T3)	1.36^{c}	1.83^{c}	70.25^{b}	107.76^{d}
Gliricidia (T4)	1.38^{d}	3.08^{a}	80.48^{ab}	274.04^{a}
Calliandra (T5)	1.43^{b}	2.67^{ab}	68.23^{b}	130.53^{b}
P value	0.000***	0.000***	0.000***	0.000***
Size of homestead				
SHG	1.37^{b}	2.50	69.01	163.37^{b}
MHG	1.46^{a}	2.50	73.01	127.60^{c}
LHG	1.50^{a}	2.50	75.03	181.61^{a}
P value	0.016^{**}	0.375^{ns}	0.488^{ns}	0.000***

*** significant at p<0.001. ** significant at p<0.01, * significant at p<0.05, ns= not significant p>0.05

Values with the same superscripts in column do not differ significantly

4.2 ANNUAL GREEN FODDER YIELD AND SURVIVAL PERCENTAGE OF TREE FODDER BANKS IN HOMEGARDENS OF VARYING SIZE CLASSES

4.2.1 Fractional and total fresh fodder biomass

Table 3 shows the annual fractional (leaf and stem) and total fresh fodder biomass of tree fodder banks in homegardens of varying size classes. Fodder tree species showed significant impact on the annual fresh fodder yield. Fodder biomass in small sized homegarden (SHG) was significantly higher in Gliricidia- T4 (18.28 Mg ha^{-1}) and Agathi-T2 (16.89 Mg ha^{-1}) when compared to Calliandra-T5 (12.45 Mg ha^{-1}), whereas the yield of Mulberry- T1 (6.89 Mg ha^{-1}) and Moringa-T3 (6.09 Mg ha^{-1}) was significantly lower. Leaf yield was also significantly higher for Gliricidia-T4 (13.17 Mg ha^{-1}) whereas stem yield was higher for Agathi-T2 (8.08 Mg ha^{-1}).

Fodder biomass in medium sized homegarden (MHG) was significantly higher in Gliricidia- T4 (26.82 Mg ha^{-1}) followed by Calliandra-T5 (21.08 Mg ha^{-1}) and Agathi- T2 (12.23 Mg ha^{-1}). The yield of Moringa-T3 (8.37 Mg ha^{-1}) and Mulberry-T1 (7.67Mg ha^{-1}) was comparatively lower than other tree species. Fractional biomass also showed similar trends.

Similar trend was also observed in fodder yields of large sized homegarden (LHG) with significantly higher values in Gliricidia- T4 (27.70 Mg ha^{-1}) followed by Calliandra-T5 (15.61 Mg ha^{-1}) and Agathi- T2 (11.67 Mg ha^{-1}), whereas the yield Mulberry-T1 (6.06 Mg ha^{-1}) and Moringa-T3 (4.61 Mg ha^{-1}) was significantly lower. Similar trend was also observed in yield of leaf and stem fractions.

Comparing different homegardens, fodder yield was significantly higher in MHG (15.23 Mg ha^{-1}) followed by LHG (13.15 Mg ha^{-1}) and SHG (12.07 Mg ha^{-1}). Leaf and stem yield also followed similar trend. In general, Gliricidia-T4 (24.27 Mg ha^{-1}) yielded significantly higher forage yield in all the systems followed by Calliandra-T5 (16.38 Mg ha^{-1}). Next best tree species was Agathi-T2 (13.59 Mg ha^{-1}) whose yield was on par with that of Calliandra. Moringa and Mulberry produced significantly lower yields. Yield from leaf and stem fractions also showed similar trend (Table 4).

4.2.2 Survival percentage of fodder tree species in homegardens of varying size classes

Survival count of the trees were taken one year after planting. The results indicated in Table 3 reveals that fodder tree species in different size class of homestead showed significant variation on survival percentage. In the small sized homegarden (SHG), the survival percentage was significantly higher in Calliandra-T5 (88.39 %) and Mulberry-T1 (86.61 %), followed by Gliricidia and Moringa. The least survival percentage was observed in Agathi-T1 (24.11 %) at the end of the experimental year.

Similar trend was observed in medium size homegarden (MHG) and large sized homegarden (LHG) with higher survival for Mulberry-T1 and Calliandra-T5, followed by other fodder tree species.

Comparing different homegardens, survival percentage was higher for SHG (59.47 %) and MHG (54.46 %) followed by LHG (41.07 %). Among the fodder tree species, survival percentage was significantly higher in Mulberry-T1 (80.06 %) and Calliandra-T5 (71.13 %), followed by Gliricidia-T4 (44.35 %), whereas survival was drastically lower for Agathi-T2 and Moringa-T3 (Table 4).

Table 3. Annual green fodder yields and survival percentage of tree fodder banks in homegardens of varying size classes

Treatments	Fractional and total fresh fodder biomass (Mg ha^{-1})			
	Leaf	Stem	Total	Survival percentage (%)
Small homegarden				
Mulberry (T1)	5.02^{c}	1.77^{e}	6.89^{c}	86.61^{a}
Agathi (T2)	8.98^{b}	8.08^{a}	16.89^{a}	24.11^{c}
Moringa (T3)	3.73^{c}	2.35^{d}	6.09^{c}	39.29^{bc}
Gliricidia (T4)	13.17^{a}	4.59^{b}	18.28^{a}	58.93^{b}
Calliandra (T5)	8.84^{b}	3.59^{c}	12.45^{b}	88.39^{a}
P value	0.000***	0.000***	0.000***	0.001***
Medium homegarden				
Mulberry (T1)	5.76^{c}	1.91^{c}	7.67^{d}	85.71^{a}
Agathi (T2)	6.71^{c}	5.36^{b}	12.23^{c}	45.54^{b}
Moringa (T3)	5.19^{c}	3.17^{bc}	8.37^{d}	29.46^{b}
Gliricidia (T4)	16.99^{a}	9.94^{a}	26.82^{a}	41.96^{b}
Calliandra (T5)	12.51^{b}	8.57^{ab}	21.08^{b}	70.54^{a}
P value	0.000***	0.002**	0.000***	0.001***
Large homegarden				
Mulberry (T1)	4.50^{cd}	1.77^{c}	6.06^{c}	67.86^{a}
Agathi (T2)	6.13^{c}	5.30^{b}	11.67^{bc}	25.60^{c}
Moringa (T3)	3.36^{d}	1.25^{c}	4.61^{d}	25.89^{c}
Gliricidia (T4)	16.85^{a}	10.84^{a}	27.70^{a}	32.14^{c}
Calliandra (T5)	10.36^{b}	5.30^{b}	15.61^{b}	54.46^{b}
P value	0.000***	0.000***	0.001***	0.000***

*** significant at $p<0.001$. ** significant at $p<0.01$, * significant at $p<0.05$, ns= not significant $p>0.05$

Values with the same superscripts in column do not differ significantly

4.3 Seasonal green fodder yield of tree fodder banks in homesteads of varying size classes

Table 5 shows the seasonal green fodder yield of tree fodder banks in homesteads of varying size classes, during the rainy period (June-November) and the summer period (December- May). In SHG, fodder tree species showed much significant difference and seasonal fodder yield during the rainy period was significantly higher in Gliricidia-T4 (10.03 Mg ha^{-1}) followed by Agathi-T2 (8.99 Mg ha^{-1}) and Calliandra- T5 (7.02 Mg ha^{-1}). Fractional fodder biomass of the leaf followed the similiar trend wherein stem fractional biomass was higher in Agathi (3.62 Mg ha^{-1}) followed by Gliricidia (2.59 Mg ha^{-1}). During the summer period (December- May) fodder yield declined, and Gliricidia-T4 (8.13 Mg ha^{-1}) yielded more forage which was on par with Agathi-T2 (7.40 Mg ha^{-1}). Similar trend was observed in MHG also. In LHG total fodder biomass was higher in Gliricidia followed by Calliandra and Agathi during both the seasons. Fractional leaf and stem showed similar trend.

In general, seasonal fodder yield was more in rainy period than summer period. Comparing seasonal green fodder yield in different homegardens, yield was more in LHG (9.96 Mg ha^{-1}) and MHG (9.27 Mg ha^{-1}), followed by SHG (7.02 Mg ha^{-1}) during the rainy period, But during the summer period yield was more in MHG (5.08 Mg $ha^{-1)}$ and SHG (4.96 Mg $ha^{-1)}$ followed by LHG (3.87 Mg ha^{-1}).Comparing different fodder tree species, yield was higher in Gliricidia followed by Calliandra and Agathi during both the seasons (Table 6).

Table 4. Comparative annual green fodder yield and survival count as influenced by varying size of homestead and different fodder tree species

Treatments	Fractional and total fresh fodder biomass (Mg ha^{-1})			Survival Percentage (%)
	Leaf	Stem	Total	
Fodder tree species				
Mulberry (T1)	5.09^{d}	1.82^{c}	6.79^{c}	80.06^{a}
Agathi (T2)	7.28^{c}	6.25^{b}	13.59^{b}	31.55^{c}
Moringa (T3)	4.09^{d}	2.26^{c}	6.36^{c}	31.55^{c}
Gliricidia (T4)	15.67^{a}	8.45^{a}	24.27^{a}	44.35^{b}
Calliandra (T5)	10.57^{b}	5.82^{b}	16.38^{b}	71.13^{a}
P value	0.000***	0.000***	0.000***	0.000***
Size of homestead				
SHG	7.95^{b}	4.08^{b}	12.07^{b}	59.47^{a}
MHG	9.43^{a}	5.79^{a}	15.23^{a}	54.46^{a}
LHG	8.25^{b}	4.90^{ab}	13.15^{b}	41.07^{b}
P value	0.023**	0.012**	0.007**	0.000***
Tree * Homegarden interaction effects	Annual green fodder yield (Mg ha^{-1})			
	SHG	MHG	LHG	**P value**
Mulberry (T1)	6.89^{c}	7.67^{d}	6.06^{c}	0.656^{ns}
Agathi (T2	16.89^{aA}	12.23^{cB}	11.67^{bcB}	0.000**
Moringa (T3)	6.09c^{AB}	8.37^{dA}	4.61^{dB}	0.01**
Gliricidia (T4)	18.28^{aB}	26.82^{aA}	27.70^{aA}	0.024**
Calliandra (T5)	12.45^{bB}	21.08^{bA}	15.61^{bB}	0.018**
P value	0.000***	0.000***	0.001***	

*** significant at p<0.001. ** significant at p<0.01, * significant at p<0.05, ns= not significant p>0.05, Values with the same superscripts in column do not differ significantly, values with the same small letters as superscripts indicate they are on par column wise and values with the same capital letters indicates that they are on par row wise.

Table 5. Seasonal green fodder yield of tree fodder banks in homesteads of varying size classes

Treatments	Fractional and total fresh fodder biomass (Mg ha^{-1})							
	Rainy period (June –November)				Summer period (Dec- May)			
	Leaf	Stem	Total	%	Leaf	Stem	Total	%
Small homegarden								
Mulberry (T1)	2.82^{b}	0.99^{c}	3.81^{c}	56.21	2.20^{c}	0.78^{c}	2.98^{c}	43.79
Agathi (T2)	5.37^{a}	3.62^{a}	8.99^{b}	54.85	3.52^{b}	3.89^{a}	7.40^{ab}	45.15
Moringa (T3)	2.53^{b}	1.68b^{c}	4.21^{c}	63.12	1.54^{c}	0.93^{c}	2.46^{c}	36.88
Gliricidia (T4)	7.44^{a}	2.59^{ab}	10.03^{a}	56.49	5.73^{a}	2.40^{b}	8.13^{a}	43.51
Calliandra (T5)	5.62^{a}	1.40^{ab}	7.02^{b}	63.55	3.22^{b}	2.19^{b}	5.41^{b}	36.45
P value	0.016^{ns}	0.020^{ns}	0.041*		0.000**	0.000**	0.000**	
Medium homegarden								
Mulberry (T1)	3.42^{c}	0.98^{b}	4.40^{b}	58.12	2.27^{b}	0.90^{d}	3.17^{c}	41.88
Agathi (T2)	4.93^{c}	3.66^{ab}	8.59^{b}	72.00	1.70^{b}	1.64^{bc}	3.34^{c}	28.00
Moringa (T3)	3.36^{c}	1.90^{b}	5.25^{b}	63.56	1.77^{b}	1.25^{c}	3.01^{c}	36.44
Gliricidia (T4)	11.96^{a}	5.83^{a}	17.78^{a}	66.84	4.83^{a}	3.99^{a}	8.82^{a}	33.16
Calliandra (T5)	7.89^{b}	5.90^{a}	13.79^{a}	66.20	4.47^{a}	2.57^{b}	7.04^{b}	33.80
P value	0.000**	0.006**	0.000**		0.000**	0.000**	0.000**	
Large homegarden								
Mulberry (T1)	2.87^{c}	1.14^{c}	3.99^{c}	63.64	1.64^{b}	0.65^{d}	2.28b^{c}	36.36
Agathi (T2)	4.26^{c}	3.99^{b}	8.26^{b}	72.14	1.88^{b}	1.31^{c}	3.19^{b}	27.86
Moringa (T3)	2.36^{c}	0.88^{c}	3.24^{c}	70.13	1.01^{b}	0.37^{d}	1.38^{c}	29.87
Gliricidia (T4)	13.26^{b}	7.78^{a}	20.99^{a}	75.80	3.64^{a}	3.07^{a}	6.70^{a}	24.20
Calliandra (T5)	6.66^{a}	3.22^{b}	9.87^{b}	62.99	3.71^{a}	2.09^{b}	5.80^{a}	37.01
P value	0.001**	0.001**	0.001**		0.000**	0.000**	0.000***	

*** significant at $p<0.001$. ** significant at $p<0.01$, * significant at $p<0.05$, ns= not significant $p>0.05$

Values with the same superscripts in column do not differ significantly

Table 6. Comparative seasonal green fodder yield as influenced by varying size of homestead and different fodder tree species

Treatments	Fractional and total fresh fodder biomass (Mg ha^{-1})							
	Rainy period (June –November)				Summer period (Dec- May)			
	Leaf	Stem	Total	%	Leaf	Stem	Total	%
Fodder tree species								
Mulberry (T1)	2.95^{d}	0.94	3.89^{e}	59.39	1.92^{c}	0.74^{c}	2.66^{d}	40.61
Agathi (T2)	4.85^{c}	3.76	8.61^{c}	64.98	2.37^{c}	2.28^{b}	4.64^{c}	35.02
Moringa (T3)	2.75^{d}	1.48	4.23^{d}	64.98	1.44^{d}	0.85^{c}	2.28^{d}	35.02
Gliricidia (T4)	10.53^{a}	5.34	15.87^{a}	68.08	4.50^{a}	2.94^{a}	7.44^{a}	31.92
Calliandra (T5)	7.28^{b}	3.87	11.14^{b}	64.43	3.936^{b}	2.21^{b}	6.15^{b}	35.57
P value	0.003***	0.050^{ns}	0.002***		0.000***	0.000***	0.001**	
Size of homestead								
SHG	4.83^{b}	2.18	7.02^{b}	58.60	3.12^{a}	1.85^{a}	4.96^{a}	41.40
MHG	6.31^{a}	3.40	9.27^{a}	64.60	3.64^{a}	2.07^{a}	5.08^{a}	35.40
LHG	5.87^{ab}	3.65	9.96^{a}	72.02	2.37^{b}	1.49^{b}	3.87^{b}	27.98
P value	0.003***	0.050^{ns}	0.002***		0.000***	0.000**	0.001***	

*** significant at p<0.001. ** significant at p<0.01, * significant at p<0.05, ns= not significant p>0.05

Values with the same superscripts in column do not differ significant

4.4 Annual dry fodder yield & leaf- stem ratio of tree fodder banks in homegardens of varying size classes

Table 7 shows annual dry fodder biomass of tree fodder banks in homegardens of varying size classes. Fodder biomass in small sized homegarden (SHG) was significantly higher in, Gliricidia- T4 (2.84 Mg ha^{-1}) and Calliandra-T5 (2.83 Mg ha^{-1}) followed by Agathi-T2 (2.75 Mg ha^{-1}). Mulberry-T1 (1.87 Mg ha^{-1}) and Moringa-T3 (1.24 Mg ha^{-1}) had significantly lower values. Annual dry leaf yield was significantly higher in Gliricidia (2.10 Mg ha^{-1}) and Calliandra (1.99 Mg ha^{-1}). Dry stem yield was higher for Agathi-T2 (1.58 Mg ha^{-1}) than other species.

Dry fodder biomass in medium sized homegarden (MHG) was significantly higher in Calliandra-T5 (6.61 Mg ha^{-1}) and Gliricidia- T4 (5.38 Mg ha^{-1}) followed by Mulberry-T1 (2.46 Mg ha^{-1}), Agathi- T2 (2.49 Mg ha^{-1}) and Moringa-T3 (1.68 Mg ha^{-1}). Fractional biomass also showed a similar trends.

Dry fodder biomass in large sized homegarden (LHG) was observed significantly higher in Gliricidia- T4 (4.94 Mg ha^{-1}) followed by Calliandra-T5 (4.35 Mg ha^{-1}), Agathi- T2 (2.07 Mg ha^{-1}). The yield of Mulberry-T1 (1.51 Mg ha^{-1}) and Moringa-T3 (1.09 Mg ha^{-1}) were comparatively lower than other tree species.

Comparing different homegardens, annual dry fodder yield was significantly higher in case of MHG (3.72 Mg ha^{-1}) followed by LHG (2.79 Mg ha^{-1}) and SHG (2.31 Mg ha^{-1}). Fractional biomass also followed the same trend. Comparing tree species, Calliandra-T5 (4.60 Mg ha^{-1}) yielded more dry forage yield followed by Gliricidia- T4 (4.39 Mg ha^{-1}), Agathi-T2 (2.44 Mg ha^{-1}) and Mulberry-T1 (1.95 Mg ha^{-1}). Forage yield was significantly lower in Moringa-T3 (1.34 Mg ha^{-1}) when compared to all other species. In case of leaf and stem yields Calliandra was found to be the best species followed by Gliricidia (Table 8).

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5 Leaf-stem ratio

Fodder tree species showed significant variation on the leaf-stem ratio (Table 7). In SHG, Gliricidia-T4 (3.01) has significantly higher leaf-stem ratio followed by Mulberry- T1 (2.67) and Calliandra -T5 (2.44). Whereas Moringa-T3 (1.04) and Agathi-T2 (0.76) had lower values. In MHG leaf- stem ratio was significantly higher in Mulberry-T1 (2.15) followed with Gliricidia-T4 (1.31). In LHG, Calliandra –T5 (3.22) showed significantly higher value followed by Gliricidia-T4 (2.93), Mulberry-T1 (1.65).

Comparing leaf-stem ratio influenced with varying size class of homestead (Table 8), it showed significant higher value in LHG (2.28) and SHG (1.67) followed by MHG (1.16), wherein fodder tree species showed significant difference, higher leaf-stem ratio was observed in Mulberry-T1 (2.09) and Gliricidia-T4(2.05) followed by Calliandra-T5(1.67). Agathi-T2 (0.94) and Moringa-T3 (1.0) had lower values.

Table 7. Annual dry fodder yield & leaf-stem ratio of tree fodder banks in homegardens of varying size classes

Treatments	Annual dry fodder yield & leaf stem ratio (Mg ha^{-1})			Leaf- stem Ratio
	Leaf	Stem	Total	
Small homegarden				
Mulberry (T1)	1.34^{b}	0.54^{b}	1.87^{b}	2.67^{a}
Agathi (T2)	1.17^{b}	1.58^{a}	2.75^{a}	0.76^{b}
Moringa (T3)	0.63^{c}	0.62^{b}	1.24^{a}	1.04^{b}
Gliricidia (T4)	2.10^{a}	0.74^{b}	2.84^{a}	3.01^{a}
Calliandra (T5)	1.99^{a}	0.84^{b}	2.83^{a}	2.44^{a}
P value	0.000***	0.012**	0.000***	0.001**
Medium homegarden				
Mulberry (T1)	1.68^{c}	0.78^{b}	2.46^{b}	2.15^{a}
Agathi (T2)	1.30^{c}	1.19^{b}	2.49^{b}	1.09^{b}
Moringa (T3)	0.67^{d}	1.02^{b}	1.68^{b}	0.66^{b}
Gliricidia (T4)	3.05^{b}	2.33^{a}	5.38^{a}	1.31^{b}
Calliandra (T5)	3.31^{a}	3.31^{a}	6.61^{a}	1.00^{b}
P value	0.000***	0.001***	0.000***	0.000**
Large homegarden				
Mulberry (T1)	0.94^{b}	0.57^{c}	1.51^{c}	1.65^{b}
Agathi (T2)	1.08^{b}	0.99^{b}	2.07^{c}	1.09^{c}
Moringa (T3)	0.71^{b}	0.39^{e}	1.09^{d}	1.82^{b}
Gliricidia (T4)	3.69^{a}	1.26^{a}	4.94^{a}	2.93^{a}
Calliandra (T5)	3.32^{a}	1.03^{ab}	4.35^{b}	3.22^{a}
P value	0.000***	0.003***	0.000***	0.000***

*** significant at $p<0.001$. ** significant at $p<0.01$, * significant at $p<0.05$, ns= not significant $p>0.05$, Values with the same superscripts in column do not differ significantly

4.5 Seasonal dry fodder yield of tree fodder banks in homesteads of varying size classes

Table 9 shows the seasonal dry fodder yield of tree fodder banks in homesteads of varying size classes, during the rainy period (June-November) and the summer period (December- May). In SHG, fodder tree species showed much significant difference and seasonal fodder yield during both the period was significantly higher in Calliandra- T5 (1.75 Mg ha^{-1} and 1.35 Mg ha^{-1}) followed by Gliricidia-T4 (1.64 Mg ha^{-1} and 1.33 Mg ha^{-1}) and Agathi-T2 (1.44 Mg ha^{-1} and 1.19 Mg ha^{-1}) than other fodder tree species. Fractional fodder biomass of the leaf followed the similiar trend. Similar trend was observed in MHG during the summer period but during dry period yield of Agathi-T2 declined and higher value was observed in Calliandra-T5 (4.32 Mg ha^{-1} and 2.21 Mg ha^{-1}) followed by Gliricidia-T4 (3.57 Mg ha^{-1} and 1.77 Mg ha^{-1}). In LHG total fodder biomass was higher in Calliandra-T5 (2.75 Mg ha^{-1} and 1.62 Mg ha^{-1}) and Gliricidia-T4 (3.74 Mg ha^{-1} and 1.19 Mg ha^{-1}) and lowest value was observed in Moringa-T3 (0.77 Mg ha^{-1} and 0.33 Mg ha^{-1}). Fractional leaf and stem showed similar trend.

In general, seasonal fodder yield was more in rainy period than summer period. Comparing seasonal green fodder yield in different homegardens, yield was more in MHG (2.30 Mg ha^{-1}) followed by LHG (2.23Mg ha^{-1}) and SHG (1.56 Mg ha^{-1}) during the rainy period, But during the summer period yield was more in MHG (1.26 Mg ha^{-1}) and SHG (1.10 Mg ha^{-1}) followed by LHG (0.87 Mg ha^{-1}).Comparing different fodder tree species, yield was higher in Calliandra followed by Gliricidia and Agathi during both the seasons. (Table 10).

Table 8. Comparative annual dry fodder yield as influenced by varying size of homestead and different fodder tree species

Treatments	Annual dry fodder yield & leaf stem ratio ($Mg\ ha^{-1}$)			Leaf- stem ratio
	Leaf	Stem	Total	
Fodder tree species				
Mulberry (T1)	1.32^{b}	0.63^{c}	1.95^{c}	2.09^{a}
Agathi (T2)	1.18^{b}	1.25^{b}	2.44^{b}	0.94^{b}
Moringa (T3)	0.67^{c}	0.67^{c}	1.34^{b}	1.00^{c}
Gliricidia (T4)	2.95^{a}	1.44^{ab}	4.39^{a}	2.05^{a}
Calliandra (T5)	2.87^{a}	1.72^{a}	4.60^{a}	1.67^{a}
P value	0.000^{***}	0.000^{***}	0.000^{***}	0.000***
Size of homestead				
SHG	1.44^{b}	0.86^{b}	2.31^{b}	1.67^{b}
MHG	1.99^{a}	1.72^{a}	3.72^{a}	1.16^{b}
LHG	1.94^{a}	0.85^{b}	2.79^{b}	2.28^{a}
P value	0.000***	0.000^{***}	0.000^{***}	0.000***

*** significant at $p<0.001$. ** significant at $p<0.01$, * significant at $p<0.05$, ns= not significant $p>0.05$, Values with the same superscripts in column do not differ significantly

Table 9. Seasonal dry fodder yield of tree fodder banks in homesteads of varying size classes

Treatments	Seasonal dry fodder yield (Mg ha^{-1})							
	Rainy period (June –November)				Summer period (Dec- May)			
Small homegarden	Leaf	Stem	Total	%	Leaf	Stem	Total	%
Mulberry (T1)	0.76^{a}	0.31^{c}	1.11^{bc}	55.61^{b}	0.59^{b}	0.25^{b}	0.87^{bc}	44.39
Agathi (T2)	0.70^{a}	0.71^{a}	1.44^{b}	54.92^{b}	0.46^{b}	0.76^{a}	1.19^{b}	45.08
Moringa (T3)	0.42^{c}	0.45^{b}	0.91^{c}	63.06^{a}	0.26^{c}	0.25^{b}	0.53^{c}	36.94
Gliricidia (T4)	1.22^{b}	0.42^{b}	1.64^{a}	55.73^{b}	0.94^{a}	0.39^{b}	1.33^{a}	44.27
Calliandra (T5)	1.28^{b}	0.47^{b}	1.75^{a}	63.50^{a}	0.73^{ab}	0.73^{a}	1.35^{a}	36.50
P value	0.000***	0.005***	0.000***		0.005**	0.005**	0.000**	
Medium homegarden								
Mulberry (T1)	1.00^{b}	0.40^{c}	1.41^{b}	58.26	0.66^{b}	0.37^{b}	1.02^{b}	41.74
Agathi (T2)	0.95^{b}	0.81^{ab}	1.75^{b}	72.02	0.33^{c}	0.36^{b}	0.68^{b}	27.98
Moringa (T3)	0.43^{bc}	0.61^{b}	1.05^{c}	63.64	0.23^{c}	0.40^{b}	0.60^{b}	36.36
Gliricidia (T4)	2.15^{a}	1.37^{a}	3.57^{ab}	66.85	0.87^{ab}	0.94^{a}	1.77^{a}	33.15
Calliandra (T5)	2.09^{a}	2.28^{a}	4.32^{a}	66.26	1.18^{a}	0.99^{a}	2.21^{a}	33.74
P value	0.000***	0.000***	0.000***		0.000**	0.000**	0.000**	
Large homegarden								
Mulberry (T1)	0.60^{b}	0.37^{c}	0.99^{b}	64.29	0.34^{b}	0.21^{b}	0.57^{b}	35.71
Agathi (T2)	0.75^{b}	0.75^{a}	1.47^{ab}	72.46	0.33^{b}	0.24^{ab}	0.57^{b}	27.54
Moringa (T3)	0.50^{b}	0.27^{c}	0.77^{b}	70.00	0.21^{c}	0.12^{c}	0.33^{c}	30.00
Gliricidia (T4)	2.90^{a}	0.90^{a}	3.74^{a}	75.86	0.80^{ab}	0.36^{a}	1.19^{a}	24.14
Calliandra (T5)	2.13^{a}	0.63^{b}	2.75^{a}	62.93	1.19^{a}	0.41^{a}	1.62^{a}	37.07
P value	0.000***	0.000***	0.000***		0.000***	0.000***	0.000***	

*** significant at $p<0.001$. ** significant at $p<0.01$, * significant at $p<0.05$, ns= not significant $p>0.05$

Values with the same superscripts in column do not differ significantly

Table 10. Comparative seasonal dry fodder yield as influenced by varying size of homestead and different fodder tree species

Treatments	Fractional and total dry fodder biomass (Mg ha^{-1})							
	Rainy period (June –November)				Summer period (Dec- May)			
Fodder tree species								
Mulberry (T1)	0.76^{b}	0.33^{c}	1.12^{b}	59.60	0.49^{b}	0.26^{c}	0.76^{c}	40.40
Agathi (T2)	0.81^{b}	0.76^{ab}	1.55^{b}	65.07	0.40^{b}	0.46^{b}	0.84^{b}	34.93
Moringa (T3)	0.46^{c}	0.44^{b}	0.92^{c}	65.06	0.24^{c}	0.26^{c}	0.50^{c}	34.94
Gliricidia (T4)	1.97^{a}	0.91^{a}	2.87^{ab}	68.16	0.84^{ab}	0.50^{ab}	1.34^{ab}	31.84
Calliandra (T5)	2.19^{a}	1.18^{a}	3.39^{a}	64.49	1.18^{a}	0.67^{a}	1.87^{a}	35.51
P value	0.000***	0.000**	0.000**		0.000**	0.000***	0.000***	
Size of homestead								
SHG	0.92^{b}	0.56^{b}	1.56^{b}	58.51	0.60^{a}	0.47^{b}	1.10^{ab}	41.49
MHG	1.34^{a}	1.07^{a}	2.30^{a}	64.61	0.64^{a}	0.65^{a}	1.26^{a}	35.39
LHG	1.33^{a}	0.83^{ab}	2.23^{a}	72.17	0.54^{b}	0.34^{b}	0.87^{b}	27.83
P value	0.000***	0.000***	0.000***		0.000***	0.000***	0.000***	

*** significant at $p<0.001$. ** significant at $p<0.01$, * significant at $p<0.05$, ns= not significant $p>0.05$

Values with the same superscripts in column do not differ significantly

4.6 PLANT QUALITY AND NUTRIENT ANALYSIS

4.6.1 Crude protein (CP) content

Fodder tree species showed significant variation on CP content in the fodder biomass (Table 11) In general, foliage fraction had higher crude protein levels than the stem fraction for all tree species. In SHG, total CP content in fodder increased from 12.29 (Mulberry-T1) to 24.68 per cent (Gliricidia- T4) and 24.65 per cent in (Calliandra-T5). Agathi and Moringa had 17 and 18.86 per cent CP in fodder biomass. Comparing CP content in leaf biomass, Agathi, Moringa, Gliricidia, and Calliandra had higher values ranging from 30.74 to 33.71 per cent. However Mulberry leaves had the least value of 17.15 per cent. However stem CP content was higher (3.24 %) in Mulberry and Moringa followed by Agathi (3.13 %). Values were significantly lower in Calliandra (2.10 %) and Gliricidia (2.07 %).

In medium sized homegarden CP content of total fodder biomass was significantly higher in Calliandra-T5 (20.36 %) followed by Gliricidia (18.02 %) and Mulberry (17.51 %). CP content in leaf biomass also had similar pattern. However stem CP content was higher for Moringa (3.50 %). Similar results were also obtained in large scale homegarden.

Comparing different homegardens (Table 12), CP content was significantly higher in case of SHG (20.01 %), followed by MHG (16.96 %) and LHG (15.94 %) which were on par. Fractional biomass of leaf followed the same trend but in stem biomass CP content was higher in MHG (3.00 %) followed by SHG and MHG. Comparing tree species, Calliandra-T5 (22.57 %) and Gliricidia- T4 (19.99 %) yielded more CP content followed by Mulberry-T1 (16.74 %). Agathi-T1 (14.81 %) and Moringa-T3 (14.06 %) was significantly lower in CP content when compared to all other species. In case of leaf CP content followed the similar trend. But in stem fraction

CP content was found higher in Moringa (3.33 %) and Mulberry (3.02 %) followed by Calliandra (2.45 %).

4.6.2 Crude protein yield

Fodder tree species showed significant variation on CP yield in the fodder biomass (Table 11). In general, foliage fraction had higher crude protein levels than the stem fraction for all tree species. In SHG, total CP yield was higher in Agathi (0.74 Mg ha^{-1}), Gliricidia (0.70 Mg ha^{-1}) and Calliandra (0.70 Mg ha^{-1}). Mulberry and Moringa showed the lower crude protein yield. In the leaf and stem fraction, leaf biomass was significantly higher in Calliandra (0.66 Mg ha^{-1}) and Gliricidia (0.65 Mg ha^{-1}) followed by other tree species and in stem fraction higher CP yield was found in Agathi (0.05 Mg ha^{-1}) compared to other tree species.

In medium sized homegarden CP yield of total fodder biomass was significantly higher in Gliricidia (1.26 Mg ha^{-1}) followed by Calliandra-T5 (1.01 Mg ha^{-1}) and Mulberry (0.44 Mg ha^{-1}) and lowest CP yield was observed in Agathi and Moringa. CP yield in leaf and stem fraction followed the similar pattern and also in LHG crude protein followed the same trend in same like as SHG and LHG.

Comparing different homegardens, CP yield was significantly higher in case of MHG (0.63 Mg ha^{-1}) followed by and SHG (0.46 Mg ha^{-1}) and LHG (0.44 Mg ha^{-1}). Fractional biomass followed the similar trend. Comparing tree species, Calliandra-T5 (1.04 Mg ha^{-1}) and Gliricidia- T4 (0.88 Mg ha^{-1}) yielded more CP yield followed by Agathi-T1 (0.36 Mg ha^{-1}) and Mulberry-T1 (0.33 Mg ha^{-1}). The Moringa-T3 (0.19 Mg ha^{-1}) was significantly lower in CP yield when compared to all other species. In case of leaf and stem yields CP yield followed the similar trend (Table 12).

Table 11. Crude protein content and crude protein yield of tree fodder banks in homesteads of varying size classes

Treatments	Crude protein content (%)			Crude protein yield (Mg ha^{-1})		
	Leaf	Stem	Total	Leaf	Stem	Total
Small homegarden						
Mulberry (T1)	17.15^{b}	3.24^{a}	12.29^{c}	0.23^{c}	0.02^{b}	0.23^{b}
Agathi (T2)	30.74^{a}	3.13^{a}	17.00^{b}	0.36^{b}	0.05^{a}	0.74^{a}
Moringa (T3)	33.71^{a}	3.24^{a}	18.86^{b}	0.21^{c}	0.02^{b}	0.23^{b}
Gliricidia (T4)	31.09^{a}	2.07^{b}	24.68^{a}	0.65^{a}	0.02^{b}	0.70^{a}
Calliandra (T5)	33.30^{a}	2.10^{b}	24.65^{a}	0.66^{a}	0.02^{b}	0.70^{a}
P value	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***
Medium homegarden						
Mulberry (T1)	24.97^{d}	2.60	17.51^{b}	0.42^{b}	0.02^{b}	0.44^{c}
Agathi (T2)	26.60^{cd}	3.12	15.31^{c}	0.35^{b}	0.04^{b}	0.38^{c}
Moringa (T3)	28.35^{bc}	3.50	13.76c	0.19^{c}	0.04^{b}	0.23^{d}
Gliricidia (T4)	30.98^{b}	2.62	18.02^{b}	0.94^{ab}	0.06^{b}	1.01^{b}
Calliandra (T5)	35.06^{a}	3.15	20.36^{a}	1.16^{a}	0.10^{a}	1.26^{a}
P value	0.000***	0.0162^{ns}	0.000***	0.000***	0.000***	0.001***
Large homegarden						
Mulberry (T1)	23.86	3.23^{a}	15.84^{b}	0.22^{c}	0.02^{a}	0.24^{b}
Agathi (T2)	24.91	2.13^{b}	13.60^{c}	0.27^{c}	0.02^{a}	0.29^{b}
Moringa (T3)	24.21	3.24^{a}	12.28^{c}	0.17^{d}	0.01^{b}	0.18^{c}
Gliricidia (T4)	25.03	2.07^{c}	17.63^{b}	0.92^{a}	0.03^{a}	0.95^{a}
Calliandra (T5)	24.91	2.10^{b}	20.63^{a}	0.83^{b}	0.02^{a}	0.85^{ab}
P value	0.358^{ns}	0.000***	0.000***	0.000***	0.005**	0.000***

*** significant at $p<0.001$. ** significant at $p<0.01$, * significant at $p<0.05$, ns= not significant $p>0.05$, Values with the same superscripts in column do not differ significantly

Table 12. Comparative crude protein content and crude protein yield of tree fodder banks influenced by homesteads of varying size classes and different fodder tree species

Treatments	Crude protein content (%)			Crude protein yield (Mg ha^{-1})		
	Leaf	Stem	Total	Leaf	Stem	Total
Fodder tree species						
Mulberry (T1)	22.00^{c}	3.02^{a}	16.74^{c}	0.29^{bc}	0.02^{b}	0.33^{b}
Agathi (T2)	27.42^{b}	2.46^{b}	14.81^{d}	0.32^{b}	0.03^{a}	0.36^{b}
Moringa (T3)	28.76^{b}	3.33^{a}	14.06^{d}	0.19^{c}	0.02^{b}	0.19^{c}
Gliricidia (T4)	29.03^{b}	2.26^{b}	19.99^{b}	0.86^{a}	0.03^{a}	0.88^{a}
Calliandra (T5)	31.10^{a}	2.45^{b}	22.57^{a}	0.89^{a}	0.04^{a}	1.04^{a}
P value	0.000***	0.000***	0.000***	0.000***	0.002***	0.000***
Size of homestead						
SHG	29.20^{a}	2.56^{b}	20.01^{a}	0.42^{b}	0.02^{b}	0.46^{b}
MHG	29.19^{a}	3.00^{a}	16.96^{b}	0.58^{a}	0.05^{a}	0.63^{a}
LHG	24.58^{b}	2.56^{b}	15.94^{b}	0.48^{b}	0.02^{b}	0.44^{b}
P value	0.000***	0.002**	0.000***	0.000***	0.000***	0.000***

*** significant at $p<0.001$. ** significant at $p<0.01$, * significant at $p<0.05$, ns= not significant $p>0.05$

Values with the same superscripts in column do not differ significantly

4.6.3 Crude fibre (CF) content

Fodder tree species showed significant variation on CF content in the fodder biomass (Table 13.). In general, stem fraction had higher crude fibre levels than the foliage fraction for all tree species. CF content was observed higher in Agathi (32.85 %) in small sized homegarden (SHG), followed by Moringa (28.82 %) and Mulberry (28.39 %) whereas the value of CF was comparatively lower in Gliricidia (22.59 %) and Calliandra (21.30 %). However leaf CF levels was higher in Mulberry (19.33 %) and Agathi (17.67 %) compared to the rest of the species. Stem CF levels was higher in Agathi and Gliricidia (48.17 %).

In medium sized homegarden (MHG), CF content was significantly higher in Moringa- (45.94 %), Agathi (39.49 %) and Calliandra (34.06 %). However leaf CF levels was higher in Agathi (22.50 %) and Mulberry (18.33 %) compared with rest of the species. Stem CF levels was higher in Moringa (60.33 %), Agathi (57.83 %) and Calliandra (54 %).

In large scale homegarden (LHG), CF content was found significantly higher in Moringa (39.22 %) and Agathi-T2 (38.07 %). However leaf CF levels was higher in Calliandra (16.27 %), Agathi (16.20 %) and Gliricidia (14.27 %) compared to the rest of the fodder species. Stem CF content was higher in Moringa (63.50 %) and Calliandra (55.17 %).

Comparing different homegardens, CF content was significantly higher in case of MHG (34.83 %) and LHG (30.03 %) which were on par followed by SHG (27.77 %). Fractional biomass of leaf and stem followed the same trend. Comparing tree species, Agathi-T2 (38.42 %) and Moringa- T3 (38.12 %) yielded more CF content followed by Calliandra-T5 (26.74 %) and Mulberry-T1 (27.39 %). Gliricidia-T4 (23.72 %) was significantly lower in CF content when compared to all other species. In case of leaf and stem yields CF content followed the similar trend (Table 14).

Table 13. Crude fibre content of tree fodder banks in homesteads of varying size classes

Treatments	Crude fibre content (%)		
	Leaf	Stem	Total
Small homegarden			
Mulberry (T1)	19.33^{ab}	44.50^{b}	28.39^{b}
Agathi (T2)	17.67^{a}	48.17^{a}	32.85^{a}
Moringa (T3)	15.83^{b}	43.33^{b}	28.82^{b}
Gliricidia (T4)	15.33^{b}	48.17^{b}	22.59^{c}
Calliandra (T5)	12.33^{c}	44.67^{b}	21.30^{c}
P value	0.000***	0.001***	0.000***
Medium homegarden			
Mulberry (T1)	18.33^{b}	37.83^{b}	24.83^{c}
Agathi (T2)	22.50^{a}	57.83^{ab}	39.49^{b}
Moringa (T3)	15.87^{bc}	66.33^{a}	45.94^{a}
Gliricidia (T4)	15.20^{c}	37.83^{c}	25.54c
Calliandra (T5)	17.20^{bc}	54.00^{ab}	34.06^{b}
P value	0.000***	0.002**	0.000***
Large homegarden			
Mulberry (T1)	13.33^{b}	41.83^{d}	24.79^{b}
Agathi (T2)	16.20^{a}	62.27^{a}	38.07^{a}
Moringa (T3)	12.73^{b}	63.50^{a}	39.22^{a}
Gliricidia (T4)	14.27^{ab}	47.83^{c}	22.15^{b}
Calliandra (T5)	16.27^{a}	55.17^{b}	25.42^{b}
P value	0.005**	0.000***	0.000***

*** significant at $p<0.001$. ** significant at $p<0.01$, * significant at $p<0.05$, ns= not significant $p>0.05$, Values with the same superscripts in column do not differ significantly

Table 14. Comparative crude fibre content of tree fodder banks in homesteads of varying size classes and different fodder tree species

Treatments	Crude fibre content (%)		
	Leaf	Stem	Total
Fodder tree species			
Mulberry (T1)	16.99[b]	45.50[c]	27.39[c]
Agathi (T2)	18.79[a]	59.94[a]	38.42[a]
Moringa (T3)	14.81[c]	57.72[a]	38.12[a]
Gliricidia (T4)	14.93[c]	44.61[c]	23.72[c]
Calliandra (T5)	15.27[c]	51.28[b]	26.74[b]
P value	0.000***	0.000***	0.000***
Size of homestead			
SHG	16.09[b]	48.00[b]	27.77[c]
MHG	17.82[a]	53.23[a]	34.83[a]
LHG	14.56[a]	54.20[a]	30.03[c]
P value	0.000***	0.004**	0.000***

*** significant at $p<0.001$. ** significant at $p<0.01$, * significant at $p<0.05$,

ns= not significant $p>0.05$, Values with the same superscripts in column do not differ significantly

4.6.4 Ash content

Fodder tree species showed significant variation in ash content in the fodder biomass (Table 15). In SHG, ash content was significantly higher in Moringa (8.02 %) for total fodder biomass as well as in leaf and stem biomass. Next higher values were observed in Mulberry (7.06 %). Lowest ash content was observed in Calliandra-T5 (4.22 %).

In medium size class of homegarden ash content was found to be significantly higher in Mulberry-T1 (8.58 %), followed by Moringa (7.05 %) and lowest was observed in Calliandra-T5 (4.06 %). In the leaf fraction Mulberry (10.45 %) and Agathi-T2 (10.33 %) had the higher ash content followed by Moringa. Stem ash content was observed significantly higher in Moringa (5.33 %) and Gliricidia (4.90 %).

In large scale homegarden Mulberry (8.39 %), Moringa (7.75 %) showed significantly higher ash content and lowest was observed in Calliandra-T5 (4.76). However leaf ash content levels was higher in Mulberry (9.89 %), Agathi (9.33 %) and Moringa (8.56 %). Stem ash content was observed significantly higher in Moringa (7 %), Mulberry (5.56 %) and Gliricidia (5.11 %) compared to other fodder tree species.

Comparing different homegardens, ash content was significantly higher in LHG (7.26 %) followed by SHG (6.81 %) which were on par with that of MHG (6.60 %). Stem yield also followed similar trend but in leaf fraction ash content was found to be significantly higher in MHG (8.71 %) followed by LHG (8.19 %) and SHG (7.96 %). Among different fodder tree species, Mulberry (7.93 %), Moringa (7.61 %), Agathi (7.12 %) showed higher ash content followed by Gliricidia (6.93 %) and the lowest ash content was observed in Calliandra (4.37 %). In leaf and stem fraction higher ash content was observed in leaf of Agathi (9.78 %), Mulberry (9.67 %) and Moringa (9.22 %) followed by Gliricidia (8.22 %) and lowest was observed in Calliandra (4.56 %). In stem biomass Moringa had the higher ash content (6.22 %) followed by other tree species (Table 16).

4.6.5 Dry matter content

Fodder tree species had significant influence on the DM content of fodder biomass (Table 15). In SHG, DM content was highest for Mulberry -T1 (29.22 %) followed by Calliandra-T5 (24.97 %). Dry matter content in MHG showed significantly higher in total fodder biomass of Mulberry- T1 (32.07 %) and Calliandra-T5 (31.36 %). Lowest DM content was observed in Moringa-T3 (20.07 %) and Gliricidia-T4 (20.06 %). In large scale homegarden DM content was significantly higher for Calliandra-T5 (27.87 %) and lowest was observed in Agathi-T2 (17.74 %) and Gliricidia-T4 (17.83 %) and among leaf fraction it followed the similar trend but in stem fraction DM content was found significantly higher in Mulberry-T1 (32.20 %) and significantly lower in Gliricidia-T4 (11.62 %).

Comparing different homegardens, no significant difference was observed in DM content of fodder biomass. Comparing fodder trees, Calliandra (30.40 %) and Mulberry (28.73 %) showed higher DM content followed by Moringa (21.79 %) and the lowest DM content was observed in Agathi (18.04 %) and Gliricidia (18.06 %). DM content of leaf and stem fraction followed similar trend (Table 16).

Table 15. Ash content and total dry matter content of tree fodder banks in homesteads of varying size classes

Treatments	Ash content (%)			DM content (%)		
	Leaf	Stem	Total	Leaf	Stem	Total
Small homegarden						
Mulberry (T1)	8.67[b]	4.33[b]	7.06[b]	26.86[a]	31.64[a]	29..22[a]
Agathi (T2)	9.67[a]	4.44[b]	6.67[b]	13.08[bc]	19.61[c]	16.02[c]
Moringa (T3)	9.56[a]	6.33[a]	8.02[a]	16.67[b]	26.66[b]	21.67[b]
Gliricidia (T4)	7.67[c]	4.67[b]	6.89[b]	16.37[b]	16.16[c]	16.31[c]
Calliandra (T5)	4.22[d]	4.22[b]	4.22[c]	22.74[a]	33.29[b]	24.97[b]
P value	0.000***	0.001***	0.001***	0.000***	0.000***	0.000***
Medium homegarden						
Mulberry (T1)	10.45[a]	4.67[b]	8.58[a]	29.17[a]	40.84[a]	32.07[a]
Agathi (T2)	10.33[a]	4.56[b]	3.42[d]	19.37[b]	22.20[c]	20.36[b]
Moringa (T3)	9.56[b]	5.33[a]	7.05[b]	12.91[c]	32.18[b]	20.07[b]
Gliricidia (T4)	8.78[c]	4.90[b]	7.10[b]	17.95[b]	23.44[c]	20.06[b]
Calliandra (T5)	4.44[d]	3.67[c]	4.06[c]	26.46[ab]	38.62[a]	31.36[a]
P value	0.000***	0.003**	0.001***	0.000***	0.000***	0.001***
Large homegarden						
Mulberry (T1)	9.89[a]	5.56[b]	8.39[a]	20.89[b]	32.20[a]	24.92[b]
Agathi (T2)	9.33[ab]	4.67[bc]	7.15[b]	17.62[c]	18.68[b]	17.74[c]
Moringa (T3)	8.56[ab]	7.00[a]	7.75[b]	21.13[b]	31.20[a]	23.64[b]
Gliricidia (T4)	8.22[b]	5.11[bc]	7.44[b]	21.90[b]	11.62[c]	17.83[c]
Calliandra (T5)	5.00[c]	4.00[c]	4.76[c]	32.05[a]	19.43[b]	27.87[a]
P value	0.000***	0.000***	0.001***	0.000***	0.000***	0.000***

*** significant at $p<0.001$. ** significant at $p<0.01$, * significant at $p<0.05$, ns= not significant $p>0.05$, Values with the same superscripts in column do not differ significantly

Table 16. Comparative ash content and total dry matter content of tree fodder banks as influenced by homesteads of varying size classes and different fodder tree species

Treatments	Ash content (%)			DM content (%)		
	Leaf	Stem	Total	Leaf	Stem	Total
Fodder tree species						
Mulberry (T1)	9.67^{ab}	4.85^{b}	7.93^{a}	25.64^{a}	34.98^{a}	28.73^{a}
Agathi (T2)	9.78^{a}	4.56^{b}	7.12^{a}	16.69^{b}	20.16^{b}	18.04^{b}
Moringa (T3)	9.22^{b}	6.22^{a}	7.61^{a}	16.90^{b}	30.01^{a}	21.79b
Gliricidia (T4)	8.22^{c}	4.89^{b}	6.93^{ab}	18.74^{b}	17.07^{b}	18.06^{b}
Calliandra (T5)	4.56^{d}	3.96^{c}	4.37^{b}	30.10^{a}	30.45^{a}	30.40^{a}
P value	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***
Size of homestead						
SHG	7.96^{b}	4.80^{b}	6.81^{b}	19.14	25.53	22.24
MHG	8.71^{a}	4.62^{b}	6.60^{b}	21.17	31.46	24.78
LHG	8.19^{b}	5.27^{a}	7.26^{a}	22.72	22.63	22.40
P value	0.000***	0.004***	0.000***	0.32^{ns}	0.06^{ns}	0.22^{ns}

*** significant at p<0.001. ** significant at p<0.01, * significant at p<0.05, ns= not significant p>0.05, Values with the same superscripts in column do not differ significantly

4.6.6 Nitrogen content

There was significant difference in total N content (Table 17) in different fodder species. In SHG, N content was found significant higher in Calliandra-T5 (3.86 %) and Gliricidia followed by Moringa. N content was found lowest in Mulberry- T1 (1.92 %). In MHG and LHG, N was significantly higher for Calliandra-T5 (3.06 %) than other species.

Comparing N content between small, medium and large scale homegarden, N content was observed significantly higher in SHG and LHG (3.21 %) followed by MHG (2.75 %).Among the different fodder trees total N content was higher in Calliandra (3.82 %) and Gliricidia (3.33 %) followed by Mulberry (2.64 %), Agathi (2.49 %) and Moringa (2.39 %) (Table 18).

4.6.7 Phosphorous content

In general, P content in fodder was significantly higher in Moringa-T3 in all three size classes of homegarden (SHG- 0.30 %, MHG- 0.30 %, LHG- 0.27 %) (Table 17).Comparing homesteads, P content in fodder was significantly higher in MHG (0.24 %) followed by LHG (0.22 %) and SHG (0.18 %). P content of different fodder trees showed significant difference and it was found higher in Moringa (0.25 %) followed by Mulberry (0.25 %) than other species (Table 18). P content was comparatively less in Gliricidia.

Table 17. Nitrogen and phosphorous content of tree fodder banks in homesteads of varying size classes

Treatments	Total N (%)			Total P (%)		
	Leaf	Stem	Total	Leaf	Stem	Total
Small homegarden						
Mulberry (T1)	2.74^{b}	0.52^{a}	1.92^{d}	0.24^{a}	0.33^{a}	0.27^{a}
Agathi (T2)	4.92^{a}	0.34^{b}	2.29^{c}	0.27^{a}	0.31^{a}	0.29^{a}
Moringa (T3)	5.40^{a}	0.52^{a}	3.00^{b}	0.25^{a}	0.34^{a}	0.30^{a}
Gliricidia (T4)	4.97^{a}	0.33^{b}	3.76^{a}	0.18^{b}	0.23^{b}	0.19^{b}
Calliandra (T5)	5.33^{a}	0.34^{b}	3.86^{a}	0.17^{b}	0.26^{b}	0.20^{b}
P value	0.000***	0.000***	0.000***	0.000***	0.001***	0.000***
Medium homegarden						
Mulberry (T1)	3.99^{d}	0.42	2.85^{b}	0.22	0.23	0.22^{b}
Agathi (T2)	4.26^{cd}	0.50	0.75^{d}	0.26	0.32	0.18^{c}
Moringa (T3)	4.54^{bc}	0.56	2.15^{c}	0.27	0.31	0.30^{a}
Gliricidia (T4)	4.96^{b}	0.42	2.99^{b}	0.11	0.30	0.19^{c}
Calliandra (T5)	5.61^{a}	0.50	3.06^{a}	0.14	0.29	0.22^{b}
P value	0.000***	0.163^{ns}	0.000***	0.014^{ns}	0.251^{ns}	0.000***
Large homegarden						
Mulberry (T1)	3.82	0.52^{a}	2.70^{c}	0.16	0.26	0.19^{d}
Agathi (T2)	3.99	0.34^{b}	2.25^{d}	0.13	0.30	0.21^{c}
Moringa (T3)	3.87	0.52^{a}	2.04^{e}	0.19	0.33	0.27^{a}
Gliricidia (T4)	4.00	0.33^{b}	3.07^{b}	0.18	0.29	0.21^{c}
Calliandra (T5)	3.98	0.34^{b}	3.12^{a}	0.21	0.31	0.23^{b}
P value	0.359^{ns}	0.000***	0.000***	0.454^{ns}	0.360^{ns}	0.000***

*** significant at $p<0.001$. ** significant at $p<0.01$, * significant at $p<0.05$, ns= not significant $p>0.05$,

Values with the same superscripts in column do not differ significantly

Table 18. Comparative nitrogen and phosphorous content of tree fodder banks as influenced by homesteads of varying size classes and different fodder tree species

Treatments	Total N (%)			Total P (%)		
	Leaf	Stem	Total	Leaf	Stem	Total
Fodder tree species						
Mulberry (T1)	3.58^{e}	0.45^{b}	2.64^{c}	0.22^{a}	0.27	0.25^{b}
Agathi (T2)	4.48^{d}	0.45^{b}	2.49^{d}	0.26^{a}	0.31	0.23^{c}
Moringa (T3)	4.82^{c}	0.55^{a}	2.39^{e}	0.26^{a}	0.32	0.28^{a}
Gliricidia (T4)	4.96^{b}	0.39^{b}	3.33^{b}	0.13^{b}	0.28	0.19^{e}
Calliandra (T5)	5.52^{a}	0.45^{b}	3.82^{a}	0.15^{b}	0.28	0.20^{d}
P value	0.000***	0.001***	0.000***	0.000***	0.025^{ns}	0.000***
Size of homesteads						
SHG	4.67	0.41^{b}	3.21^{a}	0.20	0.29	0.18^{c}
MHG	4.67	0.48^{a}	2.75^{b}	0.20	0.28	0.24^{a}
LHG	4.67	0.48^{a}	3.21^{a}	0.22	0.28	0.22^{b}
P value	1.000^{ns}	0.010**	0.001***	0.252^{ns}	0.887^{ns}	0.000***

*** significant at $p<0.001$. ** significant at $p<0.01$, * significant at $p<0.05$, ns= not significant $p>0.05$, Values with the same superscripts in column do not differ significantly

4.6.8 Potassium content

Fodder tree species had significant variation on the K content of total fodder (Table 19 and 20). K content was relatively higher in Moringa in all size classes of homegarden (SHG-1.09 %, MHG- 1.08 %, LHG-1.18 %), and the lowest was observed in Mulberry and Agathi. Total K content of stem fraction was comparatively higher than in leaf fraction. Leaf fraction had significant difference with higher K content in Agathi (0.08 %). In stem fraction K content was higher in Moringa (1.99 %) like total tree fodder biomass. Similarly in MHG, K content in leaf and stem fraction were higher in Moringa (0.15 %; 1.85 %) and Gliricidia (0.20; 1.92 %) followed by other treatments with not much prominent changes. In LHG total fodder and stem fraction was similar to SHG and MHG but the leaf fraction was observed significantly higher in Agathi-T2 (0.21 %).

Comparing total potassium content with different size class classes of homestead, it was significantly found higher in SHG (0.95 %) followed by LHG (0.87 %) and MHG (0.84 %). Total K of different fodder trees showed significant difference and it was found higher in Moringa (1.04 %) which was on par with Gliricidia (0.92 %) and Calliandra (0.92 %) followed by Agathi and Mulberry. Leaf fraction did not show much prominent changes and followed the similar trend wherein stem fraction showed higher total N content in Moringa (2.00 %), followed by Calliandra (1.80 %), Gliricidia (0.18), Agathi (1.50) and Mulberry (1.50) (Table 20).

Table 19. Potassium content of tree fodder banks in homesteads of varying size classes

Treatments	Potassium content (%)		
	Leaf	Stem	Total
Small homegarden			
Mulberry (T1)	0.18^{a}	1.86^{a}	1.02^{a}
Agathi (T2)	0.21^{b}	1.46^{b}	0.84^{b}
Moringa (T3)	0.19^{a}	1.99^{a}	1.09^{a}
Gliricidia (T4)	0.17^{a}	1.65^{ab}	0.91^{b}
Calliandra (T5)	0.10^{c}	1.74^{ab}	0.92^{b}
P value	0.000***	0.044**	0.000***
Medium homegarden			
Mulberry (T1)	0.15^{b}	1.34^{c}	0.75
Agathi (T2)	0.19^{a}	1.56^{bc}	0.87^{b}
Moringa (T3)	0.15^{b}	1.85^{ab}	1.08^{a}
Gliricidia (T4)	0.20^{a}	1.92^{a}	1.06^{a}
Calliandra (T5)	0.18^{a}	1.69^{ab}	0.94^{b}
P value	0.002**	0.007**	0.000***
Large homegarden			
Mulberry (T1)	0.18^{b}	1.30^{c}	0.73^{b}
Agathi (T2)	0.21^{a}	1.50^{bc}	0.86^{b}
Moringa (T3)	0.19^{b}	2.16^{a}	1.18^{a}
Gliricidia (T4)	0.17^{b}	1.70^{abc}	0.94^{b}
Calliandra (T5)	0.10^{c}	1.97^{ab}	1.04^{ab}
P value	0.001***	0.010**	0.001***

*** significant at $p<0.001$. ** significant at $p<0.01$, * significant at $p<0.05$, ns= not significant $p>0.05$, Values with the same superscripts in column do not differ significantly

Table 20. Comparative potassium content of tree fodder banks as influenced by homesteads of varying size classes and different fodder tree species

Treatments	Total K (%)		
	Leaf	Stem	Total
Fodder tree species			
Mulberry (T1)	0.07[b]	1.50[c]	0.79[b]
Agathi (T2)	0.08[a]	1.50[c]	0.79[b]
Moringa (T3)	0.07[b]	2.00[a]	1.04[a]
Gliricidia (T4)	0.07[b]	1.76[b]	0.92[ab]
Calliandra (T5)	0.03[c]	1.80[b]	0.92[ab]
P value	0.000***	0.000***	0.001***
Size of homesteads			
SHG	0.16[a]	1.74	0.95[a]
MHG	0.017[b]	1.67	0.84[b]
LHG	0.017[b]	1.73	0.87[b]
P value	0.000***	0.593[ns]	0.001***

*** significant at $p<0.001$. ** significant at $p<0.01$, * significant at $p<0.05$, ns= not significant $p>0.05$, Values with the same superscripts in column do not differ significantly

4.7. SOIL FERTILITY STATUS AS INFLUENCED BY FODDER TREE BANKS IN HOMESTEADS OF VARYING SIZE CLASSES

4.7.1. Organic carbon

Table 22 shows the soil organic carbon content in fodder tree plots and open contiguous area in small, medium and large homesteads. In SHG, all fodder tree plots had significantly higher soil organic carbon (SOC) content (0.85 – 1.05 %) than the open contiguous area (0.52 %). However SOC content showed no significant variation between different tree plots. A marginal increment was observed in Agathi and Moringa plots. Comparing different tree plots in MHG, SOC had a significant difference and was found higher in Mulberry (0.76 %), Gliricidia (0.75 %), Agathi (0.73 %) and the lowest SOC was observed in Moringa (0.52 %) and Calliandra (0.49 %) when compared to open contiguous plots (0.55 %). In LHG, all fodder tree plots had significantly lower soil organic carbon (SOC) content (0.17 – 0.32 %) than the open contiguous area (0.52 %).

Comparing various homesteads, SOC content was highest in SHG (0.88 %) followed by MHG (0.64 %) and LHG (0.32 %). Comparing fodder tree species, SOC content was higher in Agathi plot (0.70 %) and was on par with all other species except that of Calliandra (0.56 %) (Table 23).

4.7.2 Available nitrogen

Table 22 shows the available nitrogen content in fodder tree plots and open contiguous area in different size class of homestead. In SHG different fodder trees plots had significant difference on available nitrogen content. Higher soil N was found in Agathi-T2 (401.40 Kg ha^{-1}), followed by other fodder trees (271.79 Kg ha^{-1} – 334.50 Kg ha^{-1}) and it was higher compared to open contiguous area (217.79 Kg ha^{-1}). In MHG also, soil N content was significantly higher in tree plots (313.60 Kg ha^{-1} – 384.68 Kg ha^{-1}) compared to open contiguous plots (225.80 Kg ha^{-1}). Among trees higher values were observed in Agathi, Moringa and Calliandra plots. In LHG all fodder tree plots showed higher available N (296.87 Kg ha^{-1}- 359.59 Kg ha^{-1}) compared to open contiguous plot (234.87 Kg ha^{-1}).

Comparing different homesteads available N was higher in MHG (366.28 Kg ha^{-1}), followed by LHG (329.49 Kg ha^{-1}) and SHG (324.60 Kg ha^{-1}). Among fodder tree plots, highest N content was observed in Agathi (376.32 Kg ha^{-1}) and Moringa (352.63 Kg ha^{-1}) and the lowest value was observed in Mulberry and Calliandra (Table 23).

4.7.3 Available phosphorous

Table 22 shows the available P content in fodder tree plots and open contiguous area in different size classes of homegarden. In SHG, all fodder tree plots had significantly higher available P content (59.58 – 115.90 Kg ha^{-1}) than the open contiguous area (30.17 Kg ha^{-1}). Among tree plots Calliandra had the highest content and significantly superior to other species. Comparing different tree plots in MHG, available P had a significant difference and was found higher in Mulberry (116.40 Kg ha^{-1}), Gliricidia (113.88 Kg ha^{-1}), Calliandra (97.85 Kg ha^{-1}) and the lowest available P was observed in Agathi (61.42 Kg ha^{-1}) and Moringa (46.15 Kg ha^{-1}) when compared to open contiguous plots (65.00 Kg ha^{-1}). In LHG, all fodder tree plots had significantly higher available P content (54.90 – 114.85 Kg ha^{-1}) than the open contiguous area (30.10 Kg ha^{-1}).

Comparing different homesteads available P was higher in MHG (87.14 Kg ha^{-1}), followed by SHG (73.75 Kg ha^{-1}) and SHG (72.70 Kg ha^{-1}). Among fodder tree plots, higher P was in Calliandra (109.88 Kg ha^{-1}) followed by Mulberry (78.52 Kg ha^{-1}), Gliricidia (74.56 Kg ha^{-1}), and Agathi plots (71.87 Kg ha^{-1}) and the lowest value was observed in Moringa (56.22 Kg ha^{-1}) (Table 23).

4.7.4 Available potassium

Table 22 shows the available potassium content in fodder tree plots and open contiguous area in different size class of homesteads. No significant difference was observed on soil K content between various tree plots as well as open contiguous plots in all homesteads. Similarly, the soil K content in different homesteads were also statistically comparable, eventhough a marginal increment in K was observed in MHG (212.64 Kg ha^{-1}) compared to LHG (169.47 Kg ha^{-1}) and SHG (153.10 Kg ha^{-1}) (Table 23). However, comparing various tree plots (Table 23) soil K content was higher in Mulberry (189.89 Kg ha^{-1}), Calliandra (184.17 Kg ha^{-1}) and Agathi (181.50 Kg ha^{-1}) but lower in Moringa (150.78 Kg ha^{-1}) and Gliricidia plots (163.17 Kg ha^{-1}).

Table 21. Soil fertility and nutrient status of fodder tree banks in homesteads of varying size classes

Treatments	Organic carbon content (%)	Available N (Kg ha^{-1})	Available P (Kg ha^{-1})	Available K (Kg ha^{-1})
Small homegarden				
Mulberry (T1)	0.85^{a}	321.96^{b}	59.58^{bc}	151.50
Agathi (T2)	1.05a	401.40^{a}	77.10^{b}	173.17
Moringa (T3)	1.05^{a}	334.50^{b}	61.25^{bc}	156.17
Gliricidia (T4)	0.99^{a}	317.78^{b}	54.90^{c}	126.33
Calliandra (T5)	0.90^{a}	271.79^{bc}	115.90^{a}	171.50
Open contiguous plot (T6)	0.52^{b}	217.79^{c}	30.17^{d}	139.92
P value	0.001***	0.001***	0.000***	0.872^{ns}
Medium homegarden				
Mulberry (T1)	0.76^{a}	313.60^{d}	116.40^{a}	172.00
Agathi (T2)	0.73^{ab}	384.68^{a}	61.42^{bc}	231.67
Moringa (T3)	0.52^{c}	380.50^{b}	46.15^{c}	172.00
Gliricidia (T4)	0.75^{ab}	359.60^{c}	113.88^{a}	193.83
Calliandra (T5)	0.49^{c}	384.68^{a}	97.85^{ab}	182.67
Open plot (T6)	0.55^{bc}	225.80^{e}	65.00^{bc}	237.17
P value	0.001***	0.000***	0.005**	0.513^{ns}
Large homegarden				
Mulberry (T1)	0.37^{b}	313.60^{ab}	59.58^{bc}	159.67
Agathi (T2)	0.32^{b}	334.51^{a}	77.10^{c}	139.67
Moringa (T3)	0.26^{b}	342.87^{ab}	61.25^{bc}	124.17
Gliricidia (T4)	0.17^{b}	359.59^{a}	54.90^{c}	169.33
Calliandra (T5)	0.28^{b}	296.87^{ab}	115.90^{a}	198.33
Open plot (T6)	0.52^{a}	234.87^{b}	30.17^{d}	225.67
P value	0.001***	0.000***	0.000***	0.174^{ns}

*** significant at $p<0.001$. ** significant at $p<0.01$, * significant at $p<0.05$, ns= not significant $p>0.05$, Values with the same superscripts in column do not differ significantly

Table 22. Comparative soil fertility and nutrient status as influenced by varying size of homestead and different fodder tree species

Treatments	Organic Carbon content (%)	Available N ($Kg\ ha^{-1}$)	Available P ($Kg\ ha^{-1}$)	Available K ($Kg\ ha^{-1}$)
Fodder tree species				
Mulberry (T1)	0.67^{ab}	316.39^{c}	78.52^{b}	189.89^{a}
Agathi (T2)	0.70^{a}	376.32^{a}	71.87^{b}	181.50^{a}
Moringa (T3)	0.58^{ab}	352.63^{ab}	56.22^{c}	150.78^{b}
Gliricidia (T4)	0.64^{ab}	345.66^{b}	74.56^{b}	163.17^{b}
Calliandra (T5)	0.56^{b}	317.78^{c}	109.88^{a}	184.17^{a}
P value	0.001***	0.000***	0.000***	0.003**
Size of homestead				
SHG	0.95^{a}	329.49^{b}	73.75^{a}	153.10
MHG	0.65^{b}	366.28^{a}	87.14^{a}	212.64
LHG	0.28^{d}	324.60^{b}	73.70^{a}	169.47
Open contiguous (T6)	0.53^{c}	225.79^{c}	41.78^{b}	200.92
P value	0.000***	0.001***	0.001***	0.361^{ns}

*** significant at $p<0.001$. ** Significant at $p<0.01$, * significant at $p<0.05$, ns= not significant $p>0.05$, Values with the same superscripts in column do not differ significantly

4.8 MEAN DAILY-INTEGRATED VALUES OF PHOTOSYNTHETICALLY ACTIVE RADIATION (PAR) ABOVE AND BELOW THE CANOPIES OF HOMESTEADS OF VARYING SIZE CLASSES

Diurnal variations in understorey Photosynthetically Active Radiation (PAR) in small, medium and large scale homesteads were distinct (Table 24). In SHG, photosynthetic photon flux density (PPFD) above the canopy ranged from 320 µmoles $m^{-2}s^{-1}$(8 am) to 1670 µmoles $m^{-2}s^{-1}$(1-2 pm), and below the canopy ranged from 120 to 1001 µmoles $m^{-2}s^{-1}$. The understorey PAR transmittance ranged from 38 to 60 % during the above period.

In MHG, photosynthetic photon flux density (PPFD) above the canopy ranged from 245 µmoles $m^{-2}s^{-1}$(8 am) to 1617 µmoles $m^{-2}s^{-1}$(1-2 pm), and below the canopy ranged from 95 to 1037 µmoles $m^{-2}s^{-1}$. The understorey PAR transmittance ranged from 39 to 64 % during the above period.

In LHG, photosynthetic photon flux density (PPFD) above the canopy ranged from 315 µmoles $m^{-2}s^{-1}$(8 am) to 1675 µmoles $m^{-2}s^{-1}$(1-2 pm), and below the canopy ranged from 115 to 1058 µmoles $m^{-2}s^{-1}$. The understorey PAR transmittance ranged from 37 to 63 % during the above period.

No significant difference was observed in the PAR transmittance in different homesteads as well as in different tree plots. PAR transmittance ranged from 50.10 to 52.75 % in various homesteads. Comparing tree plots a marginal reduction in transmittance was observed in Mulberry (45.50 %) when compared to other species (Table 25).

Table 23. Mean daily-integrated values of photosynthetically active radiation (PAR) above and below the canopies of homesteads of varying size classes in Arimboor panchayath

Time (Hours)	SHG			MHG			LHG		
	I_1 (µmoles $m^{-2}s^{-1}$)	I_2 (µmoles $m^{-2}s^{-1}$)	PAR Transmittance (%)	I_1 (µmoles $m^{-2}s^{-1}$)	I_2 (µmoles $m^{-2}s^{-1}$)	PAR Transmittance (%)	I_1 (µmoles $m^{-2}s^{-1}$)	I_2 (µmoles $m^{-2}s^{-1}$)	PAR Transmittance (%)
08:00:00	320	120	38	245	95	39	315	115	37
09:00:00	415	171	41	315	133	42	425	173	41
10:00:00	590	251	43	357	182	51	849	351	41
11:00:00	955	531	56	615	321	52	1205	738	61
12:00:00	1595	960	60	1518	744	49	1612	959	59
13:00:00	1670	1001	60	1617	1037	64	1675	1058	63
14:00:00	1560	966	62	1635	1192	73	1563	1163	74
15:00:00	1430	923	65	1372	779	57	1435	1012	71
16:00:00	1166	383	33	1135	327	29	1165	400	34
17:00:00	852	272	32	165	92	56	865	251	29

I_1: above canopy PAR value, I_2: below canopy PAR value

Table 24. PAR transmittance in homesteads of varying size classes and in different fodder tree plots

Fodder tree species	PAR Transmittance %
Mulberry (T1)	45.50
Agathi (T2)	49.67
Moringa (T3)	58.57
Gliricidia (T4)	54.58
Calliandra (T5)	50.83
P value	0.065^{ns}
Size of homestead	
SHG	50.10
MHG	52.65
LHG	52.75
P value	0.696^{ns}

*** significant at p<0.001. ** significant at p<0.01, * significant at p<0.05, ns= not significant p>0.05, Values with the same superscripts in column do not differ significantly

4.9 Economics

Economics and B: C ratio for cultivation of various fodder trees in different homesteads are given in Table 26 and 27. In general the B: C ratio for Gliricidia cultivation was found to be significantly higher (1.28) than all other species (Table 27). All other species had B: C ratio less than 1. Calliandra had a B: C ratio (0.80) followed by Agathi (0.69), Moringa (0.47) and Mulberry (0.3). Comparing homegardens the cost of production was higher in MHG (1, 71,151 ₹/ ha^{-1} yr^{-1}) followed by LHG and SHG. Whereas B: C ratio was found no significant difference between three homegardens. A slightly higher value was observed in SHG (0.79).

Table. 25 Economics of fodder production in different homesteads

Treatments	Total cost of fodder production (₹ ha^{-1} yr^{-1})	Net returns (₹ ha^{-1} yr^{-1})	B: C ratio
Small homegarden			
Mulberry (T1)	1,56,313	55,141	0.35
Agathi (T2)	1,56,313	1,50,215	0.96
Moringa (T3)	1,56,313	78,403	0.50
Gliricidia (T4)	1,56,313	1,98,661	1.27
Calliandra (T5)	1,56,313	1,03,712	0.67
P value		0.000***	0.000***
Medium homegarden			
Mulberry (T1)	17,1151	61,31	0.36
Agathi (T2)	17,1151	97,813	0.57
Moringa (T3)	17,1151	66,930	0.39
Gliricidia (T4)	17,1151	2,14,562	1.26
Calliandra (T5)	17,1151	1,68,654	0.99
P value		0.000***	0.000***
Large homegarden			
Mulberry (T1)	1,69,785	48,542	0.29
Agathi (T2)	1,69,785	93,358	0.55
Moringa (T3)	1,69,785	89,489	0.53
Gliricidia (T4)	1,69,785	2,21,673	1.31
Calliandra (T5)	1,69,785	1,24,910	0.74
P value		0.001***	0.001***

*** significant at $p<0.001$. ** significant at $p<0.01$, * significant at $p<0.05$,

ns= not significant $p>0.05$, Values with the same superscripts in column do not differ significantly

Table 26. Economics of fodder production in homesteads of varying size classes and in different fodder tree species.

Treatments	Total cost of Fodder production (₹ ha^{-1} yr^{-1})	Returns from fodder (₹ ha^{-1} yr^{-1})	B : C ratio
Fodder tree species			
Mulberry (T1)	1,65,750	54,998	0.33
Agathi (T2)	1,65,750	1,13,796	0.69
Moringa (T3)	1,65,750	78,274	0.47
Gliricidia (T4)	1,65,750	2,11,632	1.28
Calliandra (T5)	1,65,750	1,32,425	0.80
P value			0.000^{***}
Size of homestead			
SHG	1,56313	1,17,226	0.79
MHG	1,71,151	1,21,854	0.71
LHG	1,69,785	1,,15594	0.68
P value			0.508^{ns}

*** significant at p<0.001. ** significant at p<0.01, * significant at p<0.05, ns= not significant p>0.05, values with the same superscripts in column do not differ significantly

DISCUSSION

5. Discussion

A one-year long field study has been undertaken to assess the forage yield and nutritive value of selected fodder tree species under hedgerow planting in selected midland homegardens of Central Kerala. The study also evaluated the short-term changes in soil nutrient status of selected homegardens with tree fodder integration and the salient results are discussed below.

5.1 PLANT HEIGHT AND COPPICE PARAMETERS OF TREE FODDER BANKS AT THE STAGE OF INITIAL CUT IN SMALL, MEDIUM AND LARGE SCALE HOMEGARDENS

5.1.1. Plant Height

The data given in Table 1 and 2 indicated the significant difference in plant height of different fodder trees in homegardens. In general Agathi was found to be significantly taller (1.72m) than all other tree species (Table 2).This could be due to its species character as Agathi have extremely rapid growth in the first year and grows fast enough to be used as an annual green manure crop (Duke, 1983). Its rapid early growth and erect habit usually enables *Sesbania grandiflora* to access sunlight by overtopping neighboring plants (Gutteridge and Shelton, 1994). In addition, studies on sesbania spacing and population density indicated increased height at high densities (Dutt and Pathania, 1986; Zsuffa, 1984). Karmakar *et al.,* (2016) reported that, in fertile sites, Agathi will attain a height of 5-6m in nine months. The next taller species was found to be Calliandra (1.43m). Earlier study indicate that Calliandra seedlings grow quickly up to 2.5-3.5 m in 180 days and up to 3-5 m within the first year (Sebuliba *et al.*, 2012). Mulberry, Moringa and Gliricidia were found to be comparatively shorter. Slow growth of Mulberry in the initial year of planting was reported by Raj *et al.,* (2016). Lower height of Moringa may be due to shaded conditions as Moringa grows well with more sunlight. Lower plant height of Gliricidia could be attributed to its branching nature (Nygren and Cruz, 1998).

Comparing plant height in different homesteads, LHG and MHG showed significantly higher plant growth when compared to SHG (Table 2). This could be due to better light availability in LHG and MHG when compared to SHG. Light is critical for survival, growth and reproduction of individuals in dense stands. Plants that could not receive sufficient light show retarded growth (Weiner *et al.*, 1990). Moreover floristic abundance was higher in SHG which might have restricted the intercrop growth in SHG.

5.1.2. Coppice Parameters

Coppice parameters like number, length and weight of coppices varied significantly in different fodder tree species (Table 1 and 2). In general, Gliricidia (3.08) and Agathi (3.00) showed better coppicing and was on par with Calliandra (2.67). Mulberry showed medium coppicing whereas coppice number was significantly lower in Moringa (Table 2). Gliricidia is able to produce profuse branching and fresh growth after every cutting (Nygren and Cruz, 1998). Similar to coppice number, coppice length was also higher in Agathi (91.87 cm) and Gliricidia (80.48 cm) compared to other tree species (50.93 to 70.25 cm). Coppice length was least in Mulberry (50.93 cm) whereas other species showed intermediate length. Coppice weight also showed significant difference between tree species. Weight of coppices was significantly highest for Gliricidia-T4 (274.04 g pl^{-1}) followed by Agathi (193.58 g pl^{-1}) and Calliandra (130.53 g pl^{-1}). Moringa (107.76 g pl^{-1}) showed intermediate value whereas Mulberry (81.73 g pl^{-1}) had the least coppice weight (Table 2). In general coppice parameters were better for Gliricidia followed by Agathi and Calliandra, whereas Mulberry and Moringa showed poor performance. Waddington (2003) reported that species such as Gliricidia have good coppicing ability and produce large amounts of high quality biomass. Young plants respond well to the first time they are coppiced, but tend to coppice less well with repeated cuttings. (Latt *et al.,2000).* Agathi species also have excellent coppice producing capacity and coppiced stands of sesbania exhibited better sprouting, greater height increment and canopy spread at 25,000 plants/ha than at 50,000 or 75,000 plants/ha (Desai and Halepyati, 2010).

Coppice number did not show any significant variation in different size class of homesteads.

Comparing coppice parameters of fodder trees in different size class of homesteads, significant difference was noticed only in coppice weight. Coppice weight of trees in homesteads was higher in LHG than other farms. This could be due to better availability of light in LHG.

5.2 SURVIVAL PERCENTAGE OF FODDER TREE SPECIES IN HOMEGARDENS OF VARYING SIZE CLASSES

Survival count of the trees were taken one year after planting and significant variation was noticed among tree species (Table 3 and 4). Among the fodder tree species, survival percentage was significantly higher in Mulberry (80.06 %) and Calliandra (71.13 %), followed by Gliricidia (44.35 %), whereas survival was drastically lower for Agathi (31.55 %) and Moringa (31.55 %) (Table 4). Raj *et al.*, (2016) also reported better establishment and survival of Mulberry fodder banks in coconut garden. 100 per cent survival was obtained even after frequent harvesting during initial year of planting. Similarly better establishment, growth and survival (98 %) of Calliandra was reported even with repeated pruning in the initial year of planting (Sagaran, 2017). Yamoah *et al.,* (1987) reported that survival of Gliricidia declined with time in all the establishment methods used and was closely related to the occurrence of rainfall, especially in the case of 0.5 m cuttings. The use of longer 1.2 m cuttings gave significantly higher survival rates during the dry season and appeared to be the best method of establishment when rainfall is erratic. Karmakar *et al.,* (2016) reported that in Agathi harvesting leaves for fodder must be done selectively, to avoid complete defoliation, and cannot be done more than a few times per year. More intensive harvesting, such as managing as a hedgerow, reduces the life of the tree.

Cutting at 1 m high five times a year can result in tree mortality. This could be the reason for severe mortality of Agathi in our fields which were harvested five times in a year.

Comparing different homegardens, survival percentage was higher for SHG (59.47 %) and MHG (54.46 %) followed by LHG (41.07 %). A portion of LHG got flooded during the previous rainy season and there were severe casualities in tree species such as Moringa, Agathi and Gliricidia. Moringa is a drought tolerant plant that can be grown in diverse soils, except those that are waterlogged. Slightly alkaline clay and sandy loam soils are considered the best media for this species due to their good drainage (Ramchandran *et al.* 1980; Abdul, 2007. Mulberry and Calliandra also suffered mortality to some extent. There were also causalities due to the falling of coconut fronds in LHG that destroyed the young seedlings in the homegarden. This could be the reason for low survival rate of trees at the end of the year. Inspite of that, good management practices like application of slurry irrigation followed by the farmer in SHG helped in better establishment and survival of seedlings in that field. In addition, some fodder trees like Mulberry and Calliandra are more favoured to grow under shady conditions and showed high survival in SHG which had comparatively more shade than other fields.

5.3 ANNUAL GREEN AND DRY FODDER YIELD OF TREE FODDER BANKS IN HOMEGARDENS OF VARYING SIZE CLASSES

The annual fractional (leaf and stem) and total fresh fodder biomass of tree fodder banks in homegardens of varying size classes is shown in Table 3 and Table 4. Comparitive analysis of the yield outputs of different tree species (Table 4 and Fig. 4) in general indicated that, Gliricidia (24.27 Mg ha^{-1}) yielded significantly higher forage yield in all the systems followed by Calliandra (16.38 Mg ha^{-1}). Next best tree species was Agathi (13.59 Mg ha^{-1}) whose yield was on par with that of Calliandra. Moringa and Mulberry produced significantly lower yields. Yield from leaf and stem fractions also showed similar trend (Table 4). Higher yields from Gliricidia could be attributed to its faster growth, profused branching and higher biomass production in short period of time. Due to its high biomass production Gliricidia is already a popular component as green manure and fodder crop in almost all the homesteads of Kerala (KAU, 2016). Gunasekaran *et al.,* (2017) reported higher edible fresh fodder biomass yield from *Gliricidia sepium* (4 harvests/year) from silvipasture model in degraded wastelands. Similarly better establishment, faster growth and higher yield outputs from Calliandra as an intercrop in coconut gardens of Kerala has been reported in the initial year of planting (Sagaran, 2017). An annual yield of 42 Mg/ha of coconut garden has been obtained from Calliandra plantation spaced 60x60 cm and from four harvests scheduled at three months interval. In Java homegarden, Agathi produced 55 t/ha of green material in 6.5 months (Gutteridge and Shelton, 1994). However, poor yields of Mulberry could be attributed to its slow growing nature in the initial year of establishment. Raj *et al.,* (2016) reported comparatively lower yield in Mulberry during the initial year of planting than the subsequent years. Poor performance of Moringa in the homegarden could be attributed to its poor shade tolerance and its low survival under competitive environment and ill-drained conditions. Moringa is a drought tolerant plant that can be grown in diverse soils, except those that are waterlogged. Slightly alkaline clay and sandy loam soils are considered the best media for this species due to their good drainage (Ramchandran *et al.* 1980; Abdul 2007). *Moringa oleifera* does not grow properly under waterlogged conditions as its roots get rotten. It can perform better under marginal conditions with ample nutritional quality. Moringa can be harvested for foliage in less than 2.5 months after transplanting. Optimal cutting intervals range from 15 to 75 days, depending on local conditions. Fodder yields are variable and may range from 27 to 120 t/ha fresh weight at the first cutting. Up to 9 cuttings/year can be achieved (Sultana *et al.*, 2014). Highest growth and forage yield are obtained under warm, dry conditions, with some supplementary fertilizer and irrigation (Radovich, 2009).

Comparing different homegardens, fodder yield was significantly higher in MHG (15.23 Mg ha^{-1}) followed by LHG (13.15 Mg ha^{-1}) and SHG (12.07 Mg ha^{-1}). In MHG, tree abundance was comparatively lower than other homegarden and an area of 8254 sq.m was available for planting fodder trees in 1 hectare of homegarden. Whereas the corresponding areas were 8198 sq.m for LHG and 7645 sq.m for SHG. Yield from LHG was around 16 per cent lower than MHG even though there was only marginal difference in area available for fodder cultivation in both the fields. This could be attributed to lower population of trees in LHG due to flood damage. In SHG the performance of fodder trees were better but the availability of understorey area for tree integration was comparatively less when extrapolated to hectare basis

The annual dry fodder biomass of tree fodder banks in homegardens of varying size classes is shown in Table 7 and Table 8. In general, Calliandra-T5 (4.60 Mg ha^{-1}) yielded more dry forage yield followed by Gliricidia (4.39 Mg ha^{-1}), Agathi (2.44 Mg ha^{-1}) and Mulberry (1.95 Mg ha^{-1}) (Fig. 6). Even though Gliricidia had higher fresh fodder yield, dry forage yield was highest for Calliandra which could be attributed to its higher dry matter (DM) content (30.40 %) than that of Gliricidia (18.06 %) (Table 16). Higher DM content in Calliandra (30-33%) has also been reported by other workers (Sagaran, 2017; Jayaprakash *et al., 2016).* Agathi had almost double fresh fodder yield than Mulberry but there was not much difference in dry forage yield which could be due to high DM content in Mulberry (28.73 %) compared to Agathi (18.04 %) (Table 16 and Fig. 12). Dry forage yield was significantly lower in Moringa (1.34 Mg ha^{-1}) when compared to all other species. Moringa had lower biomass production and less DM content in fodder which resulted in lowest fodder yield.

Comparing different homegardens, MHG produced the highest dry fodder yield (3.72 Mg ha^{-1}) following the same trend of fresh fodder yield. However dry yields from SHG and LHG were significantly lower and on par with each other. Higher fresh fodder yield coupled with higher DM content in fodder might have resulted in high dry forage yields from MHG.

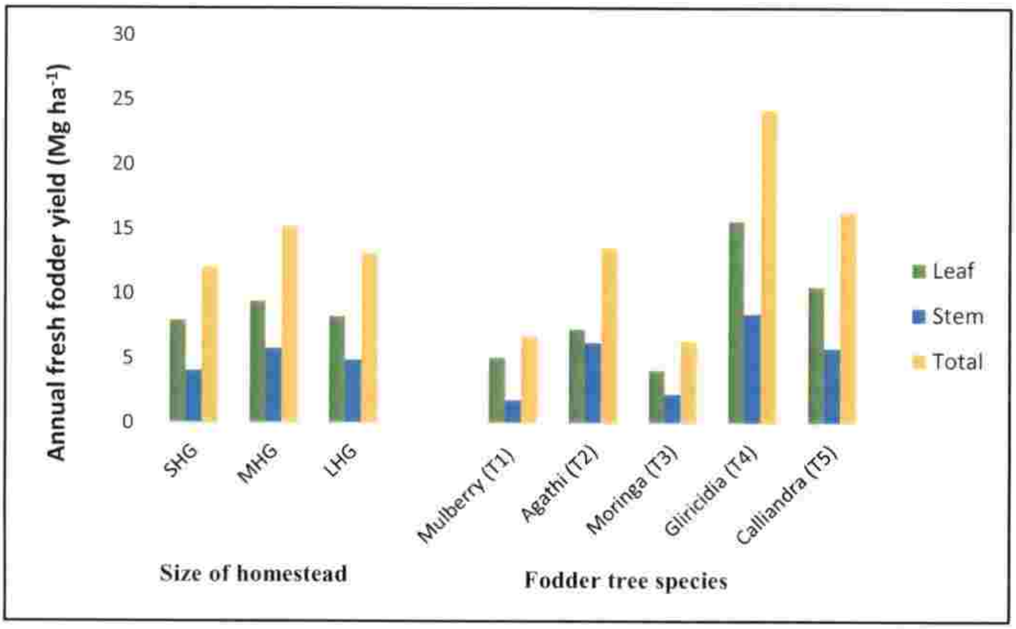

Fig 5. Comparative annual green fodder yield and survival count as influenced by varying size of homestead and different fodder tree species

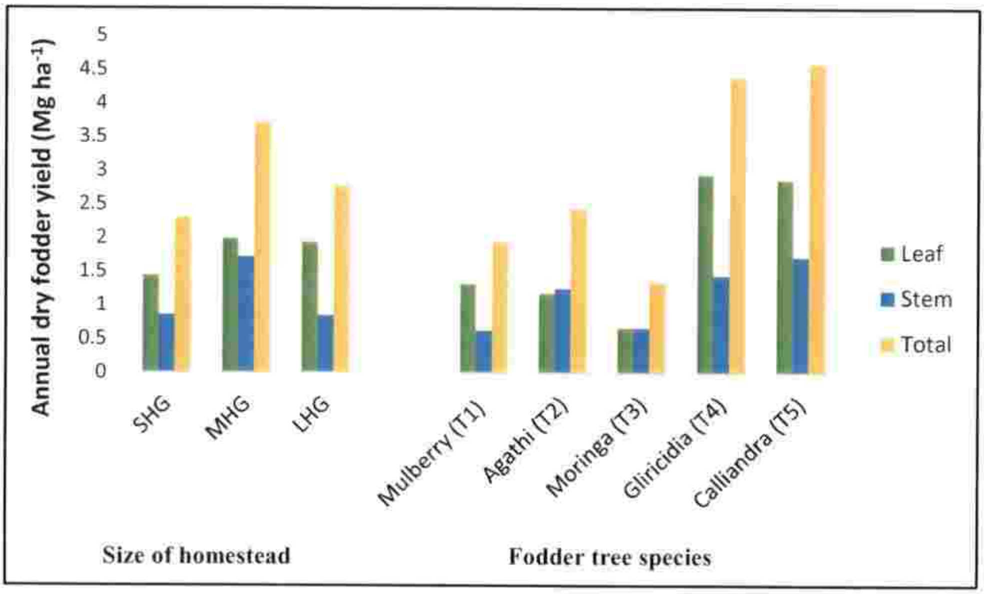

Fig 6. Comparative annual dry fodder yield as influenced by varying size of homestead and different fodder tree species

5.4 SEASONAL GREEN AND DRY FODDER YIELD OF TREE FODDER BANKS IN HOMESTEADS OF VARYING SIZE CLASSES

The seasonal green fodder yield of tree fodder banks in homesteads of varying size classes, during the rainy period (June-November) and the summer period (December- May) are represented in Table 5 and Table 6. In general, seasonal fodder yield was more in rainy period than summer period. Similiar trend was also observed in dry forage yields. Pereira *et al.* (2005) have reported a strong seasonality in fodder plants, with a significant reduction in the supply of forage during the dry season. Comparing different fodder tree species, yield was higher in Gliricidia followed by Calliandra and Agathi during both the seasons (Table 6). *Gliricidia sepium* shows relatively little growth variation due to climatic differences throughout the year and between years.

Comparing seasonal green fodder yield in different homegardens, yield was more in LHG (9.96 Mg ha^{-1}) and MHG (9.27 Mg ha^{-1}), followed by SHG (7.02 Mg ha^{-}

^{1}) during the rainy period, but during the summer period yield was more in MHG (5.08 Mg ha^{-1}) and SHG (4.96 Mg ha^{-1}) followed by LHG (3.87 Mg ha^{-1}). Similar pattern was seen in dry fodder yield also, wherein 58-72% of fodder was produced during rainy season. During summer period only 27.83 % of dry fodder was produced in LHG. During the peak rainy season at the end of August a portion of LHG got flooded and some of the seedlings especially that of Moringa and Agathi were destroyed. Some seedlings showed stunted growth and defoliation. Apart from that there was severe water scarcity in that particular field during the following summer period that drastically affected the yield. The soil organic carbon content was also found to be very poor (0.28 %) in that field which might have affected the water holding capacity of the soil. Unlike the other fields the LHG soil appeared very dry and powdery after the flood occurrence. Other findings support the results of this study; for example, drought or low rainfall conditions resulted in stunted regrowth and reduced total aboveground dry matter yield, whereas dry matter productivity was greater during the rainy season (Nouman *et al.*, 2014).In SHG and MHG soil health was comparatively higher as indicated by high carbon content. The field was also less disturbed during rainy season and soil appeared to be less dry during summer season which promoted the satisfactory growth of trees.

5.5 LEAF- STEM RATIO OF FODDER TREE SPECIES IN HOMEGARDENS OF VARYING SIZE CLASSES

Fodder tree species showed significant variation on the leaf-stem ratio (Table 7 and 8). In general, higher leaf-stem ratio was observed in Mulberry-T1 (2.09) and Gliricidia-T4 (2.05) followed by Calliandra-T5 (1.67). Agathi-T2 (0.94) and Moringa-T3 (1.0) (Table 8 and Fig. 7). Wong (1986) reported that Gliricidia produced the highest leaf-stem ratio followed by leucaena and cassava. Similarly, higher leaf-stem ratio was reported by Raj *et al.*, (2016) in Mulberry and Sagaran (2017) in Calliandra.

Comparing leaf-stem ratio in varying size class of homestead (Table 8), it showed significantly higher value in LHG (2.28) and SHG (1.67) followed by MHG

(1.16). Higher leaf -stem ratio in LHG could be due to the fact that, around 77% of fodder yields in LHG was obtained from Gliricidia, Calliandra and Mulberry which had comparatively higher leaf-stem ratios. Due to waterlogging during the rainy period there were causalities in Moringa and Agathi resulting in lower forage yields from these species. Moringa and Agathi had lower leaf -stem ratios as indicated in Table 8.

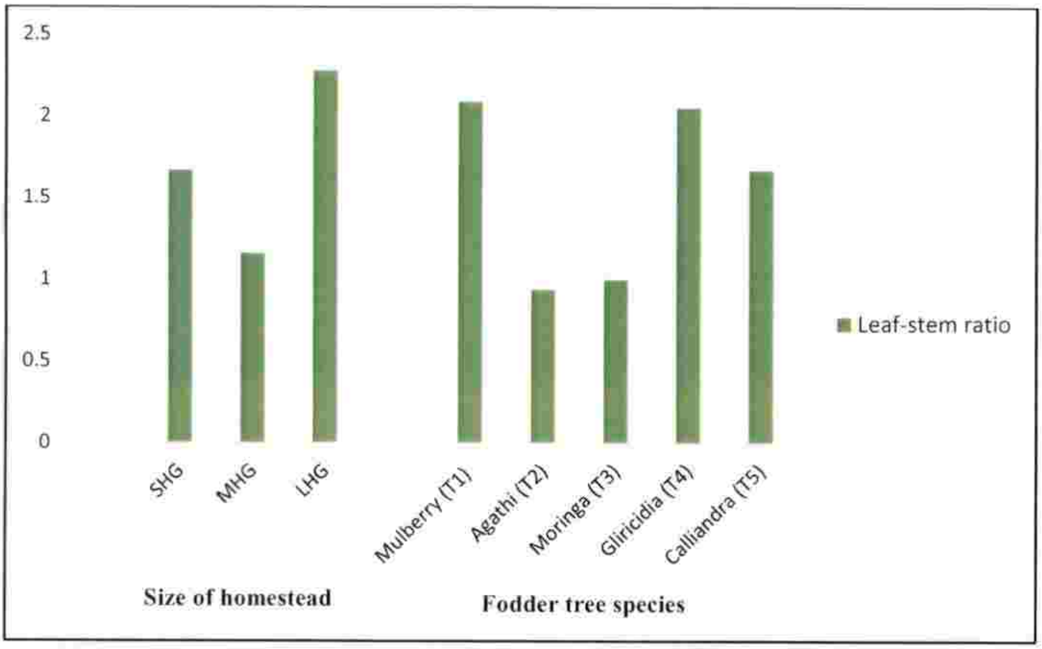

Fig 7. Comparative leaf-stem ratio of tree fodder banks as influenced by homesteads of varying size classes and different fodder tree species

5.6 Crude protein content and yield

Fodder tree species showed significant variation on CP content and yield in the fodder biomass (Table 11 and 12). In general, foliage fraction had higher crude protein levels than the stem fraction for all tree species. Comparing tree species, Calliandra (22.57 %) and Gliricidia (19.99 %) fodder had more CP content followed by Mulberry (16.74%). Raj *et al.,* (2016) reported pruning frequencies had profound influence on nutritive value of the forage. Harvesting at shortest pruning interval of 8 weeks yielded fodder with maximum CP content from Mulberry (28.87 % leaf; 8.06 % stem). A study conducted by Jayal and Kehar (1962) reported that on dry basis, Mulberry leaves contained an average of 20-23% crude protein. Islam *et al.* (1995) reported that the young shoots of fodder trees contain high crude protein than matured ones. Sagaran (2017) reported 18.10 per cent crude protein (CP) content in Calliandra fodder when harvested at an interval of two months. Agathi (14.81%) and Moringa (14.06%) were significantly lower in CP content when compared to all other species. Even though Agathi and Moringa had higher protein content in their leaves (27.42 and 28.76% respectively), the CP content in total fodder declined due to their lower leaf-stem ratios and higher stem content in the fodder which had poor protein value. Karmakar *et al.,* (2016) also reported 25-30 per cent crude protein in Agathi leaves. Nouman *et al.* (2013) reported 15.31 per cent crude protein content in Moringa.

Comparing different homegardens (Table 12 and Fig. 8), CP content was significantly higher in case of SHG (20.01 %), followed by MHG (16.96 %) and LHG (15.94 %) which were on par. SHG was shadier as indicated by its PAR availability when compared to other fields. Previous studies indicate that crude protein of the fodder grasses generally increases with increasing shade (Wilson, 1996; Parassi and Koukoura, 2009). Lin *et al.* (2001) also reported a linear relationship between crude protein content and increasing shade levels.

Comparing different homegardens, CP yield was significantly higher in case of MHG (0.63 Mg ha^{-1}) followed by and SHG (0.46 Mg ha^{-1}) and LHG (0.44 Mg ha^{-1}). Comparing tree species, Calliandra (1.04 Mg ha^{-1}) and Gliricidia (0.88 Mg ha^{-1}) yielded more CP yield followed by Agathi (0.36 Mg ha^{-1}) and Mulberry (0.33 Mg ha^{-1}). Moringa (0.19 Mg ha^{-1}) was significantly lower in CP yield when compared to all other species. In case of leaf and stem yields CP yield followed the similar trend (Table 12). Higher forage yields with high leaf-stem ratio along with higher CP concentration in the fodder resulted in higher CP yield from Calliandra and Gliricidia compared to other tree species. Sagaran (2017) also reported CP yields of 1.41 Mg from Calliandra fodder banks intercropped in one hectare of coconut garden during the initial year of planting.

Comparing different homegardens, CP yield was significantly higher in case of MHG (0.63 Mg ha $^{-1}$) followed by SHG (0.46 Mg ha $^{-1}$) and LHG (0.44 Mg ha $^{-1}$) (Table 12 and Fig. 9). Even though the CP content of fodder was higher in SHG, the CP yield was highest from MHG which could be due to higher fodder yields from MHG when compared to SHG.

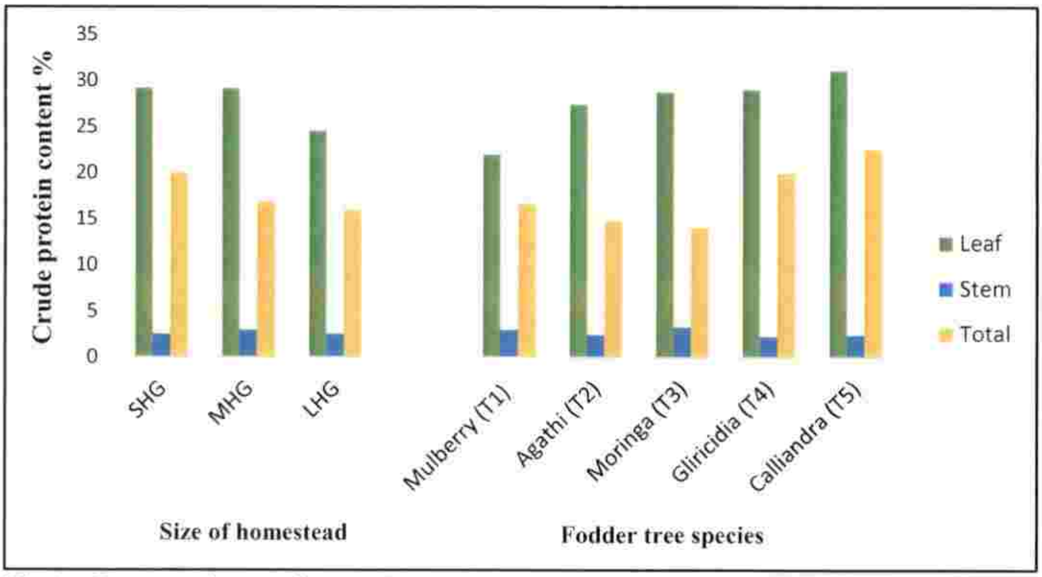

Fig 8. Comparative crude protein content and crude protein yield of tree fodder banks as influenced by homesteads of varying size classes and different fodder trees

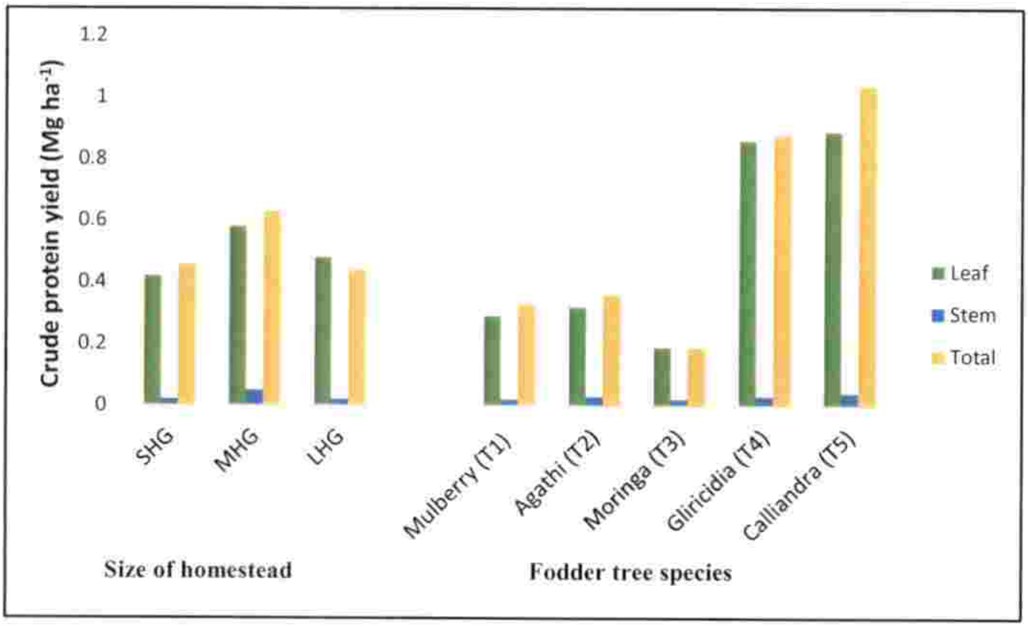

Fig 9. Comparative crude protein yield of tree fodder banks as influenced by homesteads of varying size classes and different fodder tree species

5.7 Crude fibre content of tree fodder banks in homesteads of varying size classes

Fodder tree species showed significant variation on CF content in the fodder biomass (Table 13 and 14). In general, stem fraction had higher crude fibre levels (44.61 – 59.94 %) than the foliage fraction (14.82-18.79 %) for all tree species. The CF content in total fodder varied from 23.72- 38.42%. Comparing tree species, Agathi (38.42 %) and Moringa (38.12 %) fodder contained more CF content followed by Calliandra (26.74 %) and Mulberry (27.39 %). Gliricidia (23.72%) was significantly lower in CF content when compared to all other species. The above results are in conformity with the findings of Oduro *et al.* (2008) in Moringa, Raj *et al.*, (2016) in Mulberry and Sagaran (2017) in Calliandra. Higher CF content in Agathi and Moringa fodder is due to higher stem fraction in the fodder as indicated by their low leaf-stem ratio (Table 8) coupled with high fibre content in the stem fraction. Gunasekaran *et al.*, (2017) had reported 19.24 per cent CF in Gliricidia.

Comparing different homegardens, CF content was significantly lower in SHG (27.77 %) followed by LHG (30.03 %) and MHG (34.83 %) (Table 14 and Fig. 10). This could be due to the shadier situation in SHG as indicated by its lower PAR levels. The reduced PAR delays the plant maturity, thereby reducing the fibre content in fodder (Pierson *et al*., 1990).

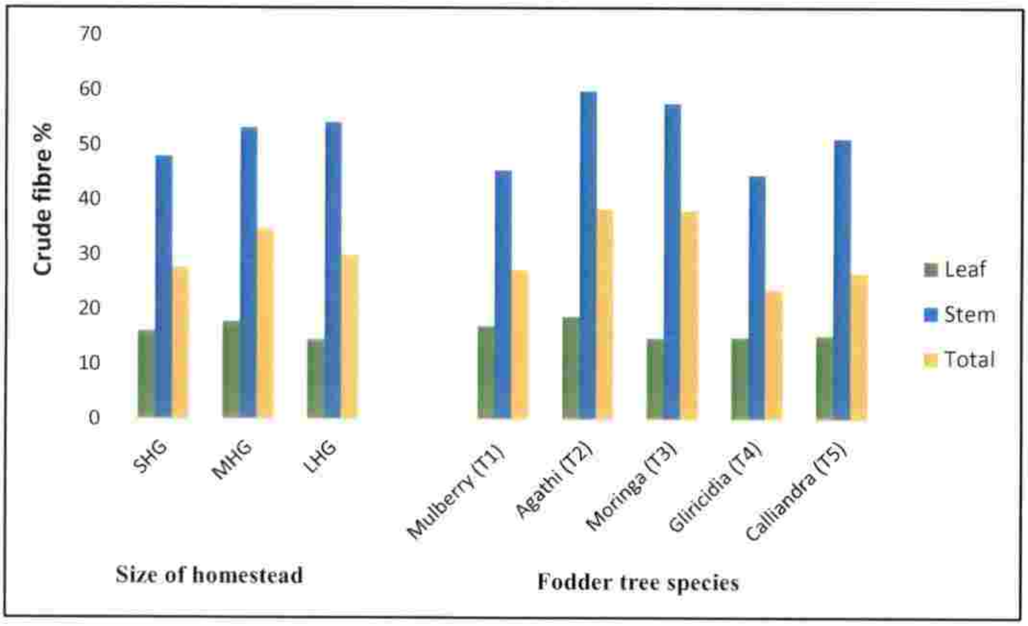

Fig 10. Comparative crude fibre content of tree fodder banks in homesteads of varying size classes and different fodder tree species

5.8 ASH CONTENT AND TOTAL DRY MATTER CONTENT OF TREE FODDER BANKS IN HOMESTEADS OF VARYING SIZE CLASSES

5.8.1 Ash content

Fodder tree species showed significant variation in ash content in the fodder biomass (Table 15 and 16). Ash content was higher in foliage fraction than stem fraction for all the tree species. In general, Mulberry (7.93 %), Moringa (7.61 %) and Agathi (7.12 %) showed higher ash content followed by Gliricidia (6.93%) and the lowest ash content was observed in Calliandra (4.37%) (Fig. 11).Raj *et al.*, (2016) reported higher ash content in Mulberry leaf (9.97%). Mahima *et al.*, (2014) also reported 9.15% ash content in Moringa. Karmakar *et al.*, (2016) reported an ash content of 6 % in Agathi. Sagaran (2017) observed lower ash content of 3.30 per cent in Calliandra. Gunasekaran *et al.*, (2017) reported 8.96 per cent ash content in Gliricidia. Comparing different homegardens, marginal variation has been observed in ash content in different homegardens, the reason for which is not clearly understood.

5.8.2 Dry matter content

Dry matter content of fodder varied significantly in different tree species. (Table 15 and 16). In general Calliandra (30.40 %) and Mulberry (28.73 %) showed higher DM content followed by Moringa (21.79%) and the lowest DM content was observed in Gliricidia (18.06 %) and Agathi (18.04 %) (Fig. 12). Higher DM content in Mulberry and Calliandra was reported by Raj *et al.*, (2016), Sagaran (2017) and Jayaprakash *et al.* (2016) .The average dry matter of Gliricidia is reported to be 25.3 per cent (Heuze *et al.*, 2015). The average dry matter of Moringa is found to be 26.2 per cent (Asaolou *et al.*, 2012). No significant difference in DM content of fodder biomass was observed between different homegardens.

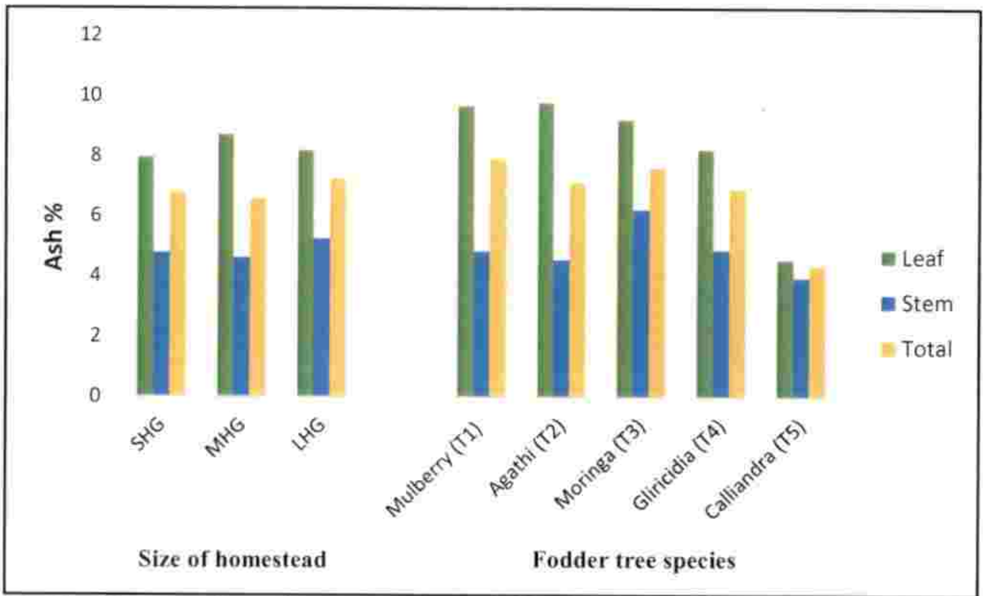

Fig 11. Comparative ash content of tree fodder banks as influenced by homesteads of varying size classes and different fodder tree species

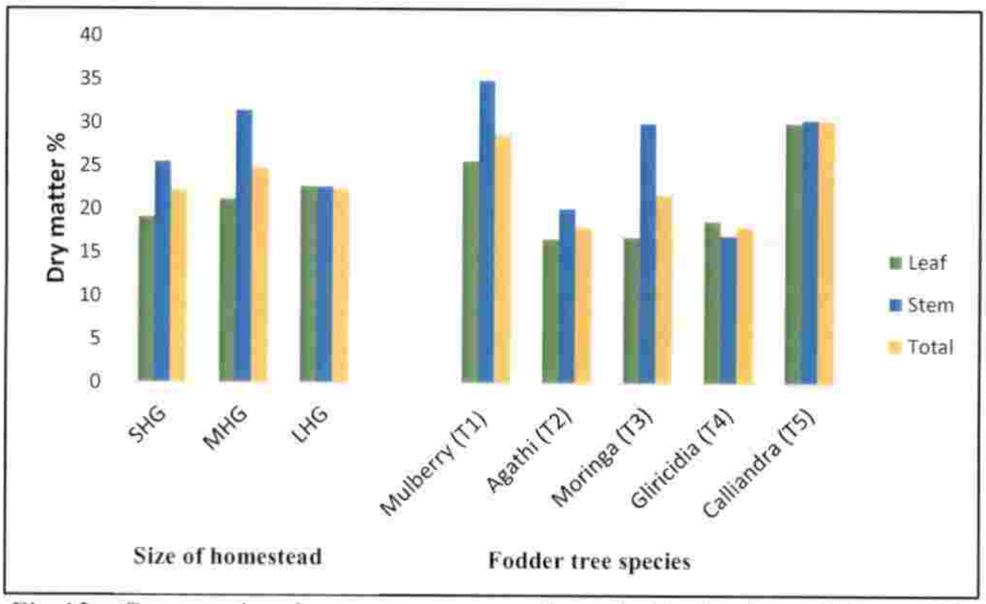

Fig 12. Comparative dry matter content of tree fodder banks as influenced by homesteads of varying size classes and different fodder tree species

5.9 NITROGEN, PHOSPHOROUS AND POTASSIUM CONTENT OF TREE FODDER BANKS IN HOMESTEADS OF VARYING SIZE CLASSES

Fodder tree species showed significant variation on N, P and K content in the fodder biomass (Table 17, 18, 19, 20). N content was higher in Calliandra (3.82 %) and Gliricidia (3.33 %) followed by Mulberry (2.64%), Agathi (2.49 %) and Moringa (2.39 %) (Table 18 and Fig. 13). P content was higher in Moringa (0.28 %) followed by Mulberry (0.25 %) than other species (Table 18 and Fig. 14). P content was comparatively less in Gliricidia. K content was relatively higher in Moringa in all size classes of homegarden (SHG-1.09 %, MHG- 1.08 %, LHG-1.18 %), and the lowest was observed in Calliandra (Table 19 and Fig. 15). In general it can be seen that Calliandra and Gliricidia are rich in N but low in phosphorous and potassium. Mulberry has medium levels of all nutrients. Moringa is found to be rich in P and K but with less N content than other species. Agathi leaves were found to have high NPK content than that of other species but, the overall nutrient content in total fodder biomass including the stem fractions was found to be poor due to its low leaf-stem ratio. Similar results have been reported by several authors. Sagaran (2017) reported higher N content and low P and K content in Calliandra species. Gliricidia is rich in protein (23 % CP) and calcium (1.2 %), two nutrients found at only low levels in non-leguminous tropical forages. The plant contains sufficiently high levels of most minerals (except phosphorus and copper) to meet tropical livestock requirements and it would therefore make an excellent feed during the dry season (Speedy and Pugliese, 1991). In Gliricidia quick decomposition of the leaves may be attributed to high concentration of nitrogen (Pandey *et al*., 2006). All Mulberry species, are useful plants that combine good chemical composition and nutritional quality, with distinctive agronomic features (Martin *et al.*, 2002). Akbulut and Ozcan (2009) studied the mineral composition of Mulberry and reported that Mulberry contain highest amount of calcium, potassium, magnesium, sodium, phosphorous and Sulphur. Saddul *et al*. (2004) studied on the chemical composition of Mulberry and found that Mulberry is a good protein and mineral resource. Green fodder of Moringa crop harvested at 2 to 3 months interval contains crude Protein (15.82 %), phosphorus (0.28 %), potassium (1.43 %) (Malik *et al.,* 2017). Hence, Moringa leaves fulfill the dietary and nutritional requirements of livestock animals. Moreover, the mixing of Moringa leaves with other fodders or grasses can also contribute towards better livestock performance and high yield of good quality products (Nouman *et al*., 2014). *Sesbania grandiflora* is valued as a fodder in many regions. In south-central Lombok, Indonesia, it is grown on bunds around paddy fields, provides up to 70 per cent of the diets of cattle and goats during the annual eight-month dry season. The leaves contain as much as 25-30 per cent crude protein. Leaves and pods are valued for fodder (Karmakar *et al.,* 2016)

Comparing nutrient content of fodder biomass in small, medium and large scale homegarden, N & K content was observed significantly higher in SHG, whereas P was found to be higher in MHG. SHG is rich in soil organic carbon content which might have improved the retention and uptake of N and K by plants. Higher P content in MHG fodder might be due to the better fertility status of the soil, better management and more uptake of nutrients.

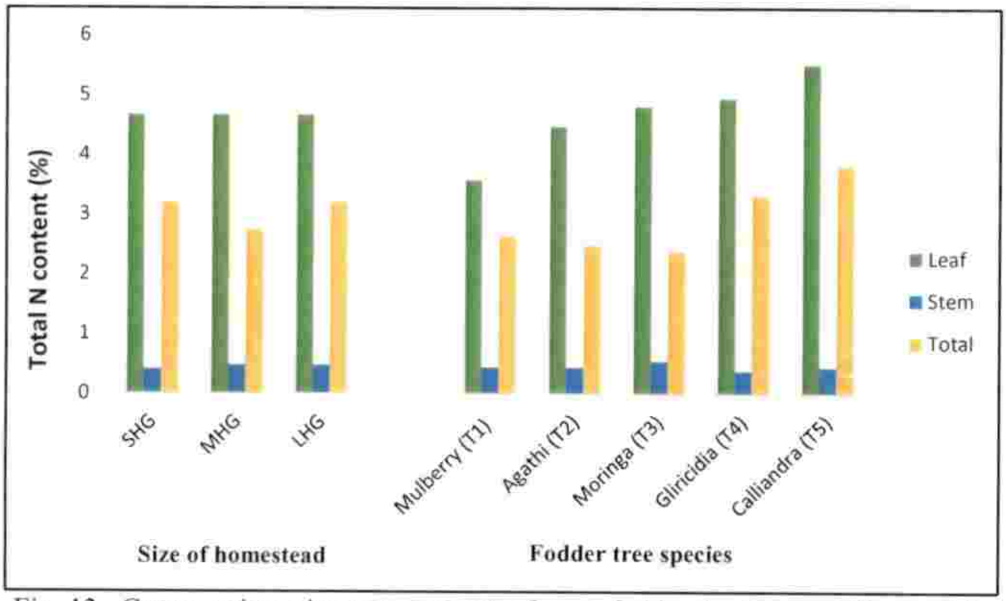

Fig 13. Comparative nitrogen content of tree fodder banks as influenced by homesteads of varying size classes and different fodder tree species

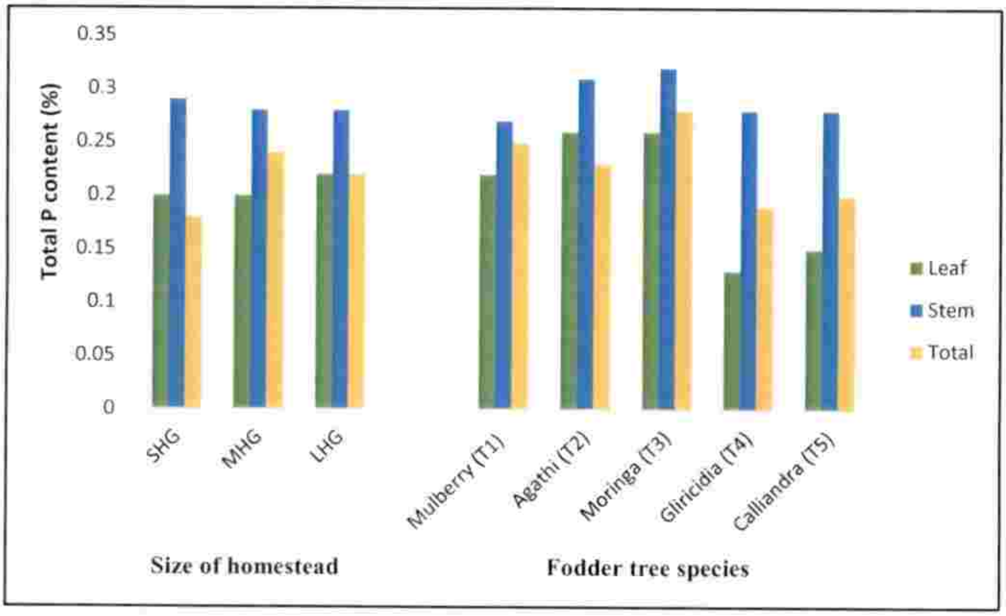

Fig 14. Comparative phosphorous content of tree fodder banks as influenced by homesteads of varying size classes and different fodder tree species

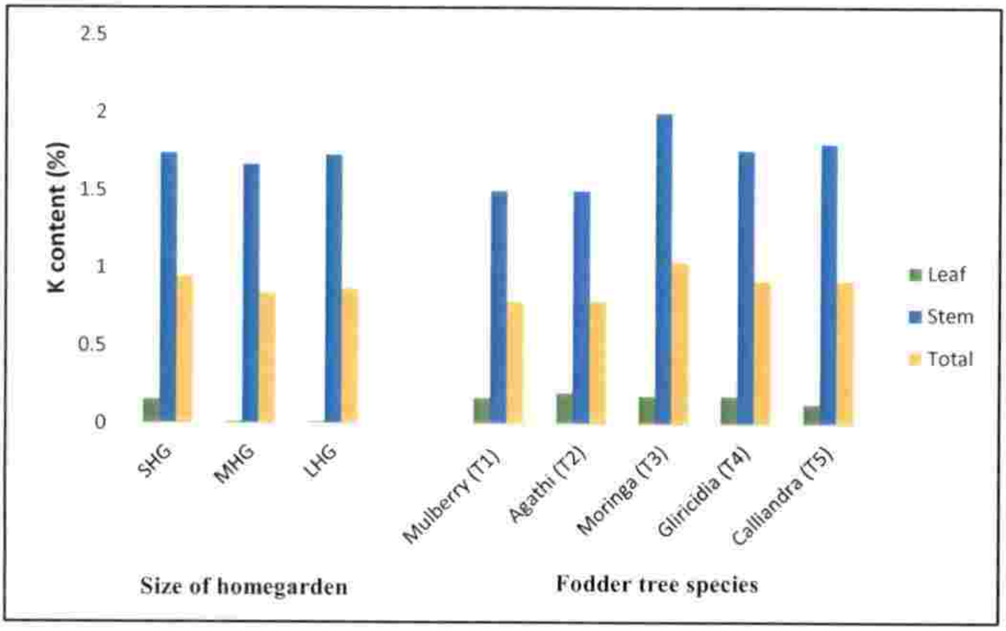

Fig 15. Comparative potassium content of tree fodder banks as influenced by homesteads of varying size classes and different fodder tree species

5.10 SOIL FERTILITY STATUS AS INFLUENCED BY FODDER TREE BANKS IN HOMESTEADS OF VARYING SIZE CLASSES

5.10.1. Organic carbon

The soil organic carbon content in fodder tree plots and open contiguous area in small, medium and large homesteads are shown in Table 21 and Table 22. In SHG, the SOC content in different fodder tree plots ranged from 0.85-1.05 per cent and showed no significant variation. However the open contiguous plots had significantly lower carbon (0.52 %) than the fodder tee plots. When compared to SHG organic carbon was comparatively lower in MHG which ranged from 0.49-0.76 per cent in various tree plots. All the tree plots in MHG had higher carbon than open plot (0.55 %) except Calliandra (0.49 %) and Mulberry (0.52 %) (Table 22 and Fig. 16). Hence an enrichment of organic carbon in soil was noticed due to tree fodder integration in SHG and MHG. This could be due to the addition of FYM in tree plots coupled with litterfall from trees. Litter production is a major process in the transfer of organic matter and nutrients from above-ground tree parts to the soil (Szott *et al*., 1991). Raj *et al*., (2016) and Sagaran (2017) also reported enrichment of SOC due to the integration of Mulberry and Calliandra fodder banks in coconut gardens.

However the SOC content in LHG ranged from 0.17-0.37 % in fodder tree plots and was significantly lower than open plots (0.52 %) (Table 22). Also LHG had lower C content than MHG and SHG in general (Table 22 and Fig. 17). Soil in LHG was of sandy nature with light texture. Studies indicate that cultivation practices accelerates the organic carbon losses in sandy soils when compared to natural vegetation. About 25-30% of organic carbon was lost from sandy soil after conversion from degraded pasture to eucalyptus in the Brazilian Cerrado in the initial year of planting (Sena *et al*., 2017). Moreover the field was also subjected to flooding and erosion which might have depleted the added FYM at the time of planting.

Comparing fodder tree species, SOC content was higher in Agathi plot (0.70 %) and was on par with all other species except that of Calliandra (0.56 %) (Table 22 and Fig. 17). The significant reduction of SOC levels in Calliandra plots could be due to its higher biomass and dry matter production (5.27 Mg ha^{-1}) when compared to other trees. There is a risk of depletion of soil carbon stocks in biomass production systems, because a higher proportion of the organic matter and nutrients are removed from the site, compared with conventional agricultural and forestry systems (Cowie *et al*., 2006). High density cultivation of Calliandra and frequent removal of biomass through harvesting might have extracted the nutrients and affected the SOC levels. It should be noticed that Calliandra has higher dry matter content than other fodder tree species which indicates higher nutrient uptake from soil.

5.10.2 Available N, P and K content in soil

The available nitrogen content in fodder tree plots and open contiguous area in different size class of homestead are shown in Table 21 and Table 22. Results indicate that available N content of all the homegardens improved significantly through tree fodder integration when compared to treeless open plot. This could be due to the addition of manures and fertilizers in tree plots coupled with N addition by nitrogen fixing species. In general N content was higher in MHG (366.28 Kg ha^{-1}), followed by LHG (329.49 Kg ha^{-1}) and SHG (324.60 Kg ha^{-1}) (Table 22 and Fig. 17). This could be due to better N retention in MHG plot. The plot was managed well and was less subjected to erosion and leaching losses of nutrients as indicated by the better growth of plants.

Comparing different fodder tree plots, highest N content was observed in Agathi (376.32 Kg ha^{-1}) and Moringa (352.63 Kg ha^{-1}), followed by Gliricidia (345.66 Kg ha^{-1}) and the lowest value was observed in Calliandra and Mulberry (Table 22 and Fig. 17). *Sesbania grandiflora* has good N fixing ability and is often maintained in gardens and around crop fields for its nitrogen contribution to the soil. Falling leaflets and flowers recycle nutrients to the ground. Due to its fast growing habit, seedlings are used for green manuring similar to annual green manure crops (Karmakar *et al.,* 2016). Even though Calliandra is a nitrogen fixer, its biomass production as well as the N content in fodder is much higher which indicates higher N uptake from the soil. This could be the reason for the soil N depletion in Calliandra plots. Mulberry is not a N fixer and will not contribute any N to soil. But it has high nutrient demand and might have utilized the N from the soil resulting in depletion. Low N content in Mulberry grown soils when compared to that of subabul has been reported by Raj *et al.,* (2016).

Similar to soil N, the available P content in soil was also significantly higher in fodder tree plots when compared to open contiguous area in different size classes of homegarden (Table 21 and 22).This could be due to addition of manures and P fertilizers in tree plots. Comparing different homegardens P content was higher in MHG (87.14 Kg ha^{-1}). MHG was managed well and less subjected to any sort of disturbance in soil which led to the retention of nutrients.

Among fodder tree plots, highest soil P was in Calliandra (109.88%) followed by Mulberry (78.52 %), Gliricidia (74.56 %), and Agathi plots (71.87 %) and the lowest value was observed in Moringa (56.22 %) (Table 22 and Fig. 18).

The data given in Table 22 shows the available potassium content in fodder tree plots and open contiguous area in different size class of homesteads. No significant difference was observed on soil K content between various tree plots as well as open contiguous plots in all homesteads. Similarly the soil K content in different homesteads were also statistically comparable, with a marginal increment observed in MHG compared to other fields. However comparing various tree plots (Table 22 and Fig. 19) soil K content was higher in Mulberry, Calliandra and Agathi but lower in Moringa and Gliricidia plots. Results given in Table 20 indicates higher K content in Moringa and Gliricidia than other species, which indicates better uptake of K by these species. This could be the reason for depleted levels of K content in Moringa and Gliricidia plots.

In general, the soil organic carbon, N and P content improved with fodder tree integration in SHG and MHG. There was no visible changes in K content. Soil N and P levels also improved in LHG whereas SOC showed a declining trend. Comparing tree species, Agathi plots showed more soil improvement with higher SOC and NPK levels whereas soil depletion was more evident in Moringa with respect to carbon, P and K, and in Calliandra in terms of carbon and nitrogen.

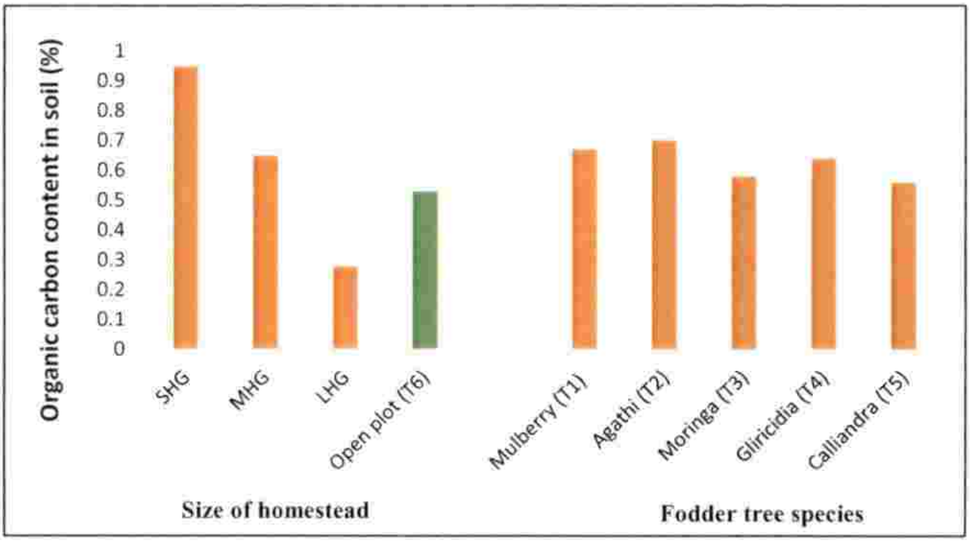

Fig 16. Influence of varying size classes of homestead and different fodder tree species on soil organic carbon content

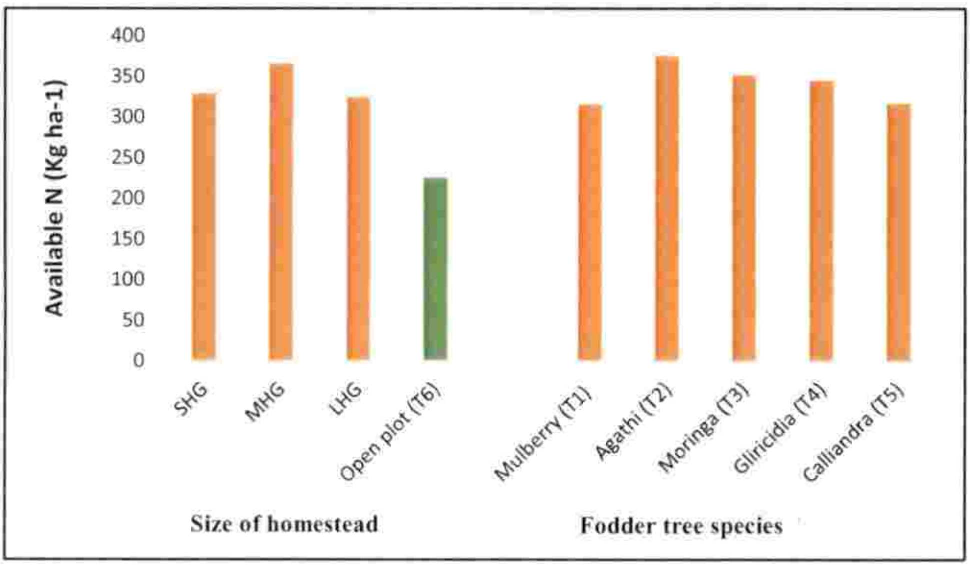

Fig 17. Influence of varying size classes of homestead and different fodder tree species on available nitrogen content in soil

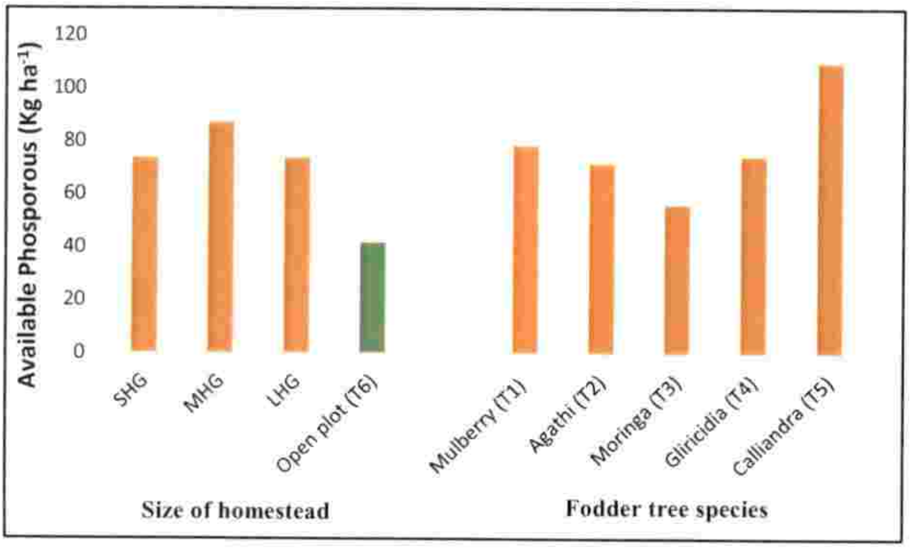

Fig 18. Influence of varying size classes of homestead and different fodder tree species on phosphorous content in soil

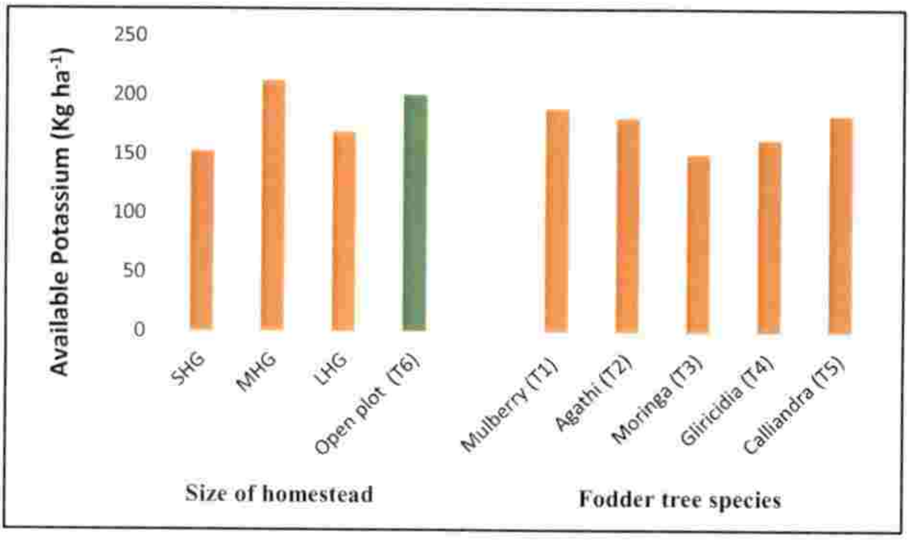

Fig 19. Influence of varying size classes of homestead and different fodder tree species on available potassium content in soil

5.11 Understorey PAR availability in homesteads

Diurnal variations in understorey Photosynthetically Active Radiation (PAR) in small, medium and large scale homesteads were distinct (Table 23). No significant difference was observed in the PAR transmittance in different homesteads as well as in different tree plots. PAR transmittance ranged from 50.10 to 52.75 % in various homesteads (Table 24 and Fig. 20, 21, 22). Eventhough the homesteads were classified as small, medium, and large, there was not much difference in the size of holdings with an area of 17, 32, and 65 cents respectively. In SHG existing trees/shrubs occupied an area of 2355 sq.m when extrapolated on hectare basis. Corresponding area under existing trees/shrubs in MHG and LHG was 1746 sq.m and 1802 sq.m. Comparatively more tree abundance was there in SHG when compared to MHG and LHG. Correspondingly a slight reduction in PAR transmittance was observed. Generally in Kerala, most of the land holdings are of small size due to land scarcity unlike other Indian states with large size holdings. In Arimboor panchayat, the land holdings were classified as small with an area of less than 25 cents, medium with an area 25-50 cents and large holdings with an area less than 1 hectare (GoK, 2011).

PAR transmittance levels in various tree plots ranged from 45.50 – 58.57% with no statistical significance. A marginal reduction in transmittance was observed in Mulberry (45.50%) when compared to other species (Table 25). Productivity and income from Mulberry was higher in open than from the partially shaded coconut garden (Meerabai, 2002). More shady situations might have caused yield reduction in Mulberry. Poor shade tolerance of Agathi has been reported by (Gutteridge and Shelton 1994). Seedling growth of Moringa is more affected by shade intensity. The seedling of *Moringa oleifera* under medium shade level produced significantly the highest biomass accumulation and partition (Ahmed *et al.,* 2014). Sagaran (2017) reported an yield of 27 Mg ha^{-1} from Calliandra fodder banks in coconut garden. The yield of Calliandra in homegarden was found to be less than under coconut gardens which could be due to higher shade levels in homegardens. Thus it can be deciphered that yield levels from homegardens can be improved by enhancing the light transmission. Probably, we need to examine the present species density and diversity and the possible stand management options to regulate them such as judicious removal of certain unwanted trees/ shrubs. Also, there is a need to adopt tree management practices such as pruning, lopping etc to improve the understorey light regimes.

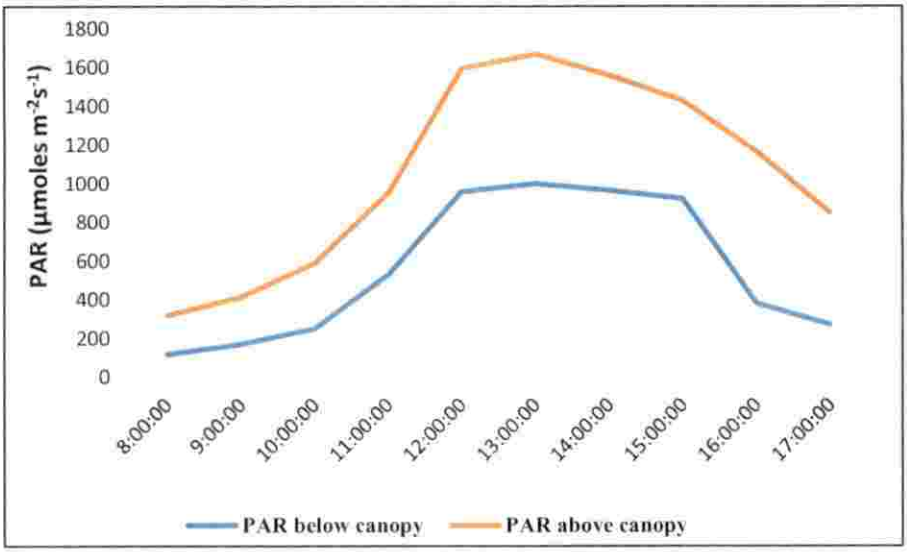

Fig 20. Mean daily-integrated values of photosynthetically active radiation (PAR) above and below the canopies of small homegarden (SHG)

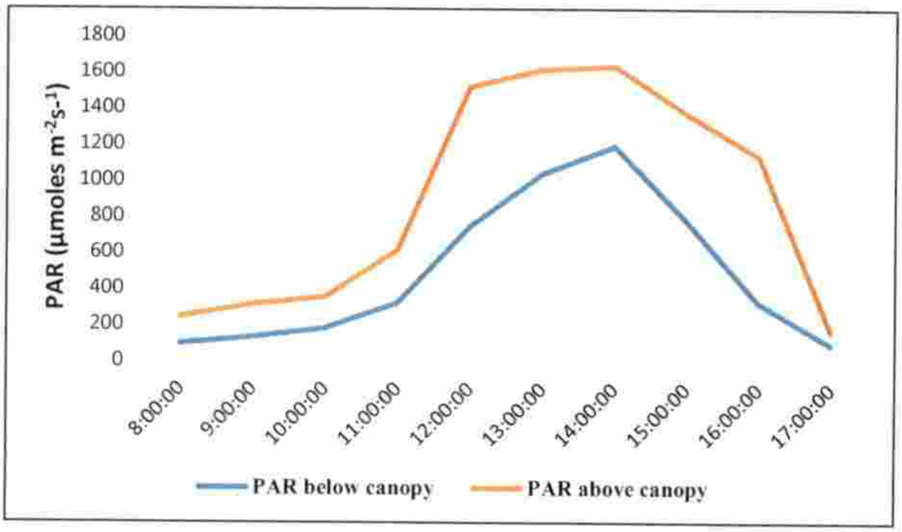

Fig 21. Mean daily-integrated values of photosynthetically active radiation (PAR) above and below the canopies of medium homegarden (MHG)

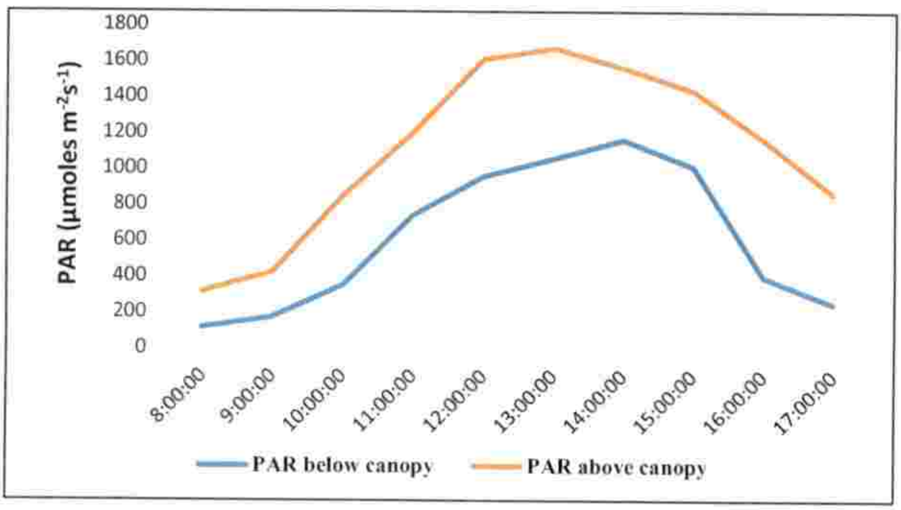

Fig 22. Mean daily-integrated values of photosynthetically active radiation (PAR) above and below the canopies of large homegarden (LHG)

5.12 Economics

Economics and benefit: cost ratio for cultivation of various fodder trees in different homesteads are given in Table 25 and 26. In general the B: C ratio for Gliricidia cultivation was found to be significantly higher (1.28) than all other species (Table 26). This could be due to higher forage yields from Gliricidia when compared to other species. This indicates that Gliricidia has faster growth, higher biomass production and gives profitable yield in the initial year of establishment itself. All other species had B: C ratio less than one. Calliandra had a B: C ratio (0.80) followed by Agathi (0.69), Moringa (0.47) and Mulberry (0.33). All these trees particularly Mulberry showed slow initial growth which resulted in reduced forage yields in the first year. As the trees are perennial and continues to yield upto 8 to 10 years, the real economics of tree fodder cultivation will be evident only in the subsequent years. Raj *et al.,* (2016) and Sagaran (2017) also reported low B: C ratio from Mulberry and Calliandra fodder banks in coconut garden during the initial year of establishment. However John (2018) and Joy (2017) observed 2 to 3 fold increase in yields and B: C ratio from Mulberry and Calliandra during the subsequent years of planting.

Comparing homegardens, the cost of production was higher in MHG (1, 71,151 ha^{-1} yr^{-1}) followed by LHG and SHG. This could be attributed to the availability of more area in MHG for tree fodder integration when compared to other fields. The initial cost for raising fodder banks in homesteads is high whereas the forage yield in the initial year of planting is comparatively less as trees are under the establishment phase. Hence B: C ratio was found to be less than one in all the homegardens. However no significant difference in B: C ratio was observed between three homegardens. A slightly higher value was observed in SHG (0.79).

SUMMARY

6. Summary

A field study entitled "Productivity of tree fodder banks in selected homegardens of Central Kerala" was carried out in selected small, medium, and large scale homegardens in Arimboor panchayat, to assess the forage yield and nutritive value of selected fodder tree species under hedgerow planting. The study also examined the understorey PAR availability in homesteads and changes in soil nutrient status of homegardens with tree fodder integration.

Salient findings of the study are summarized below:

1. All the fodder tree species established well after planting in small, medium and large size homesteads.

2. Initial growth was faster in Agathi which attained a plant height of 1.72 m in three months after planting. Calliandra was the next taller species whereas Mulberry, Moringa and Gliricidia were found to be comparatively shorter. Growth of Gliricidia was also fast but it showed more branching nature instead of growing erect. Comparing plant height in different homesteads, large home garden (LHG) and medium home garden (MHG) showed significantly higher plant growth when compared to small home garden (SHG).

3. Coppice parameters like number, length and weight of coppices varied significantly in different fodder tree species. In general, coppice parameters were better for Gliricidia followed by Agathi and Calliandra, whereas Mulberry and Moringa showed poor performance. Comparing homegardens, coppice weight of trees was higher in LHG than other farms, whereas rest of the coppice parameters were comparable.

4. Survival count of the trees after one year of planting was significantly higher in Mulberry (80.06 %) and Calliandra (71.13 %), followed by Gliricidia (44.35

%), whereas survival was drastically lower for Agathi (31.55 %) and Moringa (31.55%). Comparing different homegardens, survival percentage was higher for SHG (59.47 %) and MHG (54.46 %) followed by LHG (41.07 %).

5. The annual green forage yields differed significantly among tree species. In general, Gliricidia (24.27 Mg ha^{-1} in 5 harvests) yielded significantly higher forage yield in all the systems followed by Calliandra (16.38 Mg ha^{-1}). Next best tree species was Agathi (13.59 Mg ha^{-1}) whose yield was on par with that of Calliandra. Moringa and Mulberry produced significantly lower yields. Comparing different homegardens, fodder yield was significantly higher in MHG (15.23 Mg ha^{-1}) followed by LHG (13.15 Mg ha^{-1}) and SHG (12.07 Mg ha^{-1}).

6. The annual dry fodder biomass also varied significantly among tree species. Calliandra (4.60 Mg ha^{-1}) yielded more dry forage yield followed by Gliricidia (4.39 Mg ha^{-1}), Agathi (2.44 Mg ha^{-1}) and Mulberry (1.95 Mg ha^{-1}). Dry forage yield was significantly lower in Moringa (1.75 Mg ha^{-1}).Comparing different homegardens, MHG produced the highest dry fodder yield (3.72 Mg ha^{-1}) following the same trend of fresh fodder yield, and was significantly superior to that of SHG and LHG.

7. Comparing forage yields in different seasons, more production was obtained during the rainy period (June-November) than the summer period (December-May). Comparing fodder tree species, yield was higher in Gliricidia followed by Calliandra and Agathi during both the seasons. Comparing homegardens, yield was more in LHG (9.96 Mg ha^{-1}) and MHG (9.27 Mg ha^{-1}) during the rainy period, but during the summer period yield was more in MHG (5.08 Mg ha^{-1}) and SHG (4.96 Mg ha^{-1}).

8. Fodder tree species showed significant variation on the leaf-stem ratio. In general, higher leaf-stem ratio was observed in Mulberry (2.09), Gliricidia

(2.05) and Calliandra (1.67). followed by Agathi and Moringa. Comparing homesteads leaf-stem ratio showed significantly higher value in LHG (2.28) and SHG (1.67) followed by MHG (1.16).

9. Fodder tree species showed significant variation on CP content in the fodder biomass. In general, foliage fraction had higher crude protein levels than the stem fraction for all tree species. Comparing tree species, Calliandra (22.57 %) and Gliricidia (19.99 %) fodder had more CP content followed by Mulberry (16.74 %). Comparing different homegardens, CP content was significantly higher in case of SHG (20.01 %), followed by MHG (16.96 %) and LHG (15.94 %) which were on par.

10. Comparing tree species, Calliandra (1.04 Mg ha^{-1}) and Gliricidia (0.88 Mg ha^{-1}) yielded more CP yield followed by Agathi (0.36 Mg ha^{-1}) and Mulberry (0.33 Mg ha^{-1}). The Moringa (0.19 Mg ha^{-1}) was significantly lower in CP yield when compared to all other species. Comparing different homegardens, CP yield was significantly higher in case of MHG (0.63 Mg ha^{-1}) followed by and SHG (0.46 Mg ha^{-1}) and LHG (0.44 Mg ha^{-1}). Fractional biomass followed the similar trend.

11. Fodder tree species showed significant variation on CF content in the fodder biomass. In general, stem fraction had higher crude fibre levels (44.61 – 59.94 %) than the foliage fraction (14.82-18.79 %) for all tree species. Comparing tree species, Agathi (38.42 %) and Moringa (38.12 %) fodder contained more CF content followed by Calliandra (26.74 %) and Mulberry (27.39 %). Gliricidia (23.72 %) was significantly lower in CF content when compared to all other species. Comparing different homegardens, CF content was significantly lower in SHG (27.77 %) followed by LHG (30.03 %) and MHG (34.83 %).

12. Fodder tree species showed significant variation in ash content in the fodder biomass. Ash content was higher in foliage fraction than stem fraction for all the tree species. In general, Mulberry (7.93 %), Moringa (7.61 %) and Agathi (7.12 %) showed higher ash content followed by Gliricidia (6.93 %) and the lowest ash content was observed in Calliandra (4.37 %).

13. Dry matter content of fodder varied significantly in different tree species. In general Calliandra (30.40 %) and Mulberry (28.73 %) showed higher DM content followed by Moringa (21.79 %) and the lowest DM content was observed in Agathi (18.04 %) and Gliricidia (18.06 %). No significant difference in DM content was observed in various homegardens.

14. Fodder tree species showed significant variation on N, P and K content in the fodder biomass. N content was higher in Calliandra (3.82 %) and Gliricidia (3.33 %) followed by Mulberry (2.64 %), Agathi (2.49 %) and Moringa (2.39 %). P content was higher in Moringa (0.28 %) followed by Mulberry (0.25 %) than other species. P content was comparatively less in Gliricidia. K content was relatively higher in Moringa in all size classes of homegarden, and the lowest was observed in Calliandra. Comparing nutrient content of fodder biomass in small, medium and large scale homegarden, N & K content was observed significantly higher in SHG, whereas P was found to be higher in MHG.

15. Soil organic carbon (SOC) content in experimental plots after one year of planting showed significant variation compared to open contiguous area. Fodder tree plots contained higher SOC than open area in SHG and MHG, whereas reverse trend was observed in LHG. Comparing tree species, SOC content was higher in Agathi plot (0.70 %) and was on par with all other species except that of Calliandra.

16. The available soil nitrogen content in all fodder tree plots were significantly higher when compared to open plot in all the homesteads. Highest N content was observed in Agathi (376.32 Kg ha^{-1}) and Moringa (352.63 Kg ha^{-1}), followed by Gliricidia (345.66 Kg ha^{-1}) and the lowest value was in Calliandra and Mulberry plots. Comparing homegardens N content was comparatively higher in MHG (366.28 Kg ha^{-1}).

17. Among fodder tree plots, highest soil P was in Calliandra (109.88Kg ha^{-1}) and the lowest value was observed in Moringa (56.22Kg ha^{-1}). Comparing homegardens, P content was higher in MHG (87.14 Kg ha^{-1}) followed by SHG and LHG and were significantly higher than open area.

18. The available potassium content in fodder tree plots had significant difference. Soil K content was higher in Mulberry, Calliandra and Agathi but lower in Moringa and Gliricidia plots. Homegardens showed no significant difference with respect to K content.

19. PAR transmittance ranged from 50.10 % in SHG to 52.75 % in MHG and LHG which were on par. PAR transmittance levels in various tree plots ranged from 45.50 – 58.57 % with no statistical significance. A marginal reduction in transmittance was observed in Mulberry (45.50 %) when compared to other species.

20. The economics of fodder bank cultivation in homegardens varied significantly with respect to tree species. Gliricidia fodder banks generated higher returns and B: C ratio (1.28) whereas all other species showed B:C ratio of less than one. Comparing homegardens the cost of production was higher in MHG (1, 71,151 ₹/ ha^{-1} yr^{-1}) followed by LHG and SHG. The initial cost for raising fodder banks in homesteads is high whereas the forage yield in the initial year of planting is comparatively less as trees are under the establishment phase. As the trees are perennial and continues to yield up to 8 to 10 years, the real

economics of tree fodder cultivation will be evident only in the subsequent years.

Hence in conclusion fodder trees like Gliricidia, Calliandra, and Mulberry with good yield/persistence are found to be ideal for hedgerow planting in the understorey of homesteads. Agathi gave higher initial yields, but more intensive harvesting, such as managing as a hedgerow, reduces the life of the tree. As Agathi establishes so rapidly, frequent replanting is a management option if heavy harvesting results in tree decline. Performance of Moringa was poor in the shady situations of homesteads and also under waterlogged conditions. Hence cultivation of Moringa should be confined to light intensive as well as dry areas of homesteads. Moreover, regular lopping and pruning of component tree/shrubs in homesteads to enhance light transmission can further elevate the yield levels of fodder banks. Cultivation and proper management of multispecies tree fodder banks and feeding mixed forages will provide quality and balanced nutrition to enhance livestock production at minimal cost in homegardens.

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PRODUCTIVITY OF TREE FODDER BANKS IN SELECTED HOMEGARDENS OF CENTRAL KERALA

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(2017-17-008)

ABSTRACT

Submitted in partial fulfillment of the requirement for the degree of

MASTER OF SCIENCE IN FORESTRY

Faculty of Forestry

Kerala Agricultural University

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VELLANIKKARA, THRISSUR- 680 656

KERALA, INDIA

2019

ABSTRACT

The field study entitled "Productivity of tree fodder banks in selected homegardens of Central Kerala" was carried out as three separate experiments in selected small, medium, and large scale homegarden with livestock component in Arimboor panchayath, Thrissur, Kerala during 2018-2019. The study aimed to assess the forage yield and nutritive value of five fodder tree species *viz*. Mulberry (*Morus indica*), Agathi (*Sesbania grandiflora*), Moringa (*Moringa oleifera*), Gliricidia (*Gliricidia sepium*) and Calliandra (*Calliandra calothyrsus*) under hedgerow planting (45 x 45 cm spacing) in homegardens; and to explore the short term changes in soil nutrient status of homegardens with tree fodder integration. The treatments were laid out in randomized block design replicated four times. The trees were harvested at 1m height and at the interval of two months during rainy season and three months during summer season

The result revealed that all the tree species established well in the homegardens after planting. Initial growth of Agathi and Calliandra was faster in terms of plant height, whereas Gliricidia showed excellence in lateral branching. In general, coppice parameters were better for Gliricidia followed by Agathi and Calliandra. The annual green and dry forage yields were higher for Gliricidia (24.27 & 4.39 Mg ha^{-1}) and Calliandra (16.38 & 4.60 Mg ha^{-1}) respectively followed by Agathi and Mulberry. The yield from Moringa was comparatively poor. Seasonal fodder yields were higher for rainy period than summer.

Forage quality also differed among tree species. Calliandra (22.57 %) and Gliricidia (19.99 %) fodder had more crude protein content and yield followed by Mulberry (16.74 %). Crude fibre content was lower in Gliricidia, Calliandra and Mulberry than other species. Mulberry (7.93 %), Moringa (7.61 %) and Agathi (7.12 %) had higher ash content, whereas Moringa and Mulberry had higher P and K content. Dry matter content was significantly higher for Calliandra (30.40 %) and Mulberry

(28.73 %). Higher leaf-stem ratio was observed in Mulberry (2.09) and Gliricidia (2.05), followed by Calliandra (1.67). In general, Gliricidia and Calliandra had higher forage yields and protein content, followed by Agathi. Mulberry showed intermediate performance with respect to yield and quality. Moringa was inferior in forage yields but rich in quality attributes like ash, minerals and P content.

Comparing homegardens, yield performance of fodder banks was higher in medium homegarden (MHG) followed by large (LHG) and small homegarden (SHG). Whereas reverse trend was observed in quality attributes of fodder. Survival count of the trees after one year of planting was significantly higher in Mulberry (80.06 %) and Calliandra (71.13 %), followed by Gliricidia (44.35 %), whereas survival was drastically lower for Agathi (31.55 %) and Moringa (31.55 %). Inspite of poor yields of Mulberry in the initial year, higher persistence of Mulberry indicates its better performance in the subsequent years. Comparing different homegardens, survival percentage was higher for SHG (59.47 %) and MHG (54.46 %) followed by LHG (41.07 %). Low survival in LHG was due to waterlogging during rainy season.

In general, the soil organic carbon, N and P content improved with fodder tree integration in SHG and MHG. There was no visible changes in K content. Soil N and P levels also improved in LHG whereas SOC showed a declining trend. Comparing tree species, Agathi plots showed more soil improvement with higher SOC and NPK levels whereas soil depletion was more evident in Moringa with respect to carbon, P and K, and in Calliandra in terms of carbon and nitrogen.

PAR transmittance ranged from 50.10 % in SHG to 52.75 % in MHG and LHG which were on par. PAR transmittance levels in various tree plots ranged from 45.50 – 58.57 % with no statistical significance. A marginal reduction in transmittance was observed in Mulberry (45.50 %) when compared to other species.

The economics of fodder bank cultivation in homegardens varied significantly with respect to tree species. Gliricidia fodder banks generated higher returns and B: C ratio (1.28) whereas all other species showed B: C ratio of less than one. The initial cost for raising fodder banks in homesteads is high whereas the forage yield in the initial year of planting is comparatively less as trees are under the establishment phase.

Hence, in conclusion, fodder trees like Gliricidia, Calliandra, and Mulberry with good yield/persistence are found to be ideal for hedgerow planting in the understorey of homesteads. Agathi is not amenable to heavy pruning, hence frequent replanting is a management option due to its faster growth. Cultivation of Moringa should be confined to light intensive as well as dry areas of homesteads. Moreover, pruning of overhead trees in homesteads to enhance understorey light regimes can further elevate the yield levels of fodder banks. Scientific cultivation and management of multispecies tree fodder banks and feeding mixed forages will provide quality and balanced nutrition to enhance livestock production at minimal cost in homegardens.

APPENDICES

Appendix I

Mean weather parameters during the experimental during the experimental period (January 2018 – May 2019) recorded by the Department of Agricultural Meteorology, College of Horticulture, Vellanikkara, Kerala

Months	2018			
	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)	Relative Humidity (%)
January	33.5	20.9	0	53
February	35.7	22.5	5.2	47
March	36.7	24	33.2	59
April	36.1	24.8	28.9	69
May	33.2	22.6	483.6	79
June	29.8	23.2	730	89
July	29.6	22.5	793.2	88
August	29.2	22.2	928	87
September	32.2	22.5	290	75
October	32.8	22.9	393	76
November	32.7	23.3	66.6	68
December	33	22.5	0	63

Months	2019			
	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)	Relative Humidity (%)
January	32.9	20.4	0	55
February	35.3	23.4	0	59
March	36.7	24.8	0	65
April	36.2	25.5	76.4	70
May	34.6	24.9	78.8	74