ON-FARM EVALUATION OF SELECTED CEREAL FODDERS IN PROMINENT LAND USE SYSTEMS OF KERALA

by

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DECLARATION

I, hereby declare that this thesis entitled **"ON-FARM EVALUATION OF SELECTED CEREAL FODDERS IN PROMINENT LAND USE SYSTEMS OF 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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-Dwight Frindt

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Introduction

1. INTRODUCTION

Extinction of farmland biological diversity is currently one of the most important challenges in ecosystem management (Benton, 2007). In the past, agricultural intensification has annihilated many traditional land use practices, which had conventionally retained landraces and cultivars, as well as threatened and rare species. Deterioration of landscape biodiversity also resulted in reduced on-farm availability of green manure and fodder resources (Kumar and Takeuchi, 2009). However, there had been a revival of interest in indigenous land use systems recently, in view of their potential to provide ecosystem services.

In Kerala, land use practices and cropping patterns are diverse. Two prominent traditional land use practices in Kerala are homegardens and coconut gardens. Homegardens are agrosilvopastoral systems that exhibits intimate association of agriculture, tree production systems and livestock, which make optimum use of soil production capacity, guarantees multiple uses of natural resources, and generates multiple and sustained yields of various types of crops for livelihood and enhanced commercial use. Hence they are often regarded as the pinnacle of sustainability (Kumar and Nair, 2004). However, the current unfavourable land use trends in Kerala's socioeconomic milieu, fuelled by intense population pressure, have resulted in a paradigm shift in land use practises that has seriously impacted the stability of this unique agro-ecosystem, both quantitatively and qualitatively. Therefore, consistent efforts are required to improve the homegarden productivity. One major strategy for reviving traditional homegardens is to increase understorey productivity through judicious intercropping of shade-tolerant crops having commercial value. Such efforts can help farmers to earn substantial returns from these systems at a lower input cost.

Another prominent agricultural land use activity widely practised in Kerala is coconut cultivation. Because of its multiple uses, the coconut palm is known as Kalpavriksha or "tree of heaven". Coconut cultivation has recently become unappealing owing to the decreased productivity contributed by disease and high maintenance costs, resulting in lower income. However, the wide spacing in coconut plantations, on the other hand, provides a good opportunity for the integration of suitable agricultural crops. This is especially appropriate for Kerala, where demographic pressure on land is intense, and alternative revenue generation from coconut gardens structures a viable land use strategy. However, effective intercropping is dependent on the type of intercrop, growth phase of coconut, understorey light availability and related biophysical elements.

Livestock production is the backbone of Indian agriculture, accounting for 4.4 per cent of national GDP (Kumar *et al.*, 2018). Currently, India contributes about 15 per cent of the world's livestock population which relies on 2.3 per cent of the world's geographical area (Kumar *et al*., 2012). However, livestock productivity is limited due to the scarcity of feed and fodder. In India, only 4.4 per cent of the cultivated area is dedicated to fodder crops, which is insufficient to meet the actual demand (Mathukiya *et al.*, 2016). Similarly, Kerala produces only 60 per cent of livestock roughage requirements (KSPB, 2018), with a significant shortfall in crude protein supply.

The main feed resources for ruminants in Kerala are natural grasses, crop residues like rice straw and fodder grasses like hybrid napier and guinea grass. However the productivity of these grasses decline during dry periods. Hence, farmers primarily depend on purchased concentrate feeds, which offset their profit to a great extent. It is estimated that 60-70 per cent of total cost in livestock production is due to feed and fodder. Any attempt towards enhancing the availability of feed and economizing the feed cost would result in increased profit to livestock owners. Deficits in fodder, dry crop residues, and feed can be addressed through increased productivity, utilisation of untapped feed resources, increased land area, or imports. In this scenario, sustainable and profitable livestock production in humid tropical areas could be achieved through raising cereal fodder crops on farms to provide much needed protein and quality forage.

Cereal crops like maize, sorghum and bajra are promising fodders by virtue of high biomass production, nutritive value and palatability, wider adaptability, short harvesting period, high water use efficiency and drought tolerance. Maize is one of the most suitable crops having wide adaptability under varying agro-climatic conditions. Among the non-legume cultivated fodders, maize is the only fodder which produces better nutritional quality along with good quantity of biomass. Sorghum is also a very nutritious fodder just like corn. Sorghum cultivation is gaining popularity due to its extreme drought tolerance and suitability for dry season. Bajra is a fast growing short duration crop. Like maize and sorghum, it has also got a high biomass production potential and serves as an outstanding summer growing fodder crop for the rainfed situations (Heuze *et al.,* 2015). In Srilanka, productivity of cereal fodders is found to be higher than hybrid napier in the initial year of planting (Sarmini and Premaratne, 2017). Hence cultivation of cereals fodders has good scope for enhancing quality fodder production in Kerala.

However, the small holder farmers of Kerala do not have much open space for fodder cultivation. As an alternative, the spaces available under tree based systems such as homegardens and coconut gardens can be utilized for expanding the cultivation of fodders. Coconut is the major crop in Kerala and when grown as a monocrop at recommended spacing of 7.5 x 7.5 m, it does not fully utilize the available resources such as land space, aerial space, water and nutrients. Cultivation of cereal fodders in the interspaces of coconut offer considerable scope for enhanced resource utilization coupled with increased productivity per unit area (Subramanian and Thampan, 2014). About 80 per cent of dairy farmers in Kerala are small-scale farmers growing one or two cows in their homesteads. Incorporating cereal fodders as an understorey component in homesteads can enhance the availability of quality fodder, especially during the dry season.

Most of the cereal fodders express their superior yield potential when grown under open conditions. Several studies indicated that shade level is the most important factor affecting the yield of pastures grown in plantations and low light intensity also affects forage quality of grasses (Wilson and Wong, 1982). Patrick (2019) reported yield reduction from tree fodder banks underneath homegardens with light availability of only 50 to 52 per cent.

Cereal fodder productivity in open areas has been well studied, but its performance in partially shaded homegardens and coconut gardens with light and space constraints is not well understood. Hence, it is essential to assess the shade tolerance and yield performance of various cereal fodders under partially shaded coconut and homegardens to select the most suited crop for integration under these tree based systems. Hence the present on-farm study has been envisaged with the following objectives:

- To evaluate forage yield and nutritive value of three cereal fodders viz., maize, sorghum and bajra in major land use systems of Kerala viz., homegarden, coconut garden, and under open conditions with full sunlight.
- The study also assesses the relative performance of cereal fodders with hybrid napier, the popular fodder grass in Kerala.

Review of Literature

2. REVIEW OF LITERATURE

Homegarden and coconut garden constitute the major land use systems in Kerala. Livestock is an integral component in many of these systems. However, livestock population is declining in these systems due to inadequate feed and fodder base especially during dry seasons. Sustainable and profitable livestock production can be achieved through incorporating cereal and grass fodders into these systems. The performance of cereal fodders under partially shaded tree based systems is not fully understood. In this context a field study has been envisaged to evaluate forage yield and nutritive value of three cereal fodders viz., maize, sorghum and bajra in major land use systems of Kerala viz., homegarden, coconut garden and under open conditions. The study also assesses the relative performance of cereal fodders with hybrid napier, the popular fodder grass in Kerala. Relevant literature pertaining to the above aspects is reviewed hereunder.

2.1 RELEVANCE OF LIVESTOCK IN INDIA AND KERALA

Animal husbandry is an important sector for ensuring a more equitable and sustainable agriculture system, as well as a key contributor to the country's economic growth by increasing farmer’s income. Livestock production is inextricably linked to agriculture and they supplement and complement one another and are critical for national food security. It creates employment in the rural sector, especially for landless farmers, small and marginal farmers, women, and people from lower socio-economic group. India's livestock sector is one of the world's largest, and it plays a critical role in improving rural people's socioeconomic conditions. The importance of India's status as the world's leading producer of milk is also evident. According to the country's 20th Livestock Census (2019), the total livestock population is 535.78 million showing an increase of 4.6 per cent over Livestock Census 2012. According to the reports, a total of 20.5 million people rely on livestock for their livelihood.Two-thirds of rural communities depend on livestock for their livelihood. It also employs approximately 8.8 per cent of India's population. The livestock industry accounts for 4.11 per cent of total GDP and 25.6 per cent of total agriculture GDP in India (National Dairy Development Board, 2019). The role of livestock in the economy and sustenance of farmers is also very important.

Farmers are safeguarded by livestock against natural catastrophes such as recurring droughts and crop failures. Farmers with marginal, small, and semi-medium operational holdings (less than 4 hectares) own approximately 87.7 per cent of the livestock (Bhatta *et al.*, 2020). In India, farmers practice mixed farming which is a combination of crop and livestock production in which the output of one enterprise becomes the input of another, thus resulting in resource efficiency. Farmers receive profit from livestock in multiple ways such as generation of income, employment, food, manure etc.

In Kerala, livestock sector is prominent and one of the fastest growing sectors of the rural economy. The sector provides a significant source of revenue for the majority of smallholder farmers. The livestock population in the state was 38.36 lakh according to the 20th livestock census in 2019. Around 50 per cent of rural households in Kerala own livestock. The majority of livestock-owning households in Kerala are small, marginal or landless. Small animals such as sheep, goats, pigs, and poultry are commonly kept for commercial purposes by land-scarce poor households due to their low initial investment and operating costs (Karunakaran, 2017).

Thus, livestock is an essential component of global food production systems and a valuable asset for human survival. Considering the livestock's multifaceted role in promoting livelihoods, poverty alleviation, nutritional security, crop husbandry, and its impact on land, water, and the environment, there is a greater need for efficient resource management of the livestock sector. This entails assessing the potential availability of feed resources and devising ways and means of using these resources by livestock optimally without jeopardising the natural resources long-term ability to sustain production.

2.2 MAJOR CONSTRAINTS IN LIVESTOCK FARMING

India has a long history of being a livestock rearing nation. The rising human population pressure and its repercussions resulted in a demand for more food, thereby diverting farmers' attention away from forage farming and towards food crop production. Feed scarcity is a major impediment to expanding livestock production to meet the ever-increasing demand for meat and dairy products, particularly in developing countries (Rai *et al*., 2012). Growing livestock populations and evolving animal husbandry practises necessitate a corresponding increase in fodder to meet the requirements of livestock. The country's current fodder supply is far insufficient to meet the demand. India is currently experiencing a deficit in green fodder supply of 61.1 per cent, 21.9 per cent dry crop residues, and 64 per cent concentrate feeds (Chaudhary *et al*., 2012). Furthermore, during the lean season, availability of fodder is scarce and also expensive.

Insufficient quantity and quality fodder and lean season shortages are the major hindrances in livestock production in Kerala (Ajith *et al*., 2012). The main feed resources for ruminants in Kerala are natural grasses, crop residues like rice straw and fodder grasses like hybrid napier and guinea grass. The available forage is of low quality, lacking in energy, protein, and minerals. Moreover, productivity and quality of grasses decline drastically during dry periods. Most of the nutrient demand in offseason is met through purchased concentrate feeds incurring huge cost. In this context, increased livestock production can be achieved through the cultivation of high-quality cereal fodders with high yielding ability (Sarmini and Premaratne, 2017), in the existing cropping systems.

2.3 ROLE OF CEREAL FODDERS IN LIVESTOCK PRODUCTION

Cereal fodders such as maize, sorghum, and bajra have the ability to produce large amounts of biomass in a short period of time. Maize is one of the most adaptable crops, with a wide range of adaptability under a variety of agro-climatic conditions. It is sometimes referred to as the miracle crop or the "Queen of Cereals" because it has far greater yield potential than any other cereal crop. Maize is the only non-legume cultivated fodder that produces better nutritional quality as well as a large amount of biomass. Besides that, maize fodder is ready for harvesting in bulk about 2 months after the crop is planted (Chaudhary *et al*., 2012).

Sorghum, like corn, is a highly nutritious fodder. Sorghum cultivation is becoming more popular due to its extreme drought tolerance and suitability for the dry season.It can be harvested for green fodder immediately after the flowering stage. Recently developed improved perennial sorghum varieties, such as COFS-29 and COFS-31, are resistant to drought and temporary waterlogging. If sown in early June, these varieties can produce at least two cuts even under rainfed conditions. These two varieties, once established, can produce green fodder for at least three years (Bhatta *et al.,* 2020).

Bajra is a short-season crop that grows quickly. Like maize and sorghum, bajra also has a high biomass production potential and serves as an excellent summer growing fodder crop for rainfed areas (Heuze *et al*., 2015). It is also a fast-growing, short-duration crop that matures in 50-55 days. It has copious tillering, drought and heat tolerance, high photosynthetic efficiency, a cosmopolitan character in terms of adapting to different soil types and rich in protein content (Dairy farm guide, 2020). According to a study conducted in the northern regions of Sri Lanka, maize and sorghum outperformed CO3 hybrid napier (Sarmini and Premaratne, 2017), in the initial year of planting. As a result, cereal fodder cultivation can be promoted to enhance quality fodder production. Currently, truckloads of cereal fodders are imported to Kerala from neighbouring states like Tamil Nadu and Karnataka during lean season.

The perennial tropical fodder grass, hybrid napier is very well-known for its great yielding potential and is regarded as an excellent cut and carry forage for stall feeder systems. The majority of this grass's cultivation region in India is in the states of Tamil Nadu, Karnataka, Kerala, Andhra Pradesh, Maharashtra, and Gujarath. The grass is popular among dairy farmers in Kerala due to its high productivity, palatability, perennial nature and tolerance to different soil and climatic conditions. Hybrid napier cultivars have the following characteristics: profuse tillering, high yield potential, high dry matter and crude protein content, fast regeneration capacity, and a high leaf to stem ratio. The ability to multiply substantially via vegetative means is a distinct advantage of hybrid napier over all other forage crops (Maheswarappa and Sumitha, 2018).

2.4 GROWTH, YIELD AND QUALITY ATTRIBUTES OF CEREAL FODDERS

Cereal fodder crops like maize, sorghum and bajra are the most common fodder crops grown in India especially during the kharif season. Kumar *et al.* (2018) noted that the growth, yield and quality of a fodder crop is primarily determined by its genetic traits; however, it can be improved through various agronomic practises such as tillage operation, nutrient, weed and water management, sowing time, seed rate, intercropping system and harvesting stage etc.

Among the cereal forage crops, maize proved to be the most suitable forage as it is characterized by its high energy content and considerable protein content (Ipperisiel *et al*., 1989). Because of the high yielding ability and nutritional profile, maize is the most suitable crop for fodder and silage among the cultivated kharif forage crops (Kumar *et al*., 2017a).

The maize plant as a whole provides valuable forage for many dairy and beef animals. The crop is palatable, fast growing, and has a high dry matter production and nutritive value. Maize dry matter yield is determined by a variety of interacting environmental and genetic factors. Temperature and available soil water are important environmental factors that influence leaf area development and subsequent dry matter yield (Dwyer and Stewart, 1986). Leaf area and canopy structure are critical growth parameters for forage production. Cultural practises, as well as agricultural inputs, affect all growth attributes that directly or indirectly affect forage yield and quality.

The reason behind planting maize for green forage production is to obtain succulent vegetative part in a comparatively short time (Toosey, 1972). In maize, forage yield increases and quality decreases rapidly as the plant matures (Jung and Barkjer, 1973), indicating that harvesting at the early heading stage is generally the best time to produce high forage yield with high quality. In comparison to other grasses, forage maize has a relatively high content of non-structural carbohydrates. Forage maize responds differently to plant densities depending on the environmental and cultural factors that affect maize forage yield and quality. Widdicombe and Thelen (2002) reported that forage maize crude protein content was negatively associated with plant densities, but some researchers found no statistical relationship between crude protein content and plant densities (Soto *et al*., 2002). Nitrogen fertilisation had a substantial impact on dry matter yield. Such that the dry matter yield increased as nitrogen rates increased. The forage maize dry matter yield increased with increasing nitrogen rates, with a peak value occurring at 300 kg N ha^{-1} (Carpici *et al.*, 2010).

Sorghum, a hardy crop in dry land economies provides food, feed, and fodder security (Paterson *et al*., 2009). It is a unique crop among the major cereals and the staple food and fodder crop for unprivileged populations of world residing primarily in the semi-arid tropics (Verma *et al*., 2017). Sorghum (*Sorghum bicolor L.*) is a popular forage crop in semi-arid zones, particularly in drought-prone areas of the world (Wenzel and Van Rooyen, 2001) due to its short duration, fast growth, high productivity, and wider adaptability to a variety of agro-climatic conditions. It is widely grown for feed and fodder by subsistence growers in both rainfed and irrigated areas. The crop is drought resistant, can grow well under less fertile soils, with quick growth, high biomass accumulation and dry matter content, and the crop contains toxin hydrogen cyanide (HCN) till 45-50 days. It is more resistant to heat, drought, and water logging than other forage crops. Its fodder is fed to almost all livestock classes and can be used as hay or silage.

However, due to low protein content and the presence of hydrocyanic acid, sorghum fodder is of poor quality (Hingra *et al*., 1995). Its fodder contains more than 50 per cent digestible nutrients, including 8 per cent protein, 2.5 per cent fat, and 45 per cent nitrogen-free extract (NFE). Its feeding value has been reported to be equal to that of corn, and animals relish it due to its palatability and succulence (Wheeler, 1950). However, properly cured sorghum fodder with a small amount of protein supplement can keep cattle in good condition all winter with little or no grain supplement.

Pearl millet or bajra is an excellent forage crop because of its lower hydrocyanic acid and prussic acid content than sorghum and its green fodder is rich in protein, calcium, phosphorus and other minerals with oxalic acid within safe limits (Knairwal and Yadav, 2005). It is drought and heat tolerant, and it can grow and yield in poor, sandy, and saline soils in arid, hot, and dry climates; this gives it an advantage over other popular forage grasses in the region, such as fodder maize (Jukanti *et al.*, 2016). It is typically grown in areas with rainfall ranging from 150 to 600 mm. Pearl millet's dual-purpose nature ensures food and fodder security in the country's arid and semi-arid regions (Ramesh *et al.,*2006). Because of its short growing season, it requires little irrigation. As a result, it can even be grown in areas where water is limiting for crop growth. Although the nutritional quality of pearl millet is poor, its green fodder is used as a feed for livestock throughout the country (Faridullah *et al.,* 2010). Generally, taller varieties produced more fodder than relatively short ones (Akmal *et al*., 2002). Because of its natural resistance to drought and high temperatures, pearl millet is resistant to climate change. It is also tolerant of saline and acidic soils and is well adapted to low-productivity marginal lands.

Pearl millet has fewer pest and disease problems than other cereals and is suitable for a variety of cropping systems. It responds well to improved crop management practises, as evidenced in parts of India where it is grown as an irrigated summer crop, yielding higher forage yields. Pearl millet has recently received increased attention as a multi-cut forage crop for fresh feeding and silage production (Jukanti *et al.,* 2016), particularly in Brazil, the Middle East, and Central Asia (Rai *et al*., 2012).

2.5 INTERCROPPING OF CEREAL FODDERS IN TREE BASED SYSTEMS

2.5.1 Homegarden based intercropping systems

Homegardens are multispecies, multitier agroforestry production systems that integrate tree-crop animal components and are primarily found in the humid tropics. They are space constrained subsistence farming systems that use traditional low input technologies to produce multiple outputs, often providing livelihood and nutritional security to millions of people in the tropics. These homegardens help to preserve the biological diversity of native and exotic species, as well as managed and wild species, and play an important role in improving people's quality of life and economic and social well-being. The assemblage of diverse trees and crops arranged in multi-tiered-intimate-interlocked fashion in homegardens physiognomically resembles evergreen forests. As a result, they are frequently referred to as the most natural production systems that are both ecologically and economically sound, as well as socially acceptable. It evolved over generations of gradual crop intensification in response to increasing human pressure and the resulting scarcity of arable lands. The multi-storied configuration with a plethora of plants and other life forms are chosen based on their functional priorities and arranged judiciously to utilize the land in the best possible time and space combination (Kumar and Nair, 2004).

Nair (1993) observed that all homegardens consist of a herbaceous layer near the ground, a tree in the upper layer, and intermediate layers with different crops. The intermediate layers in the homegarden can be judiciously exploited to cultivate an array of fodder grasses and trees with proper management regimes. A baseline study conducted in Nepalese homegardens revealed that the fodder crops has the second richest diversity after the vegetable crops(Gautam *et al.*, 2008). Fodder trees such as gliricidia, calliandra, and mulberry are ideal for hedgerow planting in the understorey of homesteads. The homestead's PAR transmittance was less than 60 per cent, indicating a shady nature. Pruning of overhead trees in homesteads will improve light transmission and thus increase fodder bank yield levels (Patric *et al.*, 2020).

2.5.2 Coconut based intercropping systems

Coconut is a small holder's crop in India and over 90 per cent of the country's 5 million coconut holdings are smaller than 1 hectare in size. However, these small-scale farms do not provide the dependent families with sufficient incomes and not offering employment opportunities to family labour throughout the year. However, it is possible, to increase the productivity and net returns from coconut gardens by raising compatible subsidiary crops and incorporating livestock (Maheswarappa *et al.*, 2001). The planting system and growth habit of pure coconut palms spaced at 7.5 m x 7.5 m use only 22.3 per cent of the land effectively, while canopy uses average air space to about 30 per cent and solar radiation interception is 45-50 per cent. The effective root zone of the palm, on the other hand, is confined laterally within a radius of 2 m around the base of the palm, and over 95 per cent of the roots are located in the top 0-120 cm, of which 18.9 and 63 per cent of roots are confined to the top 0-30 cm and 31-90 cm depths, respectively (Maheswarappa *et al*., 2013). For effective utilization of underutilized soil space and solar radiation in pure stands, a variety of crops with varying stature, canopy shape and size, and rooting habit can be interplanted to form compatible combinations. Such intercropped plantations can intercept and use light at different layers and forage soil at different strata, maximising biomass production per unit area of land, time, and inputs. Multiple cropping in coconut plantations following recommended package of practice of both main crop and intercrop had no negative effect on coconut yield (Ghosh and Bandopadhyay, 2011).

Several studies indicate that cereal fodders can be cultivated under coconut palms without much yield loss. Maheswarappa *et al.* (2013) revealed that yield of sweet corn and baby corn does not differ significantly when intercropped in coconut garden as compared to open conditions. The cultivation of fodder grasses like Guinea grass and Hybrid napier in the interspaces of coconut garden is also found economically viable under irrigated conditions. The system also resulted in improvement in the nutritional status of main crop along with the sustainable increase in productivity of the system (Maheswarappa *et al.,* 2001). Studies conducted at the ICAR-CPCRI Kasargode have demonstrated that intercropping has a complementary effect on coconut productivity if proper nutrient management practices for fodder crops are used. The intercropping of fodder grass does not affect the yield of coconuts. Intercropping fodder grass with integrated nutrient management practices increased yield by 11 per cent over monocropping of coconut (Subramanian *et al*., 2019). Guinea grass, an important perennial bunch fodder grass species of the tropics recorded a green fodder yield of 85 Mg ha $^{-1}$ year $^{-1}$, when grown as intercrop in a coconut garden. The crude protein content of Hybrid Bajra Napier CO3 grass was higher when grown under coconut garden, as compared to monocrop, which is mainly attributed to the higher content of nitrogen under shaded conditions (Subramanian and Thamban, 2014).

2.6 LIGHT AVAILABILITY IN HOMEGARDENS AND COCONUT GARDENS

The productivity of the understorey is determined by the species shade tolerance or compatibility. Yirdaw and Luukkanen (2004) noted that the productivity of the understorey is generally a function of Photosynthetically Active Radiation (PAR) which varies amongst tree species. The other factors such as tree species, age, spacing, foliage type, density, leaf area index, site, latitude, season and spectral quality of incoming light also have a strong influence on the solar radiation received by the understorey vegetation (Mathew, 1992). Light appears to be one of the most critical limiting elements determining crop output in any intercropping system. Many plantation crops, like coconut and arecanut, have shown variation in understorey yield with light. For example, Kumar *et al.,* (2001) observed strong interspecific differences in understorey photosynthetic photon flux density (PPFD) data in a silvopastoral system involving four multipurpose trees (MPTs) and grass species. They found that *Acacia auriculoformis* intercept most of the incoming solar radiation while *Ailanthus triphysa* intercepted the minimum. The differences in

PPFD levels are attributed to the characteristic crown architecture and tree foliage properties.

The gradient of light from the ground layer to the top canopy is one of the factors that determine diverse niches that species exploit based on their individual needs. Crops with varied canopy patterns provide improved light interception, resulting in better utilisation of solar energy and increased biomass formation within the system (Gliessman *et al*., 1981). A typical homestead with a diverse crop mix has a multitier canopy arrangement. The leaf canopies of the components are arranged so that they occupy distinct vertical layers, with the component having foliage that is tolerant to strong light and high evaporative demand at the top and the lower components having foliage that requires or tolerates shade and high humidity at the bottom. A study conducted in Chao Phraya Basin, Thailand by Gajaseni and Gajaseni (1999) shows that the incident light intensity gradually decreased from the crown layer to the middle and lowest layers throughout the day in homegardens. Miah *et al.,* (2017) also noted that the middle and lower storey crops intercepted 55.5 and 30.8 per cent of the light, respectively in a multistorey agroforestry system in Bangladesh.On comparing the homegardens of Andaman and Nicobar to the open contiguous area, Pandey *et al.,* (2011) shows that light is reduced by 4.8 times under trees in the homegardens (2439 Lux in the homegardens vs. 11,636 Lux in the open). Patric *et al.,* (2020) also showed that the homestead's PAR transmittance was less than 60 per cent, indicating a shady situation. The proper and prudent selection of suitable intercrops can convert these low light available systems to highly productive agricultural systems.

The understorey photosynthetic photon flux density (PPFD) levels in multi-strata coconut gardens are also sufficient for the cultivation of several field crops as intercrops and a wide range of understorey crops in coconut plantations provide yields equal to or greater than those of the open (Kumar *et al*., 2012). When shade-intolerant crops [e.g., many fodder species, cereals, and legumes like soybean] are cultivated in conjunction with tree species, yield losses might occur, especially after canopy closure. The lack of light availability to the understorey crop in coconut garden systems affect the photosynthetic efficiency of intercrops, resulting in lower yields. Manjunath *et al.* (2010) reported that mean transmission of PAR in twelve years old coconut garden varied from 23.1 to 36.6 per cent of the open light conditions depending on seasons. Because leaves preferentially absorb light in the 400-700 nm wave bands, the quality of sunlight in plantations is altered as it passes through the tree canopy.

2.7 GROWTH, YIELD AND QUALITY ATTRIBUTES OF CEREAL FODDERS UNDER SHADE

Light is one of the most important factors that influence the harmony between under storey and upper storey plants in any intercropping system. In such systems, trees and crops compete for light, shade, water and other resources. This has resulted devastating effect on yield of crops. Hence light become the limiting factor for under storey vegetation since trees reduce its availability. Plants in the shade often show significant changes, such as thinner leaves, increased chlorophyll content per unit leaf mass, and an increase in Chlorophyll b (Valladares and Niinemets, 2008).

The amount of Photosynthetically Active Radiation (PAR) can drastically alter the growth environment, altering photosynthesis capability, as well as the accumulation and redistribution of dry matter, and consequently the yield. For instance, a study conducted in Javanese agroforestry system revealed that the growth and yield characters of maize exhibited an inverse trend with increase in shade (Surayana *et al.,* 2014). In multi-cropping farming systems, the mean photosynthetic photon flux density (PPFD) incident on maize was less than 700 mol m^{-2} s^{-1}, much below the light saturation point for maize (1,500 mol m^{2} s^{-1}). Since maize is grown in suboptimal light environment in these systems, the crop rarely achieves maximum photosynthetic rates. Gao *et al.,* (2020) noticed that shade treatment delayed growth and reduced dry matter production. The effect of shade has more adverse impact on crop production particularly during the silking stage. The crop yield also decreased due to shading when compared to the control. It is found that reduction of light by even 30 per cent caused a decrease in dry matter production. In general, study shows that decrease in light availability has a corresponding significant decrease in grain and stover production as well as total protein and oil component. The application of shade led to reduction in nitrogen accumulation and dry matter production in maize, which consequently decreased the overall yield of the crop. Scaria *et al*. (2016) reported good performance of different baby corn varieties in coconut gardens of Kerala. The variety CO-6 produced significantly higher fodder yield of 19.39 and 17.86 Mg ha^{-1} in summer and kharif, season respectively.

The crude protein content of maize was recorded by Manoj *et al.*, (2020) as 9.90 per cent. Hybrid napier also have a high crude protein content of about 9.98 per cent. Chaudhary *et al.* (2012) observed the crude fibre content in maize fodder variety African tall as 30.20 per cent. The crude fibre content in sorghum and hybrid napier was much higher i.e., 34.49 and 30.35 per cent respectively (Manoj *et al*., 2020). The ash content of African tall variety of maize was recorded by Kanduri *et al.* (2016) as 10.20 per cent in open field conditions. Ramya *et al.* (2017) reported the ash content present in hybrid napier and sorghum as 13.11 and 8.31 per cent at 45 days after planting. Bajra fodder noted to have a comparatively lower ash content of about 8.10 per cent.

2.8 PRODUCTION OF CEREAL FODDERS IN DIFFERENT SEASONS

Seasonal fluctuations driven by weather, plant nutrition, and management determine the availability and quality of forage throughout the year. Generally, crops produced during spring season have shown better yield as well as quality as compared to autumn season. This may be attributed to the occurrence of adequate rainfall and improved microclimatic conditions during the season. In temperate zones, pasture production and protein ratios shift seasonally. Thus, the scale and trends of these changes must be understood in order to build efficient and productive farming systems. Hanif and Akthar (2020) observed that the levels of dry matter (DM), neutral detergent fibre (NDF), acid detergent fibre (ADF), and starch in fodder maize were much greater in the spring season than in the fall season.On the other hand, crude protein (CP) levels were higher in autumn-grown maize. Mohappatra *et al*., (2019) found that fodder maize did not show significant variation in green matter production with season when grown in low cost hydroponic shed.

Kaur *et al.*, (2017) studied seasonal variation in yield and quality attributes of hybrid napier and revealed that plant height, number of tillers per plant, green fodder yield, dry fodder yield and leaf length observed the maximum in the monsoon season. The highest crude protein yield (of all harvest seasons) was reported in the summer season. Summer season also had the highest levels of quality attributes such as ether extract, ash content, and in vitro dry matter digestibility. During the monsoon season, crude fibre, neutral detergent fibre, and acid detergent fibre were at their highest levels.

Materials and Methods

3. MATERIALS AND METHODS

The present field study entitled "On-farm evaluation of selected cereal fodders in prominent land use systems of Kerala" was conducted as two separate experiments in selected homegarden and coconut garden with livestock component in Madakathara panchayath, Thrissur district, Kerala during the year 2020-21. The main objective of the study was to evaluate forage yield and nutritive value of three cereal fodders viz., maize, sorghum and bajra in major land use systems of Kerala viz., homegarden, coconut garden, and under open conditions with full sunlight. The study also assessed the relative performance of cereal fodders with hybrid napier, the popular fodder grass in Kerala. The materials used and methods adopted for the study is discussed in this chapter.

3.1 Location

The proposed study was conducted in selected homegarden and coconut garden with livestock component in Madakathara panchayath, Thrissur district, Kerala, which is the midland area lying within the geographical extremes of 10º33′0″N and 76º15′30″E.

3.1.1 Homegarden

The selected homegarden was a multitier system owned by Venugopalan Nair, (Vysappatt house, Madakathara P.O) with an area of 25 cents (0.10 hectare) comprising 7 livestock (7 cows). The major arboreal components and their abundance in the homegarden include *Artocarpus heterophyllus* (1), *Tamarindus indicus* (1), *Cyrtostachys renda* (10), *Mangifera indica* (2), *Macaranga peltate* (1) and *Cocos nucifera* (4). Other components include Colocasia, Elephant foot yam and Tapioca.

3.1.2 Coconut garden

The coconut garden selected for the proposed study was of 27 years age and owned by Ramachandran, S. (V.S. House, Madakkathara P.O). It has an area of 12 cents (0.049 hectare) and 18 coconut trees were regularly distributed at a spacing

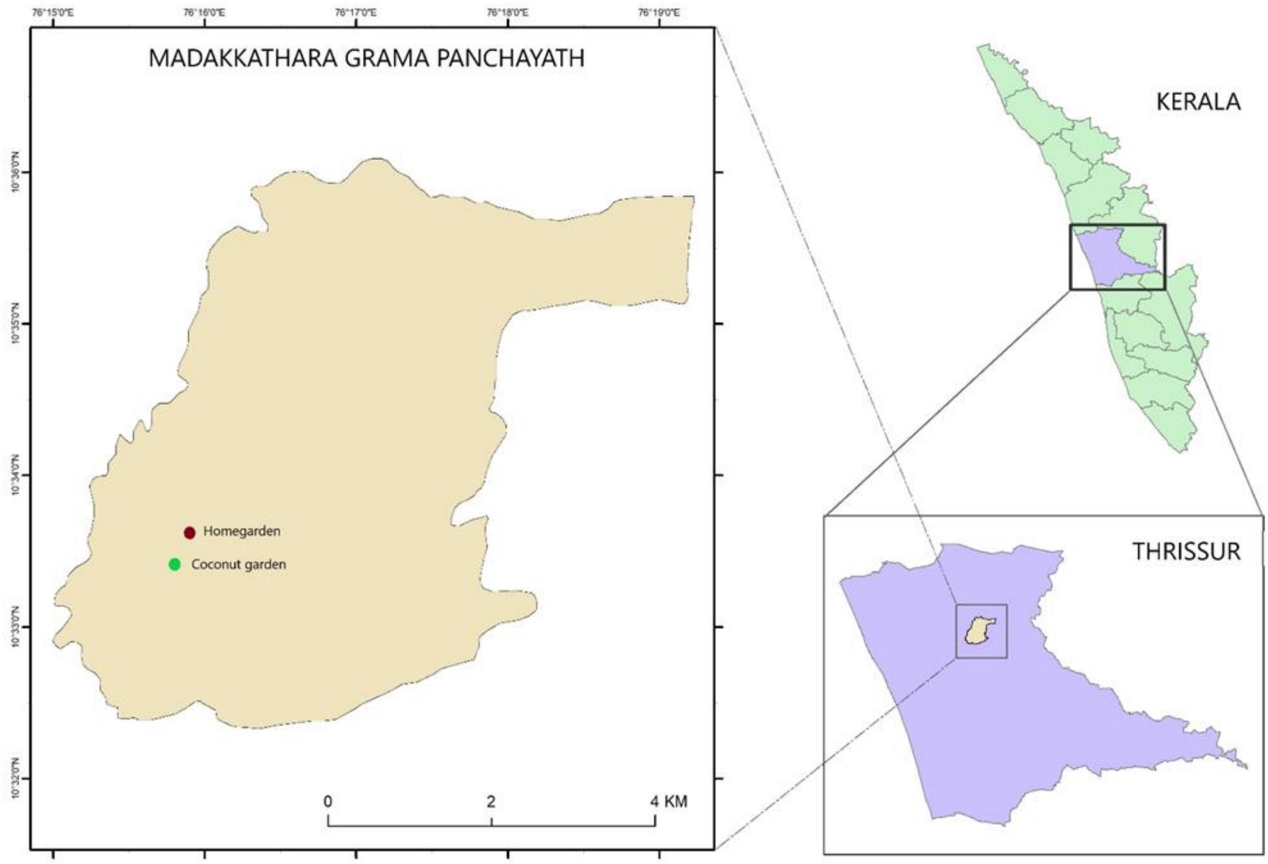

Plate 1. Study area map of Madakkathara panchayath, Thrissur District

of 7.6 m x7.6 m. The interspaces of coconut were occupied by some local grasses before the initiation of the experiment.

3.2 Climate and Soil

Madakkathara panchayath experiences a warm humid tropical climate. The maximum and minimum temperature of the area was 36.80 (March) and 21.60 (February) respectively. The average annual rainfall was 3109 mm. The South-West monsoon arrives in this region during the last week of May. There are about an average of 130 rainy days in a year. The mean relative humidity ranged from 37 per cent during February to 90 per cent during June. Information on weather parameters such as temperature, rainfall and relative humidity accessed from the Department of Agricultural Meteorology, College of Horticulture, Vellanikara are given in Appendix I and graphically represented in Fig. 1.

The soil of the homegarden was sandy loam in texture with acidic pH (5.5), low level of organic carbon (0.66 %), low available nitrogen (225 kg ha^{-1}), high level of phosphorous (28 kg ha $^{-1}$) and medium level of exchangeable potassium (245 kg ha^{-1}). In the coconut garden, the soil had low organic carbon (0.58 per cent), low available nitrogen (151.20 kg ha^{-1}), medium phosphorus (18.5 kg ha^{-1}) and low potassium (145.74 kg ha^{-1}) content. The pH of the soil was 5.59.

3.3. Materials

3.3.1 Fodder species

Cereal fodder species such as maize, sorghum, bajra and fodder grass hybrid napier were the species selected for the study.

3.3.1.1 Maize

Maize (*Zea mays L.*) is one of the most suitable crops having wide adaptability under varying agroclimatic conditions. As it has yield potential far higher than any other cereal crop, it is sometimes referred to as the miracle crop or the 'Queen of Cereals'. Among the non-legume cultivated fodders, maize is the

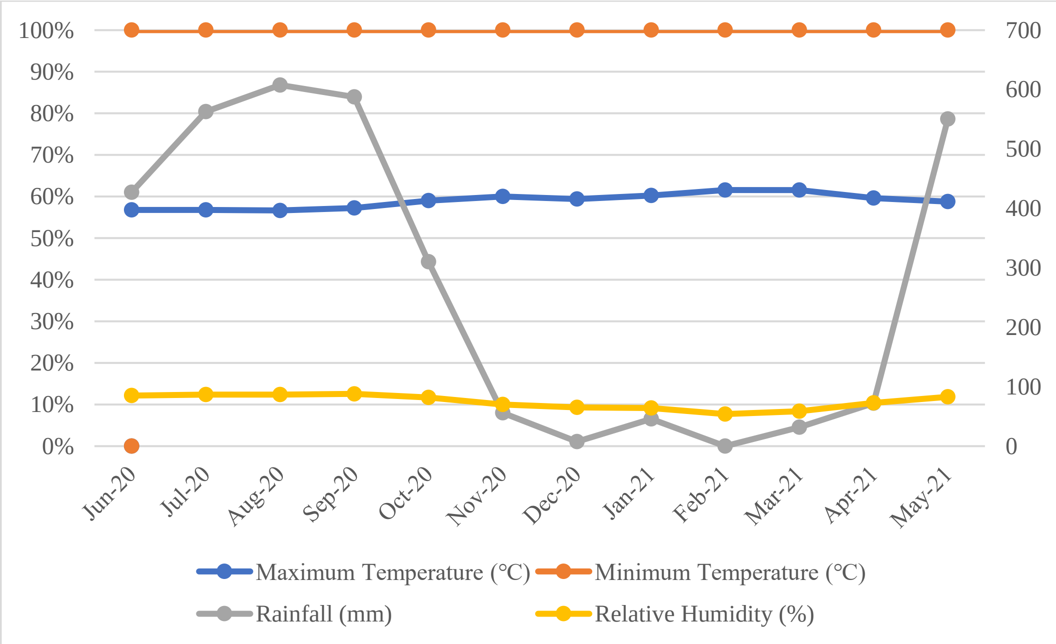

Fig 1. Mean monthly rainfall, temperature and relative humidity data from June 2020 to May 2021 at Madakkathara, Thrissur

only fodder which produces better nutritional quality along with a good quantity of biomass. Moreover, maize fodder is available for harvest in bulk approximately 2 months after sowing the crop (Chaudhary *et al*.,2012). Being a potential cereal fodder suitable to the agroclimatic conditions of Kerala, maize fodder variety, ‘African Tall’ released from Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu was selected for this study. The variety has shown a green fodder yield of 40 t ha^{-1} and crude protein content 9.80 per cent when grown under ideal field conditions (Chaudhary *et al.*, 2011).

3.3.1.2 Sorghum

Sorghum (*Sorghum bicolor*) is a drought resistant annual crop. It is soft, palatable and fast growing fodder which can be harvested after flowering stage for green fodder. The multi-cut variety, COFS 31 released by TNAU, Coimbatore was selected for the field study. It gives 5–6 cuts in one year at 60 days intervals. The leaves and stem are highly succulent in nature. It contains high protein (8.41 per cent) and less crude fibre (34.0 per cent) indicating greater potential as livestock feed (IGFRI, 2012). Rathod and Dixit (2019) noted that total green fodder yield of COFS-31 under ideal conditions was 100-150 t ha^{-1}.

3.3.1.3 Bajra

Bajra (*Pennisetum typhoides*) is a hardy crop and most suitable for cultivating in the drier regions of the country. It is a quick growing and short duration crop. It has profuse tillering, drought and heat tolerance and exhibits high photosynthetic efficiency. With regards to its adaptation to different soil types, it is sometimes referred to as a cosmopolitan crop. It also shows higher dry matter productivity as well as protein content (Dairy farm guide, 2020). The variety CO8 was selected for the field study which was released by TNAU, Coimbatore by hybridization (732 A × Sweet Giant Bajra) followed by pedigree selection. It is ready for fodder harvest in 50–55 days and produces green fodder to the tune of 30 t ha^{-1}. It has soft stem with high leaf-stem ratio and is highly palatable (IGFRI, 2012).

3.3.1.4 Hybrid Napier

Hybrid Napier, the popular fodder grass in Kerala is a perennial grass species which can be maintained in the field up to 4 - 5 years. The fodder variety CO5 released by TNAU, Coimbatore in 2012 was selected for the study. It is an interspecific hybrid between Napier grass (*Pennisetum purpureum*) and Bajra (*Pennisetum typhoides*). This is widely known as Bajra-Napier Hybrid. Compared to the Napier grass, Hybrid Napier CO5 produces larger and softer leaves. This grass is propagated through root-slips or stem-cuttings and the first cutting of the grass can be taken at 60^{th} days after planting. Later due to quick regeneration capacity, it can be harvested once in 30 - 45 days. Fodder CO5 has a high protein content (12 per cent), dry matter content (20 per cent) and crude fibre content (26.5 per cent). It produces a green forage yield of 150-300 t ha^{-1} yr^{-1} in ideal field conditions (Karforma, 2018). It is easy to digest and possesses a complete nutritional profile, thereby making this as an ideal feed for livestock.

3.3.2 Manures and fertilizers

Farmyard manure (FYM) @ 25 t ha^{-1} and N: P_2O_5: K_2O each @ 30 Kg ha^{-1} were applied uniformly for each crop. Fertilizers were applied through N: P: K mixture (18:18:18). FYM and phosphorus were applied as basal, whereas N and K were given in two equal split doses, one as basal and other 25 days after planting. Hybrid napier and sorghum being perennial fodders with recurrent harvests, an additional 20 kg N $ha^{-1}$was applied after each harvest.

3.4. Methods

The field study was conducted as two separate experiments in selected homegarden and coconut garden with livestock component in Madakathara Panchayath, Thrissur district, Kerala. The homegarden and coconut garden were selected based on the diagnostic and design (D&D) survey conducted in Madakathara Panchayath under All India Coordinated Research Project on Agroforestry (AICRP). Farmers mainly depended on local grasses, purchased rice straw and concentrate feeds for livestock rearing in the study area. Acute deficit of quality fodder was experienced during dry periods of rabi and summer season. Hence, drought tolerant, fast growing and nutrient rich cereal fodders like maize, sorghum and bajra were intercropped in partially shaded homegarden and coconut garden to assess their forage yield and nutritive value during rabi and summer season. The study also aimed to compare the differences in yield of these cereal fodders with the conventional fodder grass in Kerala, hybrid napier. The experimental details are given below.

3.5 Seasons

The cereal and grass fodder crops were cultivated during two different seasons viz., rabi and summer. The rabi crop was cultivated during October to January while summer crop from February to May. Being short duration crops, two crops of maize and bajra were taken during each season (total four crops during the study period). Multi-cut sorghum and hybrid napier being annual fodders, a single crop was planted during October and two harvests were taken during each season (total four harvests during the experimental period).

3.6 Design and layout of the experiment

Two separate experiments were conducted in the selected homegarden and the pure coconut garden. The cereal fodders viz. maize (*Zea mays L.*), sorghum (*Sorghum bicolor*) and bajra (*Pennisetum typhoides*), and the fodder grass hybrid napier (*Pennisetum typhoides* x *P. purpureum*) were grown in the understorey of homestead and in the interspaces of pure coconut garden. The crops were also grown as pure crop in the contiguous open areas in each system as control.

In each system the experiment was laid out in Randomized Block Design (RBD) involving 8 treatments (four intercrops and four sole crops), the details of which are given below.

Under each system of homegarden/coconut garden,

T1-Maize as intercrop

T2- Sorghum- as intercrop

T3-. Bajra as intercrop

T4-. Hybrid napier as intercrop

T5- Maize as sole crop

T6- Sorghum as sole crop

T7 Bajra as sole crop

T8- Hybrid napier as sole crop

Design : Randomized Block Design

No of treatments : 8

No of replications : 3

Plot size : 3 m x 3 m

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

3.7 Field culture

3.7.1 Layout and preparation of land

The experimental plots were cleared during September 2020. The field area in the interspaces of homegarden, coconut garden and open plots were ploughed twice and weeding and brush cuttings were done. The layout was done allocating a plot size of 3 m x 3 m (9 m^2) for each treatment. A crop free zone of 2 m radius around the coconut and around 0.5m to 2m radius from other trees in homegarden was maintained to reduce the competition. As per the lay out plan, proper alignment and staking was done and fodder grasses were sown or planted as follows.

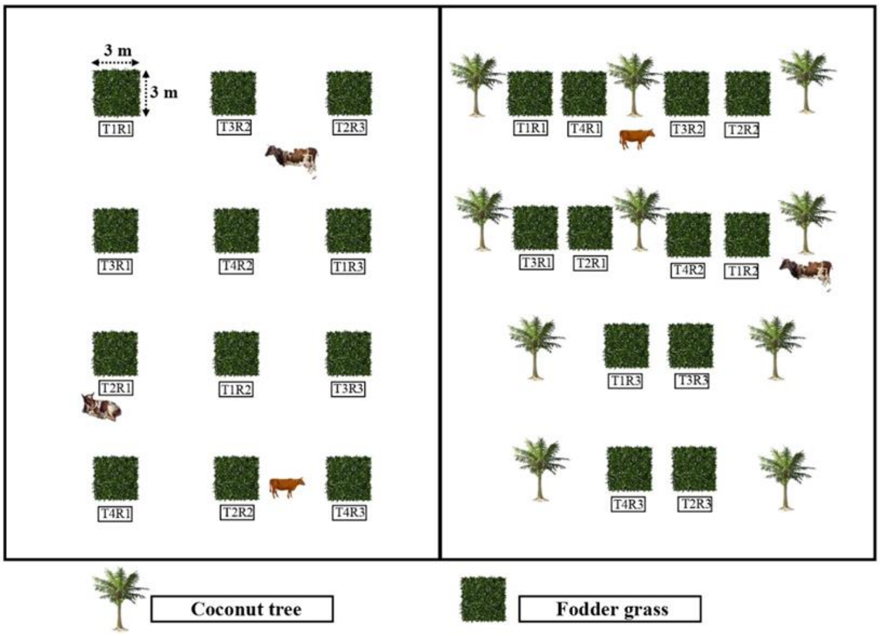

Fig 2. Layout plan of the field trial- coconut garden and open contiguous area

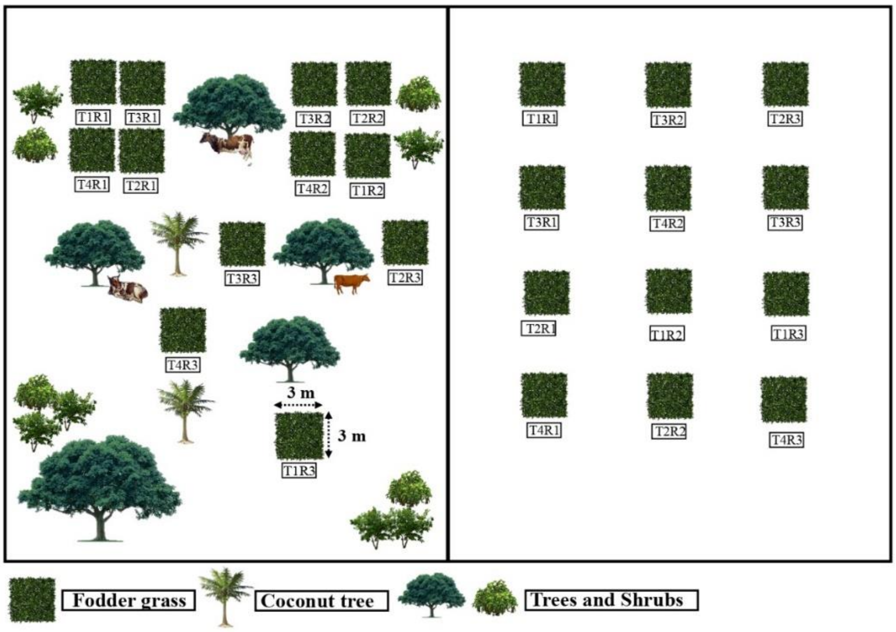

Fig 3. Layout plan of the field trial – homegarden and open contiguous area

3.7.2 Planting of fodder grass

For planting fodder crops, ridges and furrows of depth 10 cm were made as per the recommended spacing for various crops in the experimental area. Two seeds were planted in one spot manually at the spacing of 30 x 15 cm for maize and sorghum, and 25 x 10 cm for bajra. Seeds were dibbled at 5-6 cm depth for maize and sorghum and at 4 cm for bajra (KAU, 2016).

Hybrid napier, being a sterile hybrid, was planted using stem cuttings at a spacing of 50cm x 50cm. Cuttings of moderately mature stems with two nodes were prepared and planted at a 45-degree angle with one node inserted into the soil. The underground node developed into roots while the upper ones formed the shoots (KAU, 2016).

3.7.3 After cultivation

Gap filling was done 10 days after planting/sowing so as to maintain the required plant population. Regular weeding has been carried out at frequent intervals for the successful management of grasses. Remaining doses of fertilizers were applied to each crop as top dressing.

3.7.4 Plant protection

All the four experimental plots were fenced properly for protection from the attack of cattle and hens. Regular weeding was followed so that the crop growth is not affected by the weeds. No special plant protection chemicals or preparations were needed, except the application of neem cake to retard ants from taking away the cereal seeds.

Coconut garden before cultivation of fodder grass

Homegarden before cultivation of fodder grass

Open contiguous area in coconut garden before cultivation of fodder grass

Open contiguous area in homegarden before cultivation of fodder grass

Plate 2. Experimental area before cultivation of fodder grasses

Plate 3. Preparation and layout of the field

Ridges and furrows in the open area

Ridges and furrows in the homegarden

Maize seedlings

Sorghum seedlings

Bajra seedlings

Hybrid napier

Plate 4. Initial stages of the experimental area

Before planting of fodder grasses

After planting of fodder grasses

Plate 5. Experimental area before and after cultivation of fodder grasses

Plate 6. Established study area

3.8 Harvesting

For each system, the crop attained the harvesting stage at different periods of time. The fodder maize 'African tall' was harvested at the milky stage of the crop. Since 'African tall' is a seasonal crop, it was up rooted from the soil during harvesting. Harvesting of fodder sorghum was done when the crop attained 50 per cent flowering and at this stage, grass is cut at a height of 10 cm from the ground and the remaining was left in the field for the upcoming season, since it is an annual multicut fodder. Bajra was also harvested when the crop attained 50 per cent flowering and being a seasonal crop, it was also uprooted at the time of harvesting. The first harvest of hybrid napier at open condition was carried out at 70 DAP (Days After Planting) and for crops grown as intercrops in coconut garden and homegarden, harvesting done at 75 DAP and 85 DAP respectively. Subsequent harvests were taken as and when the plants attained the harvestable maturity.

3.9 Observations

Observations were recorded during rabi and summer seasons. Five plants per plot were selected at random from each treatment and tagged for taking measurements of growth parameters. Observations on fodder yield from each harvest were taken by random sampling using a quadrat (1 sq. m) from the centre of each plot.

3.9.1 Growth and yield parameters of fodder crops

Growth parameters of maize and bajra were assessed on the 45th day of sowing during the rabi as well as summer season. Hybrid napier and sorghum being annual fodders, growth parameters during rabi season were assessed during 45^{th} DAS/DAP whereas for summer season growth observations were taken at 45^{th} day after previous harvest.

3.9.1.1 Plant height

The height of the grasses was measured from the base of the stem to the growing tip and was expressed in centimetres at every 45th day after planting or cutting.

3.9.1.2 Number of leaves per plant

The number of leaves per plant was determined by adding the number of leaves in each plant.

3.9.1.3 Number of tillers per plant

If the plant is having tillers, its number was determined by counting the number of aerial shoots arising around a single plant.

3.9.1.4 Green fodder yield

Green fodder yield was assessed separately for rabi and summer seasons (each season having a duration of 4 months). Being short duration crops, 2 crops each of maize and bajra were grown for both rabi and summer seasons. However, being annual fodders, hybrid napier and sorghum were planted in October and continuously harvested for the next 8 months of rabi and summer seasons.

During each harvest, fodder biomass within 1 sq. meter quadrat from the centre of each plot was taken and their fresh weights determined to get green fodder yield. Using the net harvested area, fresh weight and net cultivated area, the fodder yield was scaled up to a hectare basis. Yield from two harvests during each season was pooled to get seasonal yields.

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

3.9.1.5 Dry fodder yield

After harvesting, sub-samples (200 g) of each fodder species were taken, chopped, and oven dried at 70ºC for 48 hours for dry matter (DM) determination

(AOAC, 1995). The fresh fodder yield from each harvest was multiplied with DM content, summed up to get cumulative dry fodder yield and was expressed on hectare basis.

3.9.1.6 Incidence of pest and diseases

No serious pest and disease incidence were noticed during the experimental period.

3.9.1.7 Plant nutrient analysis

Subsamples (200 g) of the plants were oven dried and subjected to dry matter (at 70ºC) analysis following standard procedures (AOAC, 1995). Nitrogen content in the dry matter was estimated by the modified Microkjeldahl method. Phosphorus content was determined colorimetrically by Vanado-molybdo phosphoric yellow colour method and potassium was determined by flame photometry (Jackson, 1973). All nutrient concentrations were expressed on a dry matter basis.

Plate 7. Taking observations of growth and yield attributes

Plate 8. Harvesting and feeding of fodder grass

3.9.2 Quality aspects of fodder biomass

3.9.2.1 Crude protein content

Total nitrogen (N) of oven dried fodder (leaf and stem) samples from each harvest was determined by micro Kjeldahl procedure and crude protein (CP) calculated from N content (CP= N x 6.25) according to the official methods of AOAC (1995).

3.9.2.2 Crude fibre content

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

3.9.2.3 Ash content

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

3.9.3 Understorey Photosynthetically Active Radiation (PAR) measurements

PAR measurements were carried out using Line Quantum Sensor (LQI, 2404, K131) during rabi and summer season. A battery powered data logger integrated the mean PAR at hourly intervals from 8 a.m. to 5 p.m. from each system. PAR below the canopy in homegarden and coconut garden was documented. Also, PAR readings from the open plots were noted. From this mean daily PAR, midday understorey PAR was also calculated. PAR was then converted to canopy transmittance by using the following formulae.

PAR transmittance (%): $(PAR_i / PAR_t) \times 100$

PAR_i: PAR below canopy

PAR_t : PAR above canopy

3.9.4 Economics

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

3.10 Statistical analysis

The data were subjected to statistical analysis by analysis of variance (ANOVA) using general linear model procedure in R software version 4.0.5 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 fodder grass in each land use system was done separately using RBD design.

Plate 9. Quality analysis of green biomass

Results

4. RESULTS

On-farm evaluation of selected cereal and grass fodders in prominent land use systems of Kerala were conducted in coconut garden and homegarden, located at Madakkathara panchayath, Thrissur district, Kerala during rabi and summer season in order to assess the understorey productivity and nutritive value of fodder crops. Various observations recorded during study period were analysed using appropriate statistical tools and the results are presented in this chapter.

4.1 GROWTH AND YIELD PARAMETERS OF CEREAL AND GRASS FODDERS UNDER COCONUT GARDEN AND CONTIGUOUS OPEN AREA IN RABI AND SUMMER SEASON

4.1.1 Plant height of fodder grasses

The data on plant height of the cereal and grass fodders (45 DAP/DAS) during rabi and summer season in coconut garden and open contiguous area are presented in Table 1. Fodder grasses cultivated in coconut garden and contiguous open area showed significant differences in plant height throughout the study period. Statistical analysis of the data also revealed that appreciable differences existed among the cultivated fodder grasses during both the seasons.

During both the rabi and summer season the fodder grasses grown in open area under full sunlight conditions showed relatively more plant height as compared to coconut garden. Fodder bajra recorded maximum plant height in coconut garden in rabi (141.08 cm) and summer season (144.83 cm). In open contiguous area during rabi, bajra (173.16 cm) attained maximum plant height but that is found statistically on par with maize (161.75 cm) and sorghum (161.75 cm). During summer season in open area, bajra showed a significantly higher plant height reaching up to 220.75 cm. The minimum plant height during rabi season was noticed in hybrid napier in both coconut garden (97.16 cm) and open area (100.75 cm). During summer, the minimum plant height is noticed in sorghum (124 cm) in coconut garden, but that is found statistically on par with maize (127.41 cm) and hybrid napier (126.83 cm). Similarly, in open area during summer the lowest plant height is noticed in hybrid napier (177.67 cm), but that is also on par with maize (186.91 cm) and sorghum (189.50 cm).

It can be concluded that fodder grasses exhibited more plant height during summer season as compared to rabi in coconut garden and open area. During both seasons, fodder bajra noticed to have more plant height in both land management systems. The percentage reduction in plant height in coconut garden as compared to open area is observed more in sorghum and least in hybrid napier.

4.1.2 Number of leaves of fodder grasses

The data on number of leaves of the fodder grasses (45 DAP/DAS) during rabi and summer season are presented in Table 1. In general, number of leaves was observed more in open contiguous area than coconut garden. Also, the crops grown during summer season showed relatively a greater number of leaves than in coconut garden. During both the seasons, maximum number of leaves was observed in hybrid napier (10.33 and 11.10) in open conditions. In coconut garden, hybrid napier (8.50 and 10.30) and bajra (7.91 and 9.10) showed significantly a greater number of leaves during rabi and summer. Fodder sorghum exhibited least number of leaves during both seasons in open conditions (6.08 and 7.83). During rabi season, number of leaves in maize noticed to have significant less (6.83), while in summer sorghum observed to have least number of leaves (7.83).

From the comprehensive analysis of the data table, it can be concluded that the number of leaves was found to be more during summer season and those cultivated under open contiguous area. In coconut garden maximum number of leaves is observed in bajra and hybrid napier during both seasons, while in open conditions hybrid napier out performed bajra.

4.1.3 Number of tillers of fodder grass

The data on number of tillers of the fodder grasses (45 DAP/DAS) during rabi and summer season in coconut garden and open contiguous area are presented in Table 1. Generally, fodder grasses noticed to possess a greater number of tillers during summer season and under open contiguous area. During rabi and summer season in coconut garden, sorghum exhibited the maximum count on number of tillers (6.13 and 10.30). In rabi season, maximum tillering is noticed in sorghum (7.31) and bajra (6.58) while in summer season, sorghum (11.63) and hybrid napier (10.40) produced more tillers in open area. Fodder maize didn’t show any tillering throughout the growth period in both land management systems.

It can be concluded that more tillering was observed during summer season in open contiguous area. Fodder sorghum obtained highest number of tillers in coconut garden while in open area sorghum as well as bajra obtained maximum number of tillers.

Table 1. Growth parameters of fodder crops (45 DAP/DAS) in coconut garden and open areas during rabi and summer season.

	Rabi season			Summer season		
Treatments	Height (cm)	No. of leaves	No. of tillers	Height (cm)	No. of leaves	No. of tillers
Coconut garden						
T1-Maize	121.75^{c}	6.83^{e}	0.00^{e}	127.41^{cd}	8.16^{cd}	0.00^{d}
T2-Sorghum	109.75^{cd}	4.91^{f}	6.13^{ab}	124.00^{d}	5.87^{e}	10.30^{a}
T3-Bajra	141.08^{b}	7.91^{bc}	4.25^{bc}	144.83^{c}	9.10^{bc}	2.60^{c}
T4-Hybrid napier	97.16^{d}	8.50^{b}	2.08^{de}	126.83^{cd}	10.30^{ab}	5.53^{b}
Open area						
T5-Maize	161.75^{a}	7.5^{cd}	0.00^{e}	186.91^{b}	10.53^{ab}	0.00^{d}
T6-Sorghum	161.75^{a}	6.08^{e}	7.31^{a}	189.50^{b}	7.83^{d}	11.63^{a}
T7-Bajra	173.16^{a}	7.6^{bcd}	6.58^{a}	220.75^{a}	8.63^{cd}	3.17^{c}
T8-Hybrid napier	100.75^{d}	10.33^{a}	2.83^{cd}	177.67^{b}	11.10^{a}	10.40^{a}
P value	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
CD	15.18	1.65	2.08	20.76	1.85	1.56

Values with same superscript in a column do not differ significantly
p>0.05, significant at 5 % level of significance
p<0.05, non-significant at 5 % level of significance
CD: critical difference

4.1.4 Green fodder yield

Significant changes were noticed in the green fodder yield across coconut garden and open contiguous area during first and second harvest in rabi and summer season (Table 2 and Table 3). In general, open grown fodder grasses showed a consistently higher green fodder yield and varied significantly from coconut garden.

It was observed that during rabi, the green fodder yield of all the four fodder grass grown in two land use systems exhibited a considerable increase from first harvest to second harvest. In open conditions, maize (37.16 and 40.24 Mg ha^{-1}) and sorghum (21.20 and 21.36 Mg ha^{-1}) yielded the maximum and minimum green fodder respectively across the two harvests. Also, in coconut garden during both the harvests, maize (34.01 Mg ha^{-1} and 37.59 Mg ha^{-1}) yielded the maximum green fodder yield. During both the harvests, fodder sorghum yielded the least (14.20 Mg ha^{-1} and 13.80 Mg ha^{-1}) in coconut garden. In the second harvest in both land use systems, green fodder yield of maize and hybrid napier are found to be statistically on par. The reduction in cumulative green fodder yield of maize, bajra, sorghum and hybrid napier in response to the shade in coconut garden during rabi is 7.49, 34.16, 20.51 and 6.20 per cent respectively.

During summer season, the green fodder yield of all fodder grass increased from first to second harvest in both the land use systems. During the first harvest, maize showed the maximum green fodder yield in open area (37.16 Mg ha^{-1}) and coconut garden (34.01 Mg ha^{-1}). However, the yield of maize and hybrid napier in coconut garden found to be statistically on par. Fodder sorghum yielded the least green fodder in open as well as in coconut garden during the first harvest (Table 3). During the second harvest, fodder maize exhibited the maximum green fodder yield in both open area (40.24 Mg ha^{-1}) as well as coconut garden (37.59 Mg ha^{-1}). The yield of maize and hybrid napier in coconut garden was found to be on par. In second harvest also, sorghum observed to produce the least green fodder yield in open area and coconut garden. The reduction in cumulative green fodder yield of maize, bajra, sorghum and hybrid napier as compared to open area is 11.79, 29.31, 25.43 and 8.91 per cent respectively in summer.

In general, it can be concluded that fodder maize and hybrid napier yielded the maximum green fodder yield in coconut garden during rabi and summer season. While in open contiguous area maize yielded the highest green fodder throughout the study period. During rabi as well as in summer season, least performance in green fodder yield is noticed in sorghum in both the land use systems. The percentage reduction of yield in coconut garden with respect to open contiguous area is found to be the maximum in sorghum in both seasons, while hybrid napier exhibited the least reduction in green fodder yield.

4.1.5 Dry fodder yield

The data pertaining to dry fodder yield of different fodder grass under two land management systems during rabi and summer season are depicted in Table 2 and 3. The maximum dry fodder yield was observed in the open area throughout the growing period in both systems.

During rabi, the dry fodder yield of fodder grasses in coconut garden as well as open contiguous area was comparable. Maize obtained comparatively higher dry fodder yield followed by bajra and hybrid napier. The reduction in dry fodder yield of maize, sorghum, bajra and hybrid napier in coconut garden when compared to open contiguous area is 10.94, 30.24, 21.47 and 9.65 per cent respectively during rabi season.

In summer season, during first and second harvest, maize produced the highest dry fodder yield in coconut garden (7.39 Mg ha^{-1} and 8.09 Mg ha^{-1}), which is also statistically on par with hybrid napier in both harvests. However, in open area during first harvest, maize (9 Mg ha^{-1}) out performed hybrid napier, while in second harvest the two crops are found to be statistically on par. In both harvests, lowest dry fodder yield is noticed in fodder sorghum (Table 3). The reduction in dry fodder yield of maize, sorghum, bajra and hybrid napier in coconut garden when compared to open contiguous area is 11.36, 11.57, 11.82 and 9.10 per cent respectively during summer season.

In general, during rabi and summer season, hybrid napier and maize exhibited better performance in terms of dry fodder yield in coconut garden and open area respectively. During both rabi and summer, the percentage reduction in dry fodder yield in response to shade was found least in hybrid napier.

Table 2. Yield parameters of cereal and grass fodders in coconut garden and open contiguous areas during rabi season.

Treatments	First harvest		Second harvest		Cumulative yield	Cumulative yield
	Green fodder yield (Mg ha^{-1})	Dry fodder yield (Mg ha^{-1})	Green fodder yield (Mg ha^{-1})	Dry fodder yield (Mg ha^{-1})	Green fodder yield (Mg ha^{-1})	Dry fodder yield (Mg ha^{-1})
Coconut garden						
T1-Maize	34.01^{ab}	6.19	37.59^{a}	7.08^{a}	71.60^{a}	13.27^{a}
T2-Sorghum	14.20^{e}	3.37	13.80^{d}	3.48^{c}	28.02^{c}	6.85^{c}
T3-Bajra	28.78^{abc}	4.55	18.89^{cd}	5.29^{abc}	47.67^{b}	9.84^{abc}
T4-Hybrid napier	24.51^{cd}	5.11	31.94^{ab}	6.54^{ab}	56.45^{b}	11.65^{ab}
Open area						
T5-Maize	37.16^{a}	7.39	40.24^{a}	7.51^{a}	77.40^{a}	14.90^{a}
T6-Sorghum	21.20^{de}	5.89	21.36^{cd}	3.93^{bc}	42.56^{bc}	9.82^{bc}
T7-Bajra	32.00^{ab}	7.24	27.97^{bc}	5.89^{abc}	59.97^{a}	12.53^{abc}
T8-Hybrid napier	24.49^{bcd}	5.88	35.69^{a}	6.93^{a}	60.18^{a}	12.81^{a}
P value	<0.05	>0.05	<0.05	>0.05	<0.05	<0.05
CD	8.60	-	9.13	2.74	15.05	2.02

Values with same superscript in a column do not differ significantly
$p>0.05$, significant at 5 % level of significance
$p<0.05$, non-significant at 5 % level of significance
CD: critical difference

Table 3. Yield parameters of cereal and grass fodders in coconut garden and open contiguous areas during summer season.

Treatments	First harvest		Second harvest		Cumulative yield	Cumulative yield
	Green fodder yield (Mg ha^{-1})	Dry fodder yield (Mg ha^{-1})	Green fodder yield (Mg ha^{-1})	Dry fodder yield (Mg ha^{-1})	Green fodder yield (Mg ha^{-1})	Dry fodder yield (Mg ha^{-1})
Coconut garden						
T1-Maize	37.72^{b}	7.39^{b}	39.63^{b}	9.09^{ab}	77.35^{a}	17.48^{ab}
T2-Sorghum	14.81^{c}	3.25^{d}	15.31^{d}	3.78^{c}	30.12^{c}	7.03^{cd}
T3-Bajra	16.49^{c}	4.60^{cd}	18.22^{d}	4.60^{bc}	34.71^{bc}	9.10^{cd}
T4-Hybrid napier	33.47^{b}	6.48^{bc}	34.33^{bc}	6.70^{bc}	67.80^{b}	13.18^{bc}
Open area						
T5-Maize	43.52^{a}	9.00^{a}	44.17^{a}	10.72^{a}	87.69^{a}	19.72^{a}
T6-Sorghum	22.37^{c}	3.95^{d}	20.24^{d}	4.00^{c}	42.61^{bc}	7.95^{cd}
T7-Bajra	22.53^{c}	5.44^{bcd}	24.02^{cd}	4.88^{bc}	46.55^{bc}	10.32^{bc}
T8-Hybrid napier	37.08^{b}	7.05^{b}	37.36^{bc}	7.05^{ab}	74.44^{a}	14.50^{ab}
P value	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
CD	10.48	2.76	13.88	3.43	15.28	2.94

Values with same superscript in a column do not differ significantly
p>0.05, significant at 5 % level of significance
p<0.05, non-significant at 5 % level of significance
CD: critical difference

4.1.6 Productivity per day

The duration and per day productivity of fodder grasses in different land management systems during rabi and summer season is depicted in Table 4. In general, per day productivity of fodder crops were significantly higher in open contiguous area as compared to coconut garden.

During the first harvest in rabi season, it was noticed that the per day productivity of bajra is the maximum (0.67 Mg $ha^{-1}day^{-1}$) and this is also statistically on par with maize (0.57 Mg $ha^{-1}day^{-1}$). Among the open cultivated fodder grasses, the per day productivity of bajra was significantly higher (0.88 Mg $ha^{-1}day^{-1}$. In both land management systems, sorghum fodder noticed to have minimum per day productivity. While considering the second harvest, bajra (0.73 Mg ha^{-1} day^{-1}) observed to have the highest per day productivity in coconut garden, which is statistically on par with maize (0.63 Mg $ha^{-1}day^{-1}$). The per day productivity of bajra (0.89 Mg $ha^{-1}day^{-1}$) was found to be the maximum in open area during the second harvest. Sorghum attained the minimum per day productivity in both land management systems in second harvest.

During the first harvest in summer season, the per day productivity of maize and bajra observed to be the maximum in coconut garden. However, during the second harvest, the per day productivity of bajra alone produced maximum per day productivity (0.76 Mg $ha^{-1}day^{-1}$). In open area, the per day productivity of maize and bajra was higher in both harvest in summer. Across all the harvest during summer, fodder sorghum yielded the least per day productivity in both land management systems.

In conclusion during rabi season, maize and bajra attained the maximum per day productivity in coconut garden and bajra alone produced maximum productivity in open area. However, during summer season, bajra yielded the maximum per day productivity in coconut garden, while in open area maize and bajra observed to have the maximum. In both land management systems fodder sorghum found to have the least per day productivity across the two seasons.

4.1.7 Duration of fodder crops

Considerable differences observed in the average duration of each fodder crop in rabi and summer season across the land management systems (Table 4). The duration of all the crops observed to be significantly higher in coconut garden as compared to open area. Generally, the crop duration is shorter in summer than rabi season.

During rabi, average duration of maize and bajra was 60 and 50 days respectively during both harvests in coconut garden whereas in open contiguous area the duration was 55 and 45 days respectively. Being perennial fodders, sorghum and hybrid napier had taken 65 and 75 days for the first harvest in coconut garden and 50 and 70 days in open area. For the second harvest, sorghum noticed to have same duration in coconut garden and open area (65 days), while duration of hybrid napier in coconut garden and open area was 65 and 60 days respectively.

Similarly, in summer season, average duration of maize and bajra was 60 and 50 days respectively during both harvests in coconut garden whereas in open contiguous area the duration was 55 and 45 days respectively. Duration of perennial fodders sorghum and hybrid napier during both harvests in coconut garden was 65 and 60 days while in open area they have taken 50 and 45 days respectively.

Table 4. Duration and per day productivity of fodder crops during rabi and summer season in coconut garden and open contiguous area

Treatments	Rabi				Summer			
	First harvest		Second harvest		First harvest		Second harvest	
	Duration	Per day productivity (Mg ha^{-1}day^{-1})	Duration	Per day productivity (Mg ha^{-1}day^{-1})	Duration	Per day productivity (Mg ha^{-1}day^{-1})	Duration	Per day productivity (Mg ha^{-1}day^{-1})
Coconut garden								
T1-Maize	60	0.57^{bc}	60	0.63^{b}	60	0.63^{bc}	60	0.66^{bc}
T2-Sorghum	65	0.21^{d}	65	0.22^{d}	65	0.23^{e}	65	0.26^{d}
T3-Bajra	50	0.67^{b}	50	0.73^{ab}	50	0.71^{b}	50	0.76^{ab}
T4-Hybrid napier	75	0.33^{de}	65	0.38^{cd}	60	0.37^{de}	60	0.40^{cd}
Open area								
T5-Maize	55	0.68^{b}	55	0.73^{ab}	55	1.06^{a}	55	1.02^{a}
T6-Sorghum	50	0.42^{cd}	50	0.43^{c}	50	0.45^{cd}	50	0.42^{cd}
T7-Bajra	45	0.88^{a}	45	0.89^{a}	45	0.93^{a}	45	0.93^{a}
T8-Hybrid napier	70	0.40^{cd}	60	0.31^{cd}	45	0.37^{de}	45	0.46^{cd}
P	-	<0.05	-	<0.05	-	<0.05	-	<0.05
CD	-	0.17	-	0.18	-	0.22	-	0.27

Values with same superscript in a column do not differ significantly
p>0.05, significant at 5 % level of significance
p<0.05, non-significant at 5 % level of significance
CD: critical difference

4.2 PLANT QUALITY AND NUTRIENT ANALYSIS OF CEREAL AND GRASS FODDERS IN COCONUT GARDEN DURING RABI AND SUMMER SEASON

4.2.1 Dry matter

Dry matter percentage of fodder grasses grown under the two land management systems during rabi and summer season is depicted in Table 5 and 6. Statistical analysis of the data revealed that there are no significant differences in dry matter percentage between fodder grasses during both rabi season in open contiguous area and coconut garden. However, in summer season considerable differences exist between fodder grasses in both land use systems. The dry matter percentage is found generally higher in open cultivated grasses as compared to coconut garden. Also, the summer grown crops show relatively higher dry matter percentage than rabi grown crops.

In summer season, fodder sorghum shown maximum dry matter percentage in both coconut garden (24.70 per cent) and open area (24.26 per cent). The minimum dry matter percentage is noticed in maize (18.74 per cent) and bajra (19.06 per cent) in open area and coconut garden respectively. The mean percentage reduction in dry matter in coconut garden as compared to open area during summer season in maize, sorghum, bajra and hybrid napier is 4.44, 1.78, 4.60 and 0.64 per cent respectively.

In general, maximum and minimum dry matter percentage is observed in sorghum and maize fodder respectively in both land management systems during rabi as well as summer season. Also, the reduction in dry matter percentage due to factor of shade is noticed most in maize and least in hybrid napier

4.2.2 Crude protein

Table 5 and 6 depicts the crude protein content observed in the fodder grasses grown in coconut garden and open contiguous area in rabi and summer season. Notable changes were examined in the crude protein content across the two land management systems as well as seasons.

During rabi season, the maximum crude protein in coconut garden was noticed in maize (9.57 per cent) and the lowest observed in sorghum (5.54 per cent). However statistical analysis revealed that the crude protein content of sorghum (5.54 per cent) is on par with bajra and hybrid napier in coconut garden. In open contiguous area, maize showed maximum (7.29) and hybrid napier (5.08) the minimum protein content.

In summer season, fodder maize (13.36 per cent) shows significantly higher crude protein content in coconut garden and the minimum protein content is observed in bajra (6.00 per cent). In open area, maximum crude protein is noticed in maize (9.92 per cent) and it is found statistically on par with sorghum (8.39 per cent) and hybrid napier (7.09 per cent). Fodder bajra (6.73 per cent) showed the least crude protein content in open area during summer season.

In general, grasses grown in coconut garden shows significantly higher crude protein content than those in open area. Also, the fodder grasses grown in summer season observed to have relatively more crude protein content than those in rabi season. During both the seasons, maize and bajra showed the highest and lowest crude protein content respectively in both land management systems.

4.2.3 Crude fibre

The data on crude fibre content noticed across the two land use systems during rabi and summer season are given in Table 5 and 6. An analysis of the data in the table shows no prominent variations in the crude fibre content among different fodder grasses during summer season across the land use systems. However, in rabi season considerable variations exists. In coconut garden and open area during rabi season, hybrid napier (31.17 and 31.47 per cent) showed maximum fibre content and maize (25.33 and 29.67 per cent) showed the minimum.

4.2.4 Ash content

An examination of the data in the Table 5 and 6 shows that considerable changes were observed in the ash content of the fodder grasses in rabi and summer season across coconut garden and open contiguous area. During rabi season, maize (15.11 per cent) showed maximum ash content but that is on par with bajra (13 per cent) in coconut garden. Among the open grown grasses also, maize (12.56 per cent) exhibited maximum ash content, which is also on par with sorghum (12.33 per cent). The least ash content in open area is noticed in bajra (8.44 per cent).

During summer season also, fodder maize (12.56 per cent) showed highest percentage of ash content in coconut garden, which is also on par with bajra (11.11 per cent) and hybrid napier (12.11 per cent). Regarding the percentage of ash content in open contiguous area, maize (14.44 per cent) observed to have significantly higher ash content. During summer also, minimum content of ash is noticed in bajra (10.00 per cent) in open contiguous area.

The general trend in the data table reveals that the content of ash is found to be slightly higher in open contiguous area than coconut garden in both seasons. Also, the summer grown fodder grasses exhibit comparatively more ash content percentage that rabi grown grasses. During both the seasons in coconut garden and open area, maize fodder observed to have highest percentage of ash content and bajra the least.

Table 5. Quality attributes of cereal and grass fodders in coconut garden and open areas during rabi season

Treatments	Dry matter (%)	Crude protein (%)	Crude fibre (%)	Ash content (%)
Coconut garden				
T1-Maize	18.30	9.57^{ab}	29.67^{b}	15.11^{a}
T2-Sorghum	24.50	5.54^{cd}	31.00^{ab}	9.44^{bc}
T3-Bajra	18.50	5.90^{c}	29.50^{b}	13.00^{a}
T4-Hybrid napier	20.80	7.23^{bc}	31.17^{a}	8.89^{bc}
Open area				
T5-Maize	24.10	7.29^{bc}	25.17^{c}	12.56^{a}
T6-Sorghum	25.20	5.93^{c}	33.17^{a}	12.33^{ab}
T7-Bajra	19.70	5.39^{c}	29.67^{b}	8.44^{c}
T8-Hybrid napier	21.00	5.08^{d}	31.47^{a}	9.42^{c}
P	>0.05	<0.05	<0.05	<0.05
CD	-	3.07	3.18	2.89

Values with same superscript in a column do not differ significantly
p>0.05, significant at 5 % level of significance
p<0.05, non-significant at 5 % level of significance
CD: critical difference

Table 6. Quality attributes of cereal and grass fodders in coconut garden and open areas during summer season

Treatments	Dry matter (%)	Crude protein (%)	Crude fibre (%)	Ash content (%)
Coconut garden				
T1-Maize	18.74^{b}	13.36^{a}	24.33	12.56^{a}
T2-Sorghum	24.26^{a}	8.86^{b}	30.23	9.56^{b}
T3-Bajra	19.06^{b}	6.73^{c}	25.33	11.11^{a}
T4-Hybrid napier	21.58^{ab}	8.28^{b}	33.00	12.11^{ab}
Open area				
T5-Maize	19.61^{b}	9.92^{ab}	29.17	14.44^{a}
T6-Sorghum	24.70^{a}	8.39^{b}	34.54	11.33^{b}
T7-Bajra	19.98^{b}	6.00^{d}	28.16	10.00^{b}
T8-Hybrid napier	21.72^{ab}	7.09^{bc}	27.33	11.22^{b}
P	<0.05	<0.05	>0.05	<0.05
CD	4.19	5.36	-	2.63

Values with same superscript in a column do not differ significantly
p>0.05, significant at 5 % level of significance
p<0.05, non-significant at 5 % level of significance
CD: critical difference

4.2.5 Nitrogen content

The nitrogen content noticed during rabi and summer season in different land use systems are presented in Table 7 and 8. Observations revealed marginal changes in the nitrogen content between different fodder grasses. In rabi season, fodder maize in the coconut garden (1.53 per cent) as well as open area (1.55 per cent) showed higher nitrogen percentage, but that is found statistically on par with bajra (1.40 per cent) and hybrid napier (1.16 per cent) respectively.

Similarly, in summer season also maize showed significantly higher nitrogen content in both coconut garden (1.72 per cent) and open contiguous area (1.74 per cent). In coconut garden the lowest nitrogen content is noticed in bajra (1.36 per cent). However, the percentage of nitrogen content in sorghum, bajra and hybrid napier in open area were found statistically insignificant.

Comprehensive analysis of the data reveals that generally nitrogen content is more in coconut garden as compared to open system. Also, the summer grown crops noticed to have slightly higher nitrogen content than rabi crops. During both the seasons, maize showed higher percentage of nitrogen in both land management systems.

4.2.6 Phosphorous content

No considerable changes were observed in plant phosphorous content across both land management systems between fodder grasses during summer season (Table 8). During rabi, the P content was noted relatively higher in hybrid napier and minimum in maize in coconut garden.

4.2.7 Potassium content

Insignificant differences were observed in the plant potassium content during summer season across the two land management systems. While in rabi K content was maximum in bajra and minimum in sorghum.

Also, the grasses grown in open contiguous area showed a small increase in potassium content when compared to coconut garden.

Table 7. Plant nutrient content of cereal and grass fodders in coconut garden and open areas during rabi season

Treatments	N (%)	P (%)	K (%)
Coconut garden			
T1-Maize	1.53^{ab}	0.20^{d}	1.39^{b}
T2-Sorghum	1.07^{c}	0.31^{c}	1.30^{c}
T3-Bajra	1.40^{ab}	0.34^{bc}	1.46^{b}
T4-Hybrid napier	1.16^{bc}	0.44^{b}	1.36^{b}
Open area			
T5-Maize	1.52^{ab}	0.27^{cd}	1.48^{b}
T6-Sorghum	1.01^{c}	0.36^{bc}	1.29^{b}
T7-Bajra	1.09^{c}	0.64^{a}	1.62^{a}
T8-Hybrid napier	1.16^{bc}	0.60^{a}	1.55^{a}
P	<0.05	<0.05	<0.05
CD	0.49	0.12	0.09

Values with same superscript in a column do not differ significantly
p>0.05, significant at 5 % level of significance
p<0.05, non-significant at 5 % level of significance
CD: critical difference

Table 8. Plant nutrient content of cereal and grass fodders in coconut garden and open areas during summer season

Treatments	N (%)	P (%)	K (%)
Coconut garden			
T1-Maize	1.72^{ab}	0.32	1.47
T2-Sorghum	1.40^{b}	0.60	1.20
T3-Bajra	1.36^{c}	0.42	1.42
T4-Hybrid napier	1.65^{ab}	0.64	1.41
Open area			
T5-Maize	1.74^{a}	0.47	1.39
T6-Sorghum	1.10^{bc}	0.40	1.30
T7-Bajra	1.09^{c}	0.67	1.37
T8-Hybrid napier	1.30^{bc}	0.48	1.36
P	<0.05	>0.05	>0.05
CD	0.86	-	-

Values with same superscript in a column do not differ significantly
p>0.05, significant at 5 % level of significance
p<0.05, non-significant at 5 % level of significance
CD: critical difference

4.3 UNDERSTOREY PHOTOSYNTHETICALLY ACTIVE RADIATION

Diurnal variations in Understorey Photosynthetically Active Radiation (PAR) in coconut garden and open contiguous area were distinct during rabi and summer season (Table 9). During rabi season, the understorey PAR transmittance ranged from 30.57 to 83.20 per cent in coconut garden to that of open area, while in summer, it was in the range of 28.75 per cent to 81.60 per cent. In coconut garden, mean photosynthetic photon flux density (PPFD) ranged from 106 µ moles m^{-2} sec^{-1} (5-6 p.m.) to 1573 µ moles m^{-2} sec^{-1}(1-2 p.m.) during rabi season. Similarly, in summer season, PPFD ranged from 240 µ moles m^{-2} sec^{-1} (5-6 p.m.) to 1675µ moles m^{-2} sec^{-1}(1-2 p.m.). In open contiguous area, mean photosynthetic photon flux density (PPFD) during rabi season ranged from 300 µ moles m^{-2} sec^{-1} (5-6 p.m.) to 1679 µ moles m^{-2} sec^{-1}(1-2 p.m.). Similarly, in summer season, PPFD ranged from 112 µ moles m^{-2} sec^{-1} (5-6 p.m.) to 1222µ moles m^{-2} sec^{-1} (1-2 p.m.). Mean mid-day (12-1 p.m.) understorey photosynthetic photon flux density (PPFD) levels in coconut garden and open area were 1564 µ moles m^{-2} sec^{-1} and 1011 µ moles m^{-2} sec^{-1} respectively in rabi season. Mean mid-day understorey PPFD during summer season were 1612 µ moles m^{-2} sec^{-1} and 970 µ moles m^{-2} sec^{-1} in open area and coconut garden respectively. Mean daily transmittance in coconut garden during rabi and summer season were 55.74 and 56. 83 per cent respectively.

4.4 Economics

Economics and benefit: cost (B:C) ratio for cultivation of various fodder grasses in the two land management systems during rabi and summer season are given Table 10 and 11. In general, the B:C ratio for maize cultivation in open area was found to be significantly higher during both seasons. Bajra and hybrid napier also observed to have B:C ratio more than 1 in both land use system. However, sorghum noticed to have B:C ratio less than 1 during both season in coconut garden as well as open area.

Table 9. Understorey Photosynthetically Active Radiation in open contiguous area and coconut garden during rabi and summer season.

Time (Hours)	Rabi			Summer		
	I1	I2	PAR Transmittance (%)	I1	I2	PAR Transmittance (%)
08:00:00	320	135	42.87	425	198.5	46.70
09:00:00	804	347	43.05	503	245	35.67
10:00:00	1005	543	52.87	849	447	52.65
11:00:00	1215	954	64.96	1205	880	73.00
12:00:00	1564	1011	65.40	1612	970	60.14
13:00:00	1679	1374	69.85	1675	1222	72.95
14:00:00	1245	1573	83.20	1563	1276	81.60
15:00:00	1214	993	74.95	1435	1113	77.60
16:00:00	1054	723	42.53	1165	505	43.37
17:00:00	765	634	42.94	865	282	42.65
18:00:00	300	106	30.57	240	112	38.75
Mean daily transmittance	-	-	55.74	-	-	56.83

I1: above canopy PAR value (µ moles m^{-2} sec^{-1})
I2: below canopy PAR value (µ moles m^{-2} sec^{-1})

Table 10. Economics of fodder production in coconut garden and open contiguous area during rabi season

Treatments	Total cost of fodder production during rabi (₹/ ha)	Returns from fodder during rabi (₹/ ha)	B:C ratio
Coconut garden			
T1-Maize	133750	286400	2.14
T2-Sorghum	122450	70000	0.57
T3-Bajra	111700	143010	1.28
T4-Hybrid napier	145950	169350	1.16
Open area			
T1-Maize	133750	309600	2.31
T2-Sorghum	122450	106400	0.87
T3-Bajra	111700	179910	1.61
T4-Hybrid napier	145950	180540	1.24

*Returns were calculated based on the current market prices of fodder

Table 11. Economics of fodder production in coconut garden and open contiguous area during summer season

Treatments	Total cost of fodder production during summer (₹/ ha)	Returns from fodder during summer (₹/ ha)	B:C ratio
Coconut garden			
T1-Maize	155625	309400	1.99
T2-Sorghum	145520	75300	0.52
T3-Bajra	135720	104130	0.77
T4-Hybrid napier	164765	203400	1.23
Open area			
T1-Maize	155625	350760	2.25
T2-Sorghum	145520	106525	0.73
T3-Bajra	135720	139650	1.03
T4-Hybrid napier	164765	223320	1.36

*Returns were calculated based on the current market prices of fodder

4.5 GROWTH AND YIELD PARAMETERS OF CEREAL AND GRASS FODDERS UNDER HOMEGARDEN AND CONTIGUOUS OPEN AREA IN RABI AND SUMMER SEASON

4.5.1 Plant height of fodder grasses

The data on plant height of the cereal and grass fodders (45 DAP/DAS) during rabi and summer season are presented in Table 12. Fodder crops grown in homegarden and contiguous open area exhibited significant differences in plant height throughout the study period. Observations also revealed that appreciable differences existed among the cultivated fodder crops during both the seasons.

During both the rabi and summer season the fodder crops grown in open area under full sunlight conditions showed maximum plant height as compared to homegarden. Fodder maize recorded maximum plant height in homegarden in rabi (122.16 cm) and summer season (124.53 cm) whereas in open contiguous area, bajra fodder has attained maximum plant height during both the seasons (188.83 cm and 189.73 cm respectively). Fodder bajra attained the minimum height in homegarden during both the seasons (63.17cmand 65.06cm). The plant height of maize and sorghum was found statistically on par in homegarden during both seasons. Similarly, in open contiguous area with full sunlight there is no significant difference between bajra and sorghum for rabi as well as summer season. The percentage reduction in height of plant in homegarden as compared to open area during rabi in maize, sorghum, bajra and hybrid napier is 29.62, 35.61, 66.55 and 15.37 per cent respectively, while in summer the reduction was 33.16, 43.43, 68.98 and 40.27 per cent respectively.

In general, fodder grasses observed to have more plant height during summer season as compared to rabi in both land use systems. During both seasons, maize and sorghum noticed to have more plant height in homegarden, while in open area bajra and sorghum reached the maximum plant height in rabi as well as summer. The percentage reduction in plant height in homegarden as compared to open area is found more in bajra.

.4.5.2 Number of leaves of fodder grasses

The data on number of leaves of the fodder grasses (45 DAP/DAS) during rabi and summer season are presented in Table 12. During both the seasons, maximum number of leaves was observed in maize (8.77 and 9.17) and hybrid napier (10.63 and 9.97) grown under open conditions. Also, during summer season, there is no significant difference in number of leaves between hybrid napier grown under homegarden (9.17) and open contiguous area (9.97). Fodder sorghum grown under homegarden showed the least number of leaves during rabi (5.83) and summer season (6.83).

Thus, it can be inferred that during both seasons under homegarden as well as open area, maximum number of leaves was noticed in hybrid napier and maize. Also, the number of leaves is more during summer season and those cultivated under open contiguous area.

4.5.3 Number of tillers of fodder grass

The data on number of tillers of the fodder grasses (45 DAP/DAS) during rabi and summer season are presented in Table 12. During rabi and summer season, sorghum cultivated in open area exhibited the maximum count on number of tillers (9.63 and 11.40). The number of tillers of sorghum (11.40) and hybrid napier (10.27) grown in open area was found to be statistically on par during summer season. Fodder maize didn’t show any tillering throughout the growth period.

In general, more tillering was observed during summer season in open contiguous area. Fodder sorghum obtained highest number of tillers in both land management systems during rabi as well as summer season.

Table 12. Growth parameters of fodder crops (45 DAP/ DAS) in homegarden and open condition during rabi and summer season.

	Rabi season			Summer season		
Treatments	Height (cm)	No. of leaves	No. of tillers	Height (cm)	No. of leaves	No. of tillers
Homegarden						
T1-Maize	122.16^{c}	8.10^{bc}	0.00^{e}	124.53^{c}	8.53^{bc}	0.00^{e}
T2-Sorghum	117.67^{cd}	5.83^{c}	7.50^{b}	124.30^{c}	6.83^{c}	9.40^{b}
T3-Bajra	63.17^{f}	7.20^{bc}	1.83^{d}	65.06^{e}	8.10^{bc}	1.83^{cd}
T4-Hybrid napier	93.58^{e}	7.97^{bc}	2.50^{c}	101.00^{d}	9.17^{ab}	4.50^{c}
Open area						
T5-Maize	173.58^{b}	8.77^{ab}	0.00^{e}	186.30^{b}	9.17^{ab}	0.00^{e}
T6-Sorghum	182.75^{ab}	7.53^{bc}	9.63^{a}	219.76^{a}	8.07^{bc}	11.40^{a}
T7-Bajra	188.83^{a}	7.93^{bc}	2.97^{c}	209.73^{ab}	8.30^{bc}	3.77^{c}
T8-Hybrid napier	110.58^{d}	10.63^{a}	1.87^{d}	174.97^{b}	9.97^{a}	10.27^{a}
P	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
CD	9.68	2.40	0.87	21.15	1.59	2.08

Values with same superscript in a column do not differ significantly
p>0.05, significant at 5 % level of significance
p<0.05, non-significant at 5 % level of significance
CD: critical difference

4.5.4 Green fodder yield

Substantial changes were noticed in the green fodder yield across homegarden and open contiguous area during first and second harvest in rabi and summer season (Table 13 and Table 14). In general, open grown fodder grasses showed a consistently higher green fodder yield and varied considerably from homegarden.

It was observed that during rabi, the green fodder yield of all the four fodder grass grown in two land use systems exhibited a considerable increase from first harvest to second harvest. In open conditions, maize (35.73 and 41.51 Mg ha^{-1}) and sorghum (17.04 and 18.15 Mg ha^{-1}) yielded the maximum and minimum green fodder respectively across the two harvests. But in homegarden, during first harvest, maize showed the highest green fodder yield of 28.21 Mg ha^{-1} while in second harvest hybrid napier out performed maize with a green fodder yield of 41.51 Mg ha^{-1}. In homegarden during both the harvests, fodder sorghum yielded the least (9.01 and 9.51 Mg ha^{-1}). There are no significant differences in the green fodder yield of maize and hybrid napier during the two harvests in rabi season in respective land use systems. The reduction in cumulative green fodder yield of maize, bajra, sorghum and hybrid napier in response to shade in rabi is 38.72, 47.37, 28.87 and 14.20 per cent respectively.

During summer season, the green fodder yield of all fodder grass increased from first to second harvest in both the land use systems. During the first harvest, maize (50.02 Mg ha^{-1}) and hybrid napier (33.6 Mg ha^{-1}) showed the maximum green fodder yield in open area and homegarden respectively. However, the yield of maize and hybrid napier found to be statistically on par in homegarden. Fodder sorghum yielded the least green fodder in open (19.1 Mg ha^{-1}) as well as in homegarden (10 Mg ha^{-1}) in first harvest. During the second harvest, fodder maize exhibited the maximum green fodder yield in both open area (52.3 Mg ha^{-}1) as well as homegarden (41.5 Mg ha^{-1}). But there is statistically no significant difference between the yield of maize and hybrid napier in both the systems. In second harvest also, sorghum observed to produce the least green fodder yield in open area (20.20

Mg ha^{-1}) and homegarden (11.4 Mg ha^{-1}). The reduction in cumulative green fodder yield of maize, bajra, sorghum and hybrid napier as compared to open area is 21.24, 45.55, 24.54 and 7.18 per cent respectively in summer.

In general, it can be concluded that hybrid napier and maize yielded the maximum green fodder yield in both homegarden and open area during rabi and summer season. During rabi as well as in summer season, least performance in green fodder yield is noticed in sorghum in both the land use systems. The percentage reduction of yield in homegarden with respect to open contiguous area is found to be the maximum in sorghum in rabi and summer season, while in both seasons' hybrid napier exhibited the least reduction in green fodder yield.

4.5.5 Dry fodder yield

The data pertaining to dry fodder yield of different fodder grass under two land management systems during rabi and summer season are depicted in Table 13 and 14. The maximum dry fodder yield was observed in the open area throughout the growing period in both systems. In general, second harvest showed the maximum values of dry fodder yield.

During rabi, maize (8.20 Mg ha^{-1} and 9.84 Mg ha^{-1}) and hybrid napier (6.57 Mg ha^{-1} and 7.79 Mg ha^{-1}) showed significantly higher dry fodder yield in open area and homegarden at first and second harvest respectively. The minimum yield was observed in fodder sorghum in both the land use systems across all the harvests. It can also be seen that dry fodder yield of hybrid napier in open area and homegarden was on par, however maize showed significant differences in dry fodder yield across the two land use systems. The reduction in dry fodder yield in homegarden with respect to open contiguous area of maize, sorghum, bajra and hybrid napier is 41.82, 52.09, 32.98 and 14.35 per cent respectively.

In summer season, during first and second harvest, hybrid napier produced the highest dry fodder yield in homegarden (8.20 Mg ha^{-1} and 8.49 Mg ha^{-1}), while in open area maize (9.82 Mg ha^{-1} and 11.93 Mg ha^{-1}) out performed hybrid napier. During first harvest, significant differences exist in the dry fodder yield between maize and hybrid napier in respective land use systems. However, in the second harvest, dry fodder yield of both crops was statistically in par. In both harvests, lowest dry fodder yield is noticed in fodder sorghum (Table 13 and 14). The mean reduction in dry fodder yield of maize, sorghum, bajra and hybrid napier in homegarden when compared to open contiguous area is 34.30, 46.30, 34.62 and 6.73 per cent respectively during summer season.

In general, during rabi and summer season, hybrid napier and maize exhibited better performance in terms of dry fodder yield in homegarden and open area respectively. During both rabi and summer, the percentage reduction in dry fodder yield in response to shade was found to be maximum for sorghum and minimum for hybrid napier.

Table 13. Yield parameters of fodder crops in homegarden and open conditions during rabi season.

Treatments	First harvest		Second harvest		Cumulative yield	Cumulative yield
	Green fodder yield (Mg ha^{-1})	Dry fodder yield (Mg ha^{-1})	Green fodder yield (Mg ha^{-1})	Dry fodder yield (Mg ha^{-1})	Green fodder yield (Mg ha^{-1})	Dry fodder yield (Mg ha^{-1})
Homegarden						
T1-Maize	28.21^{bc}	5.07^{bcd}	28.95^{bc}	5.42^{c}	57.16^{c}	10.49^{c}
T2-Sorghum	9.01^{e}	2.12^{e}	9.51^{e}	2.35^{e}	18.52^{e}	4.47^{e}
T3-Bajra	10.61^{cd}	2.94^{de}	11.78^{cd}	3.42^{de}	33.38^{de}	6.36^{de}
T4-Hybrid napier	25.67^{bc}	6.57^{abc}	36.78^{b}	6.44^{bc}	60.42^{bc}	13.01^{bc}
Open area						
T5-Maize	35.73^{a}	8.20^{a}	41.51^{a}	9.84^{a}	93.27^{a}	18.03^{a}
T6-Sorghum	17.04^{cde}	4.57^{cd}	18.15^{cd}	4.76^{cd}	35.19^{d}	9.33^{cd}
T7-Bajra	21.10^{abcd}	4.64^{cd}	25.83^{bc}	4.86^{cd}	46.93^{c}	9.49^{cd}
T8-Hybrid napier	30.78^{ab}	7.40^{ab}	39.64^{b}	7.79^{b}	70.42^{b}	15.19^{ab}
P	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
CD	8.96	2.40	6.96	1.70	15.21	2.56

Values with same superscript in a column do not differ significantly
$p>0.05$, significant at 5 % level of significance
$p<0.05$, non-significant at 5 % level of significance
CD: critical difference

Table 14. Yield parameters of fodder crops in homegarden and open condition during summer season

Treatments	First harvest		Second harvest		Cumulative yield	Cumulative yield
	Green fodder yield (Mg ha^{-1})	Dry fodder yield (Mg ha^{-1})	Green fodder yield (Mg ha^{-1})	Dry fodder yield (Mg ha^{-1})	Green fodder yield (Mg ha^{-1})	Dry fodder yield (Mg ha^{-1})
Homegarden						
T1-Maize	32.00^{bc}	6.23^{c}	41.5^{ab}	8.06^{ab}	73.50^{b}	14.29^{bc}
T2-Sorghum	10.00^{d}	2.42^{e}	11.4^{d}	2.59^{d}	21.40^{d}	5.01^{de}
T3-Bajra	20.3^{c}	3.95^{d}	29.2^{bcd}	6.06^{bc}	49.50^{c}	10.01^{cd}
T4-Hybrid napier	33.60^{bc}	7.45^{bc}	39.70^{abc}	8.49^{ab}	73.51^{b}	15.94^{ab}
Open area						
T5-Maize	45.02^{a}	9.82^{a}	48.30^{a}	11.93^{a}	93.32^{a}	21.75^{a}
T6-Sorghum	19.1^{c}	4.63^{d}	20.2^{cd}	4.70^{cd}	39.30^{c}	9.33^{cd}
T7-Bajra	29.2^{c}	6.14^{c}	36.4^{ab}	9.17^{ab}	65.60^{b}	15.31^{bc}
T8-Hybrid napier	38.7^{b}	8.20^{b}	40.5^{abc}	8.89^{ab}	79.20^{b}	17.09^{ab}
P	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
CD	5.39	1.38	12.63	3.12	15.62	2.74

Values with same superscript in a column do not differ significantly
$p>0.05$, significant at 5 % level of significance
$p<0.05$, non-significant at 5 % level of significance
CD: critical difference

4.5.6 Productivity per day

The duration and per day productivity of fodder grasses in different land management systems during rabi and summer season is depicted in Table 15. In general, per day productivity of fodder crops were significantly higher in open contiguous area as compared to homegarden.

During the first harvest in rabi season, it can be noticed that the per day productivity of bajra is the maximum (0.46 Mg ha^{-1}day^{-1}) and this is also statistically on par with maize (0.41 Mg ha^{-1}day^{-1}). Among the open cultivated fodder grasses, the per day productivity of maize was significantly higher (0.94 Mg ha^{-1}day^{-1}). In both land management systems, sorghum fodder noticed to have the minimum per productivity (0.15 Mg ha^{-1}day^{-1} in homegarden and 0.28 Mg ha^{-1}day^{-1}in open area). While considering the second harvest, bajra (0.71 Mg ha^{-1}day^{-}1) and maize (0.63 Mg ha^{-1}day^{-1}) observed to have the highest per day productivity in homegarden. The per day productivity of bajra (0.89 Mg ha^{-1}day^{-1}) is also found to be the maximum in open area during the second harvest, but this is found to be statistically on par with maize (0.73 Mg ha^{-1}day^{-1}). During the second harvest also, sorghum attained the minimum per day productivity in both land management systems (0.21 Mg ha^{-1}day^{-1} in homegarden and 0.31 Mg ha^{-1}day^{-1} in open area).

In summer season, during the first harvest in homegarden, hybrid napier (0.86 Mg ha^{-1}day^{-1}) attained a significantly higher per day productivity, while in open area maize (1.13 Mg ha^{-1}day^{-}1) yielded the maximum. However, during the second harvest, the per day productivity of hybrid napier (0.90 Mg ha^{-1}day^{-1}) was maximum but this is found to be statistically on par with maize (0.69 Mg ha^{-1}day^{-1}). Fodder bajra (1.03 Mg ha^{-1}day^{-1}) produced the maximum per day productivity in open area during the second harvest and this is also found to be on par with maize (0.95 Mg ha^{-1}day^{-1}). Across all the harvest during summer, fodder sorghum yielded the least per day productivity in both land management systems.

In conclusion, during rabi season, maize and bajra attained the maximum per day productivity in homegarden as well as in open contiguous area. However, during summer season, hybrid napier yielded the maximum per day productivity in homegarden and maize and bajra produced the maximum in open contiguous area. In both land management systems fodder sorghum found to have the least per day productivity across the two seasons.

4.5.7 Duration of fodder crops

Considerable differences observed in the average duration of each fodder crop in rabi and summer season across the land management systems (Table 15). The duration of all the crops observed to be significantly higher in homegarden as compared to open area. Generally, the crop duration is shorter in summer than rabi season.

During rabi, average duration of maize and bajra was 70 and 55 days respectively during both harvests in homegarden whereas in open contiguous area the duration was 55 and 45 days respectively. Being perennial fodders, sorghum and hybrid napier have taken 80 and 90 days for the first harvest in homegarden and 65 and 70 days in open area. For the second harvest, sorghum noticed to have same duration in homegarden and open area (65 days), while duration of hybrid napier in homegarden and open area was 80 and 60 days respectively.

Seasonal fodders maize and bajra exhibited the same duration in summer season as that of rabi. Duration of perennial fodders, sorghum and hybrid napier during both harvests in homegarden was 65 and 45 days while in open area they have taken 45 and 40 days respectively.

Table 15. Duration and per day productivity of fodder crops during rabi and summer season in homegarden and open contiguous area

Treatments	Rabi				Summer			
	First harvest		Second harvest		First harvest		Second harvest	
	Duration	Per day productivity (Mg $ha^{-1} day^{-1}$)	Duration	Per day productivity (Mg $ha^{-1} day^{-1}$)	Duration	Per day productivity (Mg $ha^{-1} day^{-1}$)	Duration	Per day productivity (Mg $ha^{-1} day^{-1}$)
Homegarden								
T1-Maize	70	0.41^{cd}	70	0.63^{b}	70	0.53^{cd}	70	0.69^{bc}
T2-Sorghum	80	0.15^{f}	65	0.21^{d}	65	0.15^{f}	65	0.17^{d}
T3-Bajra	55	0.46^{c}	55	0.71^{b}	55	0.41^{e}	55	0.58^{c}
T4-Hybrid napier	90	0.32^{de}	80	0.38^{cd}	45	0.86^{b}	45	0.90^{ab}
Open area								
T5-Maize	55	0.94^{a}	55	0.73^{ab}	55	1.13^{a}	55	0.95^{a}
T6-Sorghum	65	0.28^{e}	65	0.43^{c}	45	0.43^{de}	45	0.45^{c}
T7-Bajra	45	0.57^{b}	45	0.89^{a}	45	0.65^{c}	45	1.03^{a}
T8-Hybrid napier	70	0.49^{bc}	60	0.53^{cd}	40	0.85^{b}	40	0.99^{a}
P	-	<0.05	-	<0.05	-	<0.05	-	<0.05
CD	-	0.11	-	1.38	-	0.12	-	3.12

Values with same superscript in a column do not differ significantly

$p>0.05$, significant at 5 % level of significance

$p<0.05$, non-significant at 5 % level of significance

CD: critical difference

4.6 PLANT QUALITY AND NUTRIENT ANALYSIS OF CEREAL AND GRASS FODDERS IN HOMEGARDEN DURING RABI AND SUMMER SEASON

4.6.1 Dry matter

Dry matter percentage of fodder grasses grown under the two land management systems during rabi and summer season is depicted in Table 16 and 17. Statistical analysis of the data revealed that there are no significant differences in dry matter percentage between fodder grasses during both season in open contiguous area and homegarden. The dry matter percentage is found generally higher in open cultivated grasses as compared to homegarden. Also, the summer grown crops show relatively higher dry matter percentage than rabi grown crops.

In rabi season, fodder sorghum shown maximum dry matter percentage in both homegarden (24.10 per cent) and open area (24.90 per cent). The minimum dry matter percentage is noticed in maize in homegarden (18.50 per cent) and open contiguous area (19.59 per cent). A similar pattern of results can also be derived for the summer grown crops (Table 6). The reduction in dry matter in homegarden as compared to open area during rabi season in maize, sorghum, bajra and hybrid napier is 5.56, 3.22, 4.56 and 3.27 per cent respectively, while during summer the percentage reduction in dry matter was 2.54, 3.97, 4.24 and 3.65 per cent respectively.

In general, maximum and minimum dry matter percentage is observed in sorghum and maize fodder respectively in both land management systems during rabi as well as summer season. Also. the reduction in dry matter percentage due to factor of shade is noticed most in maize and least in hybrid napier.

4.6.2 Crude protein

Table 16 and 17 depicts the crude protein content observed in the fodder grasses grown in homegarden and open contiguous area in rabi and summer season. Notable changes were examined in the crude protein content across the two land management systems as well as seasons.

During rabi season, the maximum crude protein in homegarden was noticed in maize (9.20 per cent) and the lowest observed in sorghum (6.68 per cent). However statistical analysis revealed that the crude protein content of sorghum is on par with bajra and hybrid napier in homegarden. In open contiguous area, there are no significant differences among the grasses in terms of crude protein content.

In summer season, fodder maize (10.01 per cent) shows significantly higher crude protein content in homegarden and the minimum protein content is observed in sorghum (6.49 per cent). In open area, maximum crude protein is noticed in maize (9.86 per cent) and it is found statistically on par with bajra (7.90 per cent) and hybrid napier (8.68 per cent). Fodder sorghum (6.22 per cent) showed the lowest crude protein content in open area during summer season.

From the statistical analysis of the data, it can be concluded that grasses grown in homegarden shows significantly higher crude protein content than those in open area. Also, the fodder grasses grown in summer season observed to have more crude protein content, in general than those in rabi season. During both the seasons, maize and sorghum showed the highest and lowest crude protein content respectively in both land management systems.

4.6.3 Crude fibre

The data on crude fibre content noticed across the two land use systems during rabi and summer season are given in Table 16 and 17. An analysis of the data in the table shows no prominent variations in the crude fibre content among different fodder grasses. There is also no significant variation in fibre content between homegarden and open contiguous area.

4.6.4 Ash content

An examination of the data in the Table 16 and 17 shows that considerable changes were observed in the ash content of the fodder grasses in rabi and summer season across homegarden and open contiguous area. During rabi season, maize (11.33 per cent) showed maximum ash content but that is on par with all other grasses i.e., sorghum (9.22 per cent), bajra (7.74 per cent) and hybrid napier (8.78 per cent) in homegarden. Among the open grown grasses also, maize (12.33 per cent) exhibited maximum ash content, which is also on par with sorghum (12.11 per cent) and hybrid napier (10.03 per cent). The least ash content in open area is noticed in bajra (8.33 per cent).

During summer season also, fodder maize (10.44 per cent) showed highest percentage of ash content in homegarden, which is also on par with sorghum (8.44 per cent), bajra (8.43 per cent) and hybrid napier (10.22 per cent). Regarding the percentage of ash content in open contiguous area, maize (12.67 per cent) observed to have the maximum and that is also found to be on par with sorghum (10.44 per cent) and hybrid napier (11.44 per cent). During summer also, minimum content of ash is noticed in bajra (9.22 per cent) in open contiguous area.

The general trend in the data table reveals that the content of ash is found to be slightly higher in open contiguous area than homegarden in both seasons. Also, the summer grown fodder grasses exhibit comparatively more ash content percentage that rabi grown grasses. During both the seasons in homegarden and open area, maize fodder observed to have highest percentage of ash content and bajra the least.

Table 16. Quality attributes of fodder crops in homegarden and open conditions during rabi season.

Treatments	Dry matter (%)	Crude protein (%)	Crude fibre (%)	Ash content (%)
Homegarden				
T1-Maize	18.50	9.20[a]	28.01	11.33[bcd]
T2-Sorghum	24.10	6.68[bc]	28.83	9.22[c]
T3-Bajra	18.80	7.83[b]	28.50	7.74[cd]
T4-Hybrid napier	20.7	8.24[b]	31.00	8.78[cd]
Open area				
T5-Maize	19.59	8.32[b]	32.01	12.33[ab]
T6-Sorghum	24.90	6.54[bc]	29.33	12.11[bc]
T7-Bajra	19.70	7.78[bc]	28.17	8.33[cd]
T8-Hybrid napier	21.40	8.12[b]	29.50	10.03[bc]
P	>0.05	<0.05	>0.05	<0.05
CD	-	3.57	-	3.86

Values with same superscript in a column do not differ significantly
p>0.05, significant at 5 % level of significance
p<0.05, non-significant at 5 % level of significance
CD: critical difference

Table 17. Quality attributes of fodder crops in homegarden and open conditions during summer season.

Treatments	Dry matter (%)	Crude protein (%)	Crude fibre (%)	Ash content (%)
Homegarden				
T1-Maize	19.20	10.01^{a}	29.07	10.44^{bc}
T2-Sorghum	24.20	6.49^{d}	29.75	8.44^{cd}
T3-Bajra	19.20	8.35^{c}	27.60	8.43^{cd}
T4-Hybrid napier	21.10	9.02^{bc}	30.07	10.22^{abc}
Open area				
T5-Maize	19.70	9.86^{b}	31.06	12.67^{ab}
T6-Sorghum	25.20	6.22^{d}	30.35	10.44^{bc}
T7-Bajra	20.05	7.90^{bc}	27.33	9.22^{c}
T8-Hybrid napier	21.90	8.68^{bc}	31.36	11.44^{ab}
P	>0.05	<0.05	>0.05	<0.05
CD	-	4.68	-	3.29

Values with same superscript in a column do not differ significantly
p>0.05, significant at 5 % level of significance
p<0.05, non-significant at 5 % level of significance
CD: critical difference

4.6.5 Nitrogen content

The nitrogen content noticed during rabi and summer season in different land use systems are presented in Table 18 and 19. In rabi season, fodder maize in the homegarden (1.79 per cent) as well as open area (1.49 per cent) showed significantly higher nitrogen percentage. The remaining fodder grasses such as sorghum, bajra and hybrid napier are statistically on par in both the land management systems (Table 18).

Similarly, in summer season also maize showed significantly higher nitrogen content in both homegarden (1.89 per cent) and open contiguous area (1.86 per cent). The percentage of nitrogen content in sorghum, bajra and hybrid napier in both systems were also found statistically insignificant (Table 19)

Comprehensive analysis of the data reveals that generally nitrogen content is more in homegarden as compared to open system. Also, the summer grown crops noticed to have slightly higher nitrogen content than rabi crops. During both the seasons, maize showed higher percentage of nitrogen in both land management systems and all others were statistically found insignificant in respective land use systems.

4.2.6 Phosphorous content

No considerable changes were observed in plant phosphorous content across both land management systems between fodder grasses during rabi and summer season (Table 18 and 19). During rabi and summer season, the observed phosphorous content is found slightly higher in open area as compared to homegarden. Bajra fodder showed maximum phosphorous content in respective land use systems during both seasons. Also, it is noticed that there is a slight increment in content of phosphorous during summer season.

4.2.7 Potassium content

Detailed analysis of Table 18 and 19 revealed that during rabi and summer season potassium content of all the four fodder grasses were on par ranging between 1.33- 1.41 per cent and 1.18-1.68 per cent respectively in homegarden. In open contiguous area during rabi, fodder bajra (1.50 per cent) exhibited maximum potassium content which is also statistically on par with hybrid napier (1.42 per cent). While in summer, hybrid napier (1.94 per cent) noticed to have maximum potassium content in open area and that is also found on par with bajra (1.91 per cent) in respective land management system.

In general, summer grown fodder grasses exhibited more potassium content than rabi crops. Also, the grasses grown in open contiguous area showed a small increase in potassium content as compared to homegarden. In open area, bajra and hybrid napier exhibited maximum potassium content during both seasons. However, in homegarden there are no significant differences among the fodder grasses in terms of potassium concentration.

Table 18. Plant nutrient content of fodder crops in homegarden and open conditions during rabi season

Treatments	N (%)	P (%)	K (%)
Homegarden			
T1-Maize	1.79[a]	0.30	1.33 [b]
T2-Sorghum	0.92[bc]	0.37	1.34 [b]
T3-Bajra	1.09[b]	0.40	1.41 [b]
T4-Hybrid napier	1.14[b]	0.19	1.35 [b]
Open area			
T5-Maize	1.49[a]	0.31	1.36 [b]
T6-Sorghum	0.95[bc]	0.22	1.37 [b]
T7-Bajra	0.89[bc]	0.41	1.50[a]
T8-Hybrid napier	1.00[b]	1.27	1.42[a]
P	<0.05	>0.05	<0.05
CD	0.57	-	0.10

Values with same superscript in a column do not differ significantly
p>0.05, significant at 5 % level of significance
p<0.05, non-significant at 5 % level of significance
CD: critical difference

Table 19. Plant nutrient content of fodder crops in homegarden and open conditions during summer season.

Treatments	N (%)	P (%)	K (%)
Homegarden			
T1-Maize	1.89^{a}	0.48	1.44^{b}
T2-Sorghum	1.17^{bc}	0.53	1.18^{b}
T3-Bajra	1.18^{bc}	0.52	1.40^{b}
T4-Hybrid napier	1.41^{ab}	0.38	1.68^{b}
Open area			
T5-Maize	1.86^{a}	0.46	1.78^{b}
T6-Sorghum	1.02^{c}	0.40	1.83^{b}
T7-Bajra	1.04^{c}	0.77	1.91^{a}
T8-Hybrid napier	1.23^{bc}	0.41	1.94^{a}
P	<0.05	>0.05	<0.05
CD	0.75	-	0.92

Values with same superscript in a column do not differ significantly
p>0.05, significant at 5 % level of significance
p<0.05, non-significant at 5 % level of significance
CD: critical difference

4.7 UNDERSTOREY PHOTOSYNTHETICALLY ACTIVE RADIATION

Diurnal variations in Understorey Photosynthetically Active Radiation (PAR) in homegarden and open contiguous area were distinct (Table 20). During rabi season, the understorey PAR transmittance ranged from 26.67 to 40.08 per cent in homegarden to that of open area, while in summer, it was in the range of 22.32 per cent to 73 per cent. In homegarden, mean photosynthetic photon flux density (PPFD) ranged from 40 μ moles m^{-2} sec^{-1} (5-6 p.m.) to 502 μ moles m^{-2} sec^{-1}(1-2 p.m.) during rabi season. Similarly, in summer season, PPFD ranged from 106 μ moles m^{-2} sec^{-1} (5-6 p.m.) to 1196μ moles m^{-2} sec^{-1}(1-2 p.m.). In open contiguous area, mean photosynthetic photon flux density (PPFD) during rabi season ranged from 191 μ moles m^{-2} sec^{-1} (5-6 p.m.) to 1684 μ moles m^{-2} sec^{-1}(1-2 p.m.). Similarly, in summer season, PPFD ranged from 297 μ moles m^{-2} sec^{-1} (5-6 p.m.) to 1635μ moles m^{-2} sec^{-1} (1-2 p.m.). Mean mid-day (12-1 p.m.) understorey photosynthetic photon flux density (PPFD) levels in homegarden and open area were 492 μ moles m^{-2} sec^{-1} and 1586 μ moles m^{-2} sec^{-1} respectively in rabi season. Mean mid-day understorey PPFD during summer season were 1518 μ moles m^{-2} sec^{-1} and 822 μ moles m^{-2} sec^{-1} in open area and homegarden respectively during summer season. Mean daily PAR transmittance in homegarden during rabi and summer season are 31.72 and 49.18 per cent respectively.

4.8 Economics

Economics and benefit: cost (B:C) ratio for cultivation various fodder grasses in the two land management systems during rabi and summer season are given Table 21 and 22. In general, the B:C ratio for maize cultivation in open area was found to be significantly higher during both seasons. Also, the B:C ratio for cultivation of maize in open and homegarden are statistically on par. Hybrid napier have B:C ratio greater than 1 in both land use systems. Bajra noticed to have B:C ratio more than 1 in open area during both seasons. But in rabi season bajra observed to have B:C ratio less than 1 in homegarden while in summer season B:C ratio was greater than 1. However, sorghum noticed to have B:C ratio less than 1 during both season in coconut garden as well as open area.

Table 20. Understorey Photosynthetically Active Radiation in open contiguous area and homegarden during rabi and summer season.

Time (Hours)	Rabi			Summer		
	I1	I2	PAR Transmittance (%)	I1	I2	PAR Transmittance (%)
08:00:00	216	86	38.80	315	128	40.00
09:00:00	560	224	40.08	321	134	41.32
10:00:00	1008	337	33.45	357	184	52.00
11:00:00	1110	359	32.34	615	322	52.65
12:00:00	1586	492	30.99	1518	822	54.52
13:00:00	1213	417	34.42	1617	1018	63.26
14:00:00	1684	503	29.87	1635	1196	73.00
15:00:00	1364	363	26.67	1372	853	62.00
16:00:00	476	371	32.25	1145	250	22.32
17:00:00	323	159	29.27	856	376	43.97
18:00:00	191	40	20.77	297	106	35.96
Mean daily transmittance	-	-	31.72	-	-	49.18

I1: PAR value in open contiguous area, I2: PAR value in homegarden

Table 21. Economics of fodder production in homegarden and open contiguous area during rabi season

Treatments	Total cost of fodder production during summer (Rs/ ha)	Returns from fodder during summer (Rs/ ha)	B:C ratio
Homegarden			
T1-Maize	1,53,620	2,94,000	1.91
T2-Sorghum	1,42,250	53,500	0.38
T3-Bajra	1,31,620	1,48,500	1.13
T4-Hybrid napier	1,45,700	2,19,900	1.51
Open area			
T1-Maize	1,53,620	3,73,280	2.43
T2-Sorghum	1,42,250	98,250	0.69
T3-Bajra	1,31,620	1,96,800	1.50
T4-Hybrid napier	1,45,700	2,37,600	1.63

*Returns were calculated based on the current market prices of fodder grasses

Table 22. Economics of fodder production in homegarden and open contiguous area during summer season

Treatments	Total cost of fodder production during rabi (Rs/ ha)	Returns from fodder during rabi (Rs/ ha)	B:C ratio
Homegarden			
T1-Maize	1,22,420	2,28,640	1.87
T2-Sorghum	1,11,400	46,300	0.42
T3-Bajra	1,02,420	67,170	0.66
T4-Hybrid napier	1,34,500	1,87,350	1.39
Open area			
T1-Maize	1,22,420	3,08,960	2.52
T2-Sorghum	1,11,400	87,975	0.79
T3-Bajra	1,02,420	1,40,790	1.37
T4-Hybrid napier	1,34,500	2,11,260	1.57

*Returns were calculated based on the current market prices of fodder grasses

Discussion

5. DISCUSSION

The results of the experiment titled "On-farm evaluation of selected cereal fodders in prominent land use systems of Kerala" are discussed here under with reference to the published literature on the subject.

5.1 GROWTH AND YIELD ATTRIBUTES OF CEREAL AND GRASS FODDERS UNDER COCONUT GARDEN AND CONTIGUOUS OPEN AREA IN RABI AND SUMMER SEASON

5.1.1 Plant height of fodder grasses

Plant growth and development are influenced by environmental factors such as light intensity and temperature. There will be a minimum, optimum and maximum light intensity required for plant growth and development because such factors determine the species which can be effectively grown in a region (Hakansson *et al.* 2002). The relative growth rate of plant species can differ tremendously. This could be due to habitat-related changes in abiotic elements like temperature, water, light, and nutrition (Poorter, 1989). In the present study, open area cultivated fodder grasses shown relatively more plant height than coconut garden grown grasses during rabi as well as summer season (Table 1 and Fig 3). Shaded plants generally exhibited reduced growth and had lesser physiological responses than non-shaded plants (Rai *et al.*, 2012). However, Jose *et al.* (2019) observed that the plant height of hybrid napier variety CO3 was found more in coconut garden with PAR transmittance of 56.08 per cent than open plot with full sunlight.

In the current study, fodder bajra attained maximum plant height (141.08 and 144.83 cm) followed by maize (121.75 and127.41 cm), sorghum (109.75 and 124.00 cm) and hybrid napier (97.16 and 126.83 cm) in coconut garden during rabi and summer season respectively. The open area cultivated grasses also showed a similar trend in the height of plants. Also, the maximum percentage reduction in plant height due to shade was observed in fodder sorghum (32.14 % in rabi and

33.66 % in summer). Akhtar *et al*. (2013) also observed growth reduction in sorghum when grown as an intercrop.

The significant differences in plant height among the cultivated fodder grasses are due to genetic reasons. Plant height is a character that is influenced 80 percent by genetic constitution and less by environmental factors (Carli *et al.*, 2009).

5.1.2 Number of leaves

Leaf production in plants is directly associated with available light. In the current study, the number of leaves was observed more in open contiguous areas as compared to coconut garden (Table 1 and Fig 4). Jose *et al.* (2019) also recorded a reduction in the number of leaves in the coconut garden for different fodder grass species as compared to open areas. This is due to the reduction in rate of leaf development due to reduced PAR transmittance (Gautier *et al*., 1999). Among the cultivated fodder grasses in the coconut garden, the number of leaves was obtained maximum in hybrid napier (8.50 and 10.30) followed by bajra (7.91 and 9.10), maize (6.83 and 8.16), and sorghum (4.91 and 5.87) during rabi and summer season respectively. Fodder grasses cultivated in the open contiguous area also exhibited a similar pattern. The reduction in leaves number was maximum in sorghum (19.2 %) followed by hybrid napier (17.71 %), maize (8.9 %), and bajra (3.9 %) during rabi season. However, in the summer season, the maximum reduction was seen in sorghum (25.30 %) followed by maize (22.51 %), hybrid napier (7.21 %), and bajra (5.16 %). Braconnier (1998) observed that the number of leaves present in the maize plants increased with available light. He recorded that the average number of leaves in maize plants at 100, 72, 41, and 31 per cent PAR transmission was 11.1, 10.6, 10.6, and 10.1 respectively.

5.1.3 Number of tillers

The most critical factor influencing tillering ability in plants is the availability of light. Adequate lighting at the base of plants results in active basal vegetative buds, thus producing tillers (Santos and Diola, 2015). In the present experiment, the open contiguous area cultivated fodder grasses were noticed to have more tillers than coconut garden (Table 1). Tiller production by COFS-31 sorghum fodder variety was noticed to have a reduction in tillering when intercropped with fodder cowpea (Prasanth *et al.,* 2019). During the entire study period, a direct relationship exists between the number of tillers and available PAR.

Among the cultivated fodder grasses in the coconut garden, sorghum (6.13 and 10.30) was noticed to have the maximum number of tillers followed by hybrid napier (2.08 and 5.53) and bajra (4.25 and 4.60) during the rabi and summer season respectively. In hybrid napier, the production of tillers increased after each cutting. The reduction in tillering was maximum in bajra fodder (35.41 %) during the summer season and hybrid napier (37.21 %) during rabi season in coconut garden as compared to open plots. The minimum reduction in tillering was recorded in sorghum during rabi (16.14 %) as well as summer season (11.44 %). Wadi *et al.* (2004) recorded that the number of regrown tillers was higher in plants cut at 60-day intervals. This was associated with a higher number of tiller buds and a higher total non-structural carbohydrate concentration in the stubble following cutting at a 30 cm height. Tillering was absent in the African tall maize fodder variety.

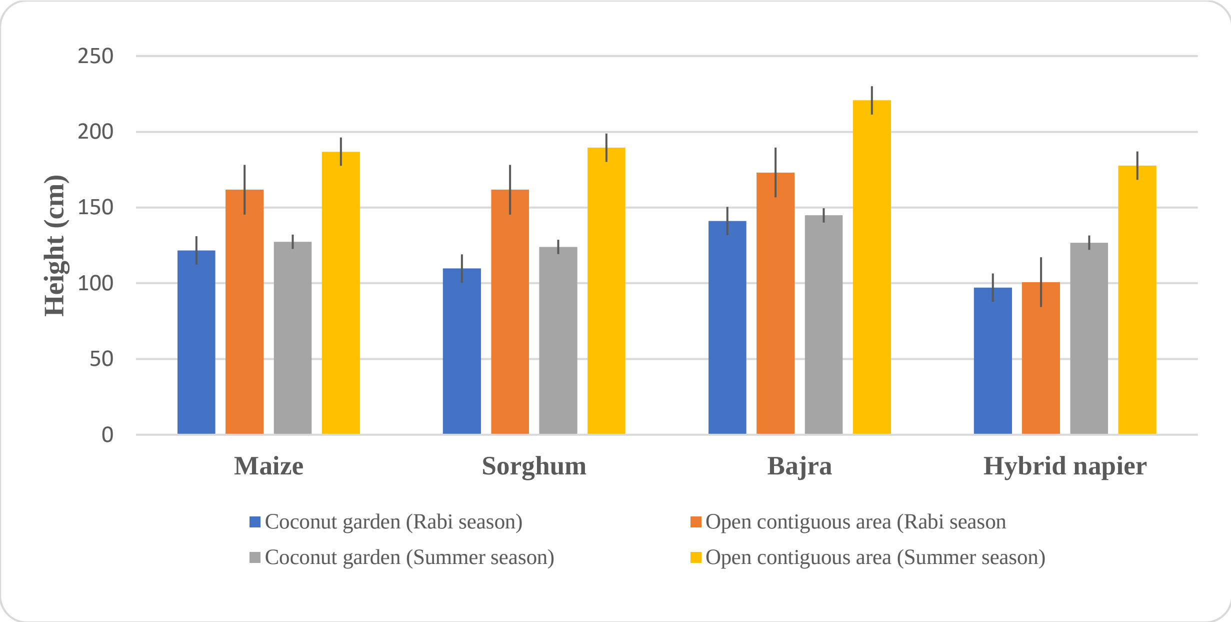

Fig 4. Plant height of fodder grasses in coconut garden and open contiguous area during rabi season.

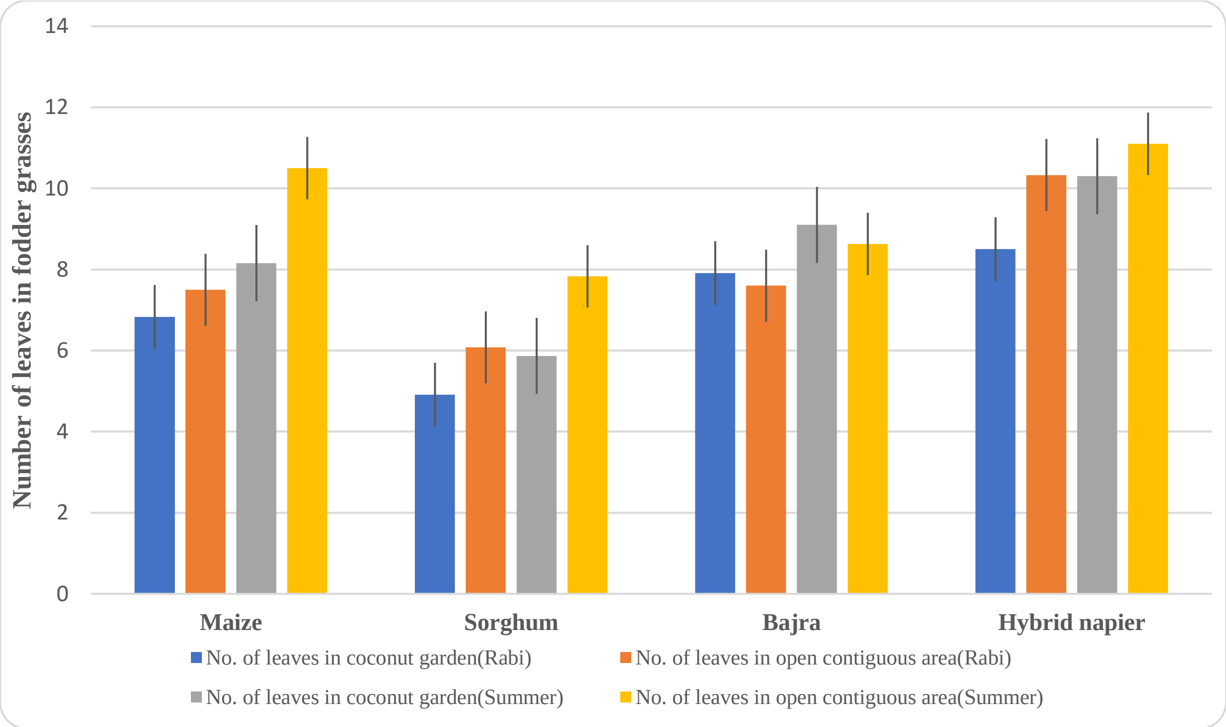

Fig 5. Number of leaves in different fodder grasses in coconut garden and open contiguous area during rabi and summer season.

5.1.4 Green fodder yield

The current study revealed that all the fodder species produced significantly higher yields under the open contiguous areas with full sunlight than coconut garden during the rabi and summer seasons (Fig 5 and 6). Among the cultivated fodder grasses in the open area, maize (77.40 and 87.69 Mg ha^{-1}) was noticed to have the maximum cumulative yield (From 2 crops per season) followed by hybrid napier (60.18 and 74.44 Mg ha^{-1}), bajra (59.97 and 46.55 Mg ha^{-1}), and sorghum (42.56 and 42.61 Mg ha^{-1}) during rabi and summer season respectively. The average yield per crop of maize was 38.70 Mg ha^{-1} and 43.85 Mg ha^{-1} during the rabi and summer season respectively. In the dry zone of Karnataka, Manoj *et al.* (2020) also recorded a comparable green fodder yield of 103 Mg $ha^{-1}yr^{-1}$ from three crops of maize (one crop per season). The green fodder yield of the bajra napier hybrid variety Suguna was 44.16 per cent higher in an open condition than in the coconut garden with 18-20 per cent shade. The productivity of *Pennnisetum purpureum is also* noticed to have been maximum in open conditions without shade by Muhtarudin *et al.,* (2020). However, feed quality was shown to be better in the shade than in the open plots (Deepthi *et al.,* 2021).

A similar yield trend was also observed in the coconut garden wherein the maximum green fodder yield was obtained in maize (71.60 and 77.35 Mg ha^{-1}) followed by hybrid napier (56.45 and 67.80 Mg ha^{-1}), bajra (47.67 and 34.71 Mg ha^{-1}), and sorghum (28.02 and 30.12 Mg ha^{-1}) during rabi and summer season respectively. The reduction in green fodder yield in coconut garden as compared to open contiguous area was least in hybrid napier (6.20 and 8.91 %) followed by maize (7.49 and 11.79 %), bajra (20.51 and 25.43 %), and sorghum (34.16 and 29.31 %). Even though grasses tolerate shade, the productivity will start declining when the percentage of shade received is more than 50 per cent (Soares *et al.,* 2009). Reduction in fodder productivity under canopies of trees happens because of the competitive interaction between trees and grasses for sunlight when moisture in the soil is not limiting (Pandey *et al.,* 2011). The mean daily PAR transmittance in the coconut garden during the rabi and summer season was 55.74 and 56.83 per cent.

Also, the mid-day par transmittance was estimated at 69.85 per cent and 72.95 per cent. Hence, the better light availability might be the reason for comparatively less reduction in the rate of production in coconut garden as compared to open contiguous areas in the present study. Braconnier (1998) recorded that fresh matter production (vegetative part) decreased from 13.8 Mg ha $^{-1}$ in the open to 6.2 Mg ha $^{-1}$ in a coconut garden that intercepted about 29 per cent of light radiation. In the present study, area of 7825.5 sq. m of land was available under coconut garden for cultivation of fodder grasses (excluding the coconut basin). Hence the cumulative green fodder yield of maize, sorghum, bajra and hybrid napier in one hectare of coconut garden was estimated to be 56.03, 21.93, 37.30 and 44.17 Mg ha^{-1} respectively during the rabi season, whereas in summer season the yield was 60.53, 23.57, 27.16 and 53.06 Mg ha^{-1} respectively.

5.1.5 Dry fodder yield

Dry fodder yield of different fodder grasses in open contiguous areas and coconut garden followed a similar pattern as that of green fodder production. The open contiguous area was consistently noticed to have maximum dry weight as compared to the coconut garden (Fig 5 and 6). The reduction in dry fodder yield of hybrid napier due to shade in the coconut garden is also recorded by Antony and Thomas (2016).

Among the fodder grasses, maize exhibited better performance in the coconut garden as well as open contiguous areas. In the coconut garden, the maximum cumulative dry fodder yield was noticed in maize (13.27 and 17.84 Mg ha^{-1}) followed by hybrid napier (11.65 and 13.18 Mg ha^{-1}), bajra (9.84 and 9.10 Mg ha^{-1}), and sorghum (6.85 and 7.03 Mg ha^{-1}) during rabi and summer season respectively. Also, the reduction in dry fodder yield was observed maximum in sorghum (30.24 %) and minimum in hybrid napier (9.65 %) during rabi season. However, the reduction was maximum in bajra (11.82 %) during the summer season and the least reduction was observed here also in hybrid napier (9.10). The reduction in forage yield due to shade in these fodder grasses are not that significant, which indicates the possibility of integrating cereal fodders in coconut garden for enhancing the livestock sector.

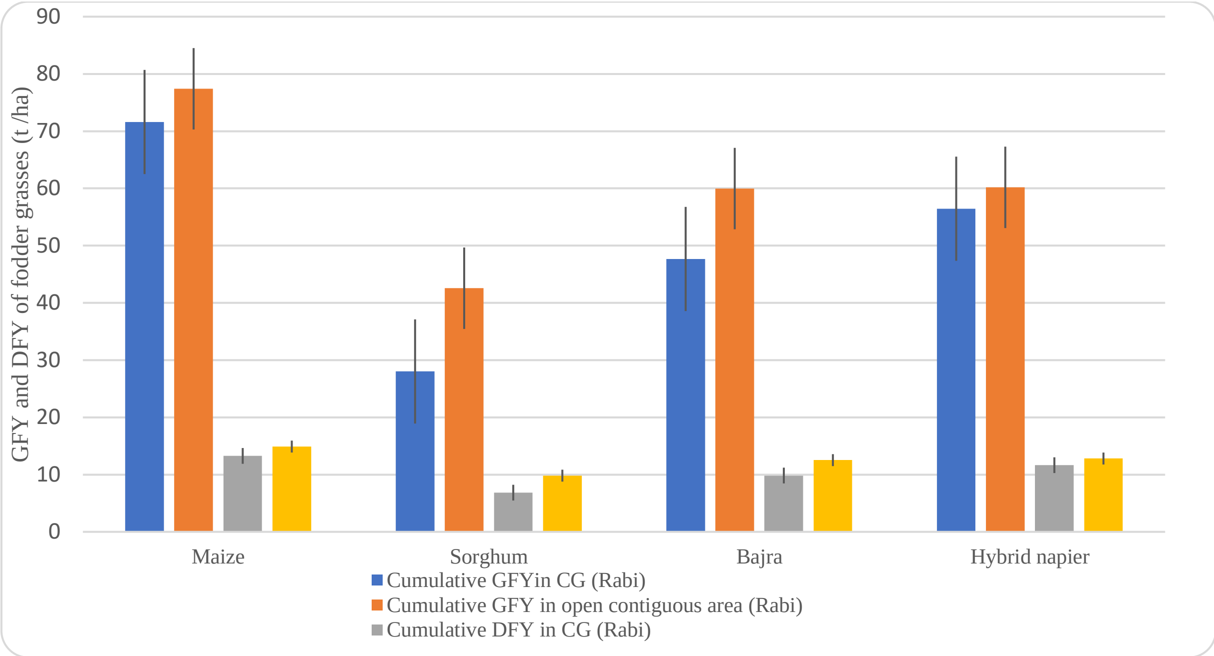

Fig 6. Cumulative green fodder yield (GFY) and dry fodder yield (DFY) of fodder grasses in coconut garden (CG) and open contiguous area during rabi season.

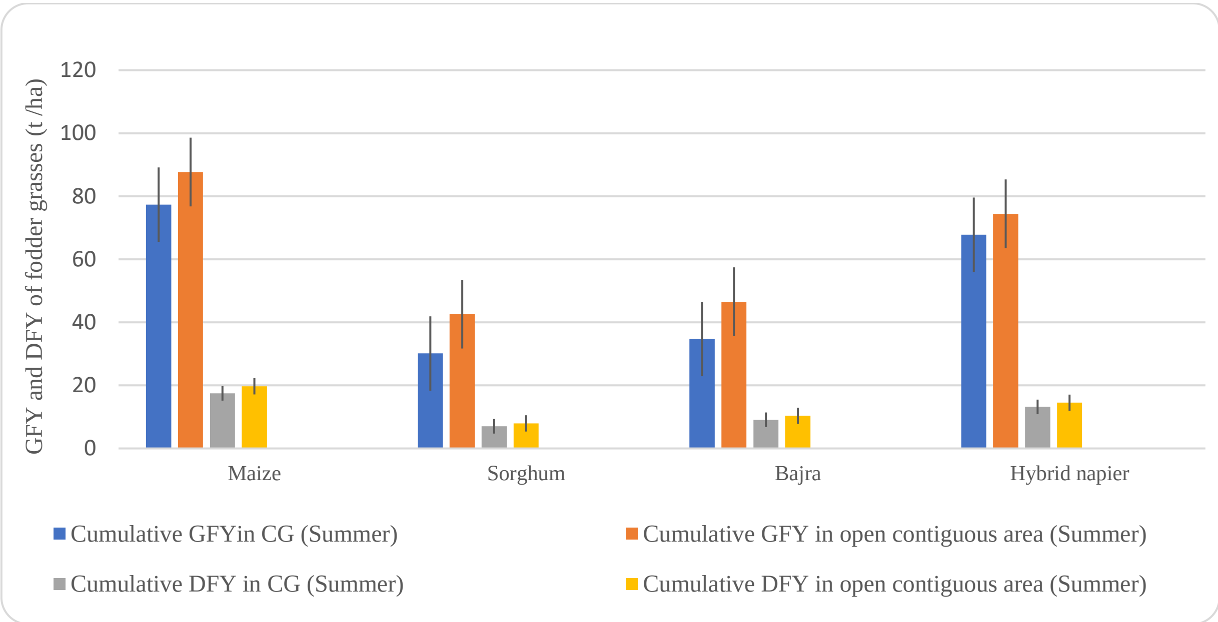

Fig 7. Cumulative green fodder yield (GFY) and dry fodder yield (DFY) of fodder grasses in coconut garden (CG) and open contiguous area during the summer season.

5.1.6 Per day productivity and duration of fodder grasses

Differences in species and land management systems have a significant influence on the harvesting period of fodder grasses. In general, the grasses grown in open conditions with full sunlight takes less duration and hence more per day productivity. Increment in the intensity of available light will correspondingly increase the rate of growth of fodder species (Maria *et al*., 2019). Throughout the study period, maize and bajra exhibited the maximum per day productivity in both land management systems (Table 12). Being seasonal fodders, the average duration of maize and bajra in the open contiguous areas was about 55 and 45 days, while in the coconut garden, the duration of these crops increased by about 5 days. This is due to the slower growth rate in coconut garden due to reduced PAR transmittance. The per-day productivity of hybrid napier in coconut garden was 0.38 and 0.40 Mg ha^{-1} day^{-1} during rabi and summer season respectively. This is low as compared to maize (0.63 Mg ha^{-1} day^{-1} in rabi and 0.66 Mg ha^{-1} day^{-1} in summer) and bajra (0.73 Mg ha^{-1} day^{-1} in rabi and 0.76 Mg ha^{-1} day^{-1} in summer).

Braconier (1998) also recorded that the amount of light received enhanced maize growth rate, leading it to grow faster and attained more height during the flowering period. Grass planted in shade has growth rates slower than grass cultivated in unshaded land. This is due to the reduced rate of photosynthesis in shaded land because of the reduction in PAR transmittance as compared to open area full sunlight (Muhtarudin *et al*., 2020).

5.1.7 Dry matter

The variations in dry matter content between fodder grasses and land management systems were found insignificant during rabi season. However, in the summer season, dry matter percentage exhibited significant differences. Generally, dry matter content was recorded more in open contiguous areas than in coconut garden (Fig 7 and 8). This might be due to the lesser amount of moisture content in fodder grasses grown in open contiguous areas. On considering the different fodder grasses in open contiguous areas, the percentage of dry matter was maximum in fodder sorghum (25.20 and 24.70 %) followed by hybrid napier (21.00 and 21.72 %), bajra (19.70 and 19.98 %), and maize (19.55 and 19.61 %) during rabi and summer season respectively. A similar trend was observed in the coconut garden also. A study on the nutritive composition of sorghum fodder by Chakravarthi *et al.* (2017) noted that the dry matter percentage of fodder sorghum was about 26.30 per cent. Kanduri *et al.* (2016) studied the proximate composition of African tall fodder maize and reported a dry matter percentage of 22.38. Norton *et al*. (1991) also recorded the reduction in dry matter content with the reduction in available light in tropical fodder grasses such as Guinea, Signal, and Bahia. The average annual yield of temperate forage grasses was reduced by 22 and 36 per cent at 50 and 70 per cent shade, respectively, when compared to full sunlight (Mercier *et al.*, 2020). Several other studies of temperate production systems have also found that dry matter yields are lower under shade or silvopasture systems than in open systems (Belesky, 2005; Feldhake *et al.*, 2010).

5.1.8 Crude protein

Crude protein content was considerably higher in fodder crops cultivated under coconut garden (Fig 7 and 8). Kaushal *et al.* (2000) and Sebetha *et al.* (2010) also observed similar findings in which the shade and percentage of crude protein have a direct relationship. The higher concentration of crude protein in grasses grown under coconut garden is due to the ability of grass to more easily absorb the availability of soil nitrogen under shaded conditions (Wilson and Ludlow, 1990; Wilson and Wong, 1982).

Among the cultivated fodder grasses in the coconut garden, maize fodder (9.57 %) had more crude protein content followed by hybrid napier (7.23 %), bajra (5.90 %), and sorghum (5.54 %) during rabi season. However, in the summer season, the protein content of sorghum (8.86 %) increased and outperformed bajra (6.73 %). In the southern dry zone of Karnataka, the CP content of maize was recorded as 9.90 per cent (Manoj *et al.*, 2020). The CP content of hybrid napier was noted as 9.98 per cent in coconut garden by Jose *et al.* (2019). The increase in crude protein content of fodder grasses in coconut garden as compared to open areas was maximum in hybrid napier (29.74 and 14.37 %), followed by maize (23.80 and 25.74 %), bajra (8.64 and 10.84 %), and least in sorghum (6.58 % and 5.64 %) during rabi and summer season respectively. Lin *et al.* (2001) also observed that the percentage of crude protein (CP) increased in most of the shade-grown forages under study. Allard *et al.* (1991) also obtained similar findings in tropical grasses. Kephart and Buxton (1993) discovered a 31 per cent increase in protein content in cold and warm-season grasses cultivated in 63 per cent shadow compared to plants grown in full sunlight. *Pennisetum purpureum* grass cultivated in the understorey of oil palm had an average crude protein content of 13.42 per cent, while the grasses grown in open fields had an average crude protein content of 11.99 per cent only (Muhtarudin *et al.,* 2020). Norton *et al.* (1991) also found that plants grown in shade had higher nitrogen content than plants grown on open land.

5.1.9 Crude fibre

Detailed analysis of the study revealed that crude fibre content in fodder grasses exhibited significant differences in rabi season only in two land management systems. During the current study, crude fibre content was found less in the coconut garden as compared to the open contiguous area (Fig 7 and 8). Studies revealed that shade reduces the crude fibre content in grasses. The presence of shade inhibits the occurrence of lignification processes in plant parts due to reduced light intensity. *Pennisetum purpureum* grass planted under the shade of oil palm has a lower crude fiber content (26.70 per cent with light intensity 2006.7 lux) than those planted in the land without shade (30.45 per cent with light intensity 12093.3 lux) (Muhtarudin *et al*., 2020).

In the coconut garden, crude fibre content was noticed minimum in maize (25.00 and 24.33 per cent), followed by bajra (29.50 and 25.33 per cent), sorghum (31.00 and 30.23 per cent), and hybrid napier (31.17 and 33.00 per cent) during rabi and summer season respectively. The reduced content of crude fibre in maize enhances the palatability of fodder and is preferred more compared to other fodders.

The crude fibre content of maize estimated during the study is lower than that of the result of Chaudhary *et al.* (2012). He recorded the crude fibre content in African tall fodder maize as 30.20 per cent. In the southern dry zone of Karnataka, the crude fibre content of sorghum and hybrid napier was estimated at 34.49 and 30.35 per cent respectively (Manoj *et al.*, 2020).

5.1.10 Ash content

The percentage of ash content in fodder grasses varied significantly throughout the study period. In general, the ash content was higher in open contiguous areas than in coconut garden (Fig 7 and 8). The increase in photosynthesis rate in open conditions might be the reason for increased mineral accumulation and consequent increase in ash content.

Considering the different grasses in the coconut garden, ash content was noticed maximum in maize (15.11 per cent) followed by bajra (13.00 per cent), sorghum (9.44 per cent) and hybrid napier (8.89 per cent) during rabi season. However, in the summer season, hybrid napier (12.11 per cent) outperformed both sorghum (9.56 per cent) and bajra (11.11 per cent). In another study, the percentage of ash content in fodder maize and sorghum was also recorded as 10.28 and 8.27 per cent respectively (Manoj *et al.,* 2020).

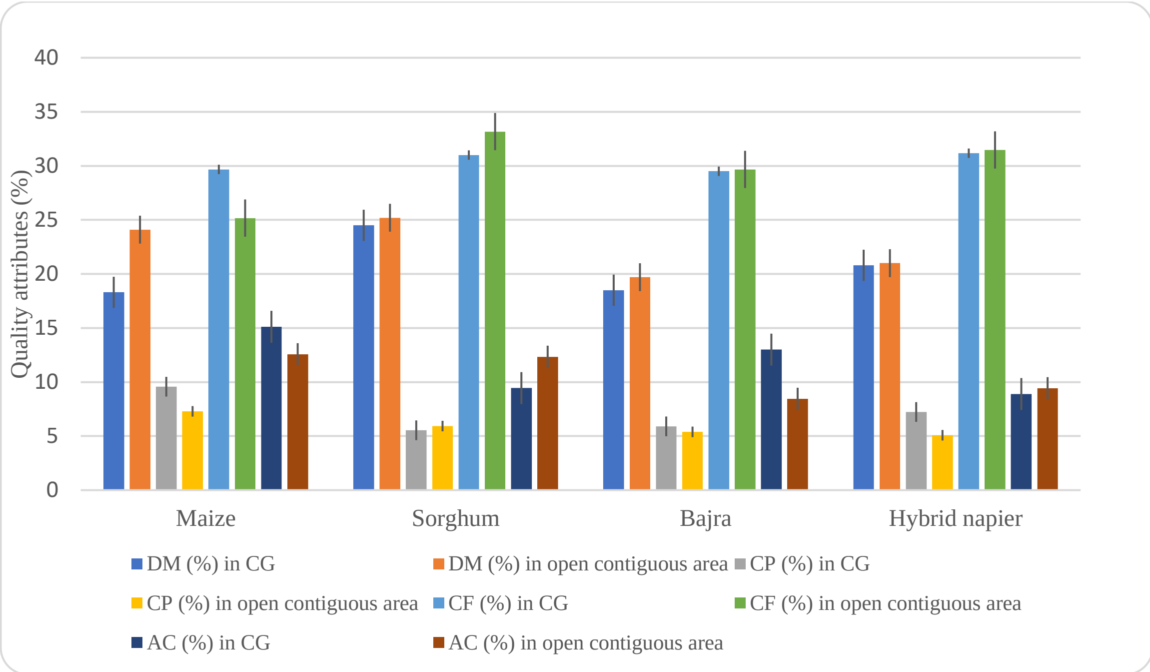

Fig 8. Quality attributes of fodder grasses in coconut garden (CG) and open contiguous area during rabi season.

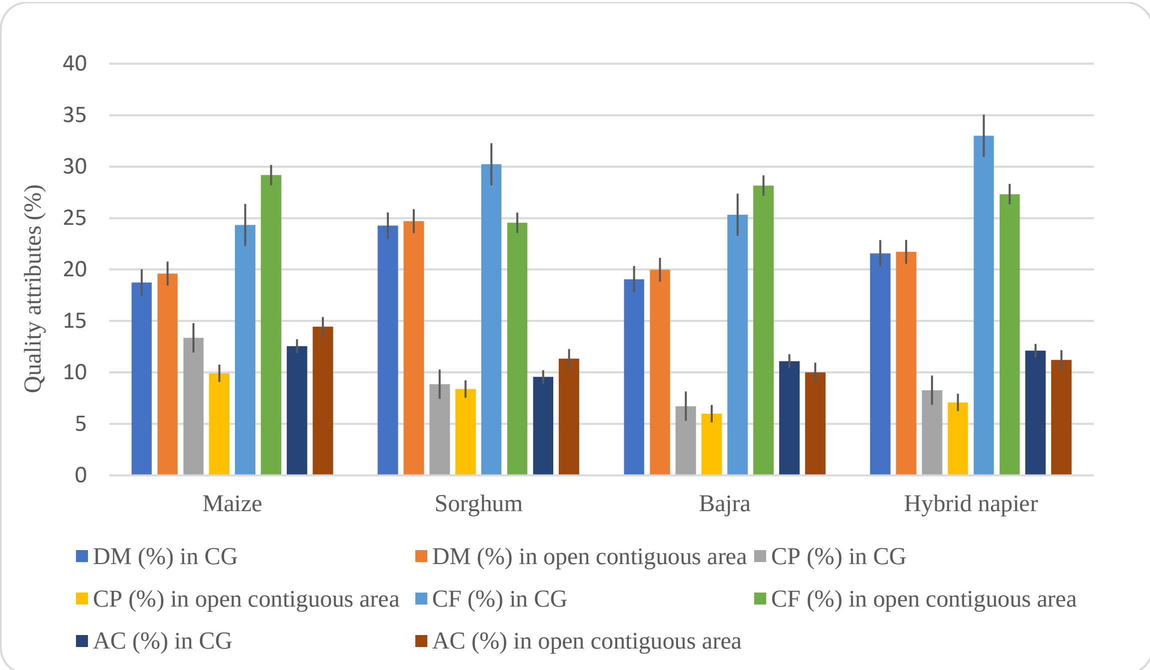

Fig 9. Quality attributes of fodder grasses in coconut garden (CG) and open contiguous area during summer season.

5.1.11 Nitrogen, Phosphorus and Potassium content of fodder

Fodder grasses under study exhibited significant differences in N, P, and K content during rabi season in coconut garden as well as open contiguous areas (Fig 9 and 10). In general, the grasses cultivated under the coconut garden show more N content. Several field experiments in silvopastoral systems also revealed a significant increase in growth and nutrient uptake, particularly N, in grasses grown under shade (Ovalle and Avendafio, 1988; Stuart-Hill and Tainton, 1989; Wilson *et al*., 1990). The presence of relatively higher moisture combined with moderate soil temperature in the shade might have resulted in a faster rate of N mineralization, litter breakdown and N turnover than that occurs in open conditions with full sunlight (Humphreys, 1994; Wilson, 1996). In the coconut garden, the N content was more in maize (1.53 per cent) followed by bajra (1.40 per cent), hybrid napier (1.16 per cent), and sorghum (1.07 per cent). A similar pattern of results was also observed in open contiguous areas. The N content in hybrid napier was also estimated as 1.15 per cent by Singh *et al.,* 2018.

The phosphorus content of fodder grasses also varied significantly in rabi season. In general P concentration was more in open-grown fodder grasses. in coconut garden during the rabi season, P concentration was maximum in hybrid napier (0.44 per cent) followed by bajra (0.34 per cent), sorghum (0.31 per cent), and maize (0.20 per cent).

The potassium content was also noticed in more open contiguous areas as compared to coconut garden. But bajra fodder exhibited more K content in the coconut garden than open areas. The reason for this is not clearly understood. In coconut garden, the K is found maximum in bajra (1.46 per cent) followed by maize (1.39 per cent), hybrid napier (1.36 per cent), and sorghum (1.30 per cent). The open contiguous area also followed a similar result.

In the summer season, nitrogen content only varied significantly among fodder grasses. However, phosphorus and potassium content exhibited insignificant differences in both land management systems. Nitrogen content in summer was noticed to have a similar trend as that of rabi season. In fodder maize, the recorded N, P, and K content by Singh *et al.* (2020) were 1.70, 0.25, and 0.72 per cent respectively. In maize leaf nutrient analysis by Braconnier (1998), an increase in N content with increasing shade was clearly evident. The N content in leaves at 100, 72, 41, and 31 per cent was estimated to be 2.95, 3.21, 3.37, and 3.49 per cent respectively.

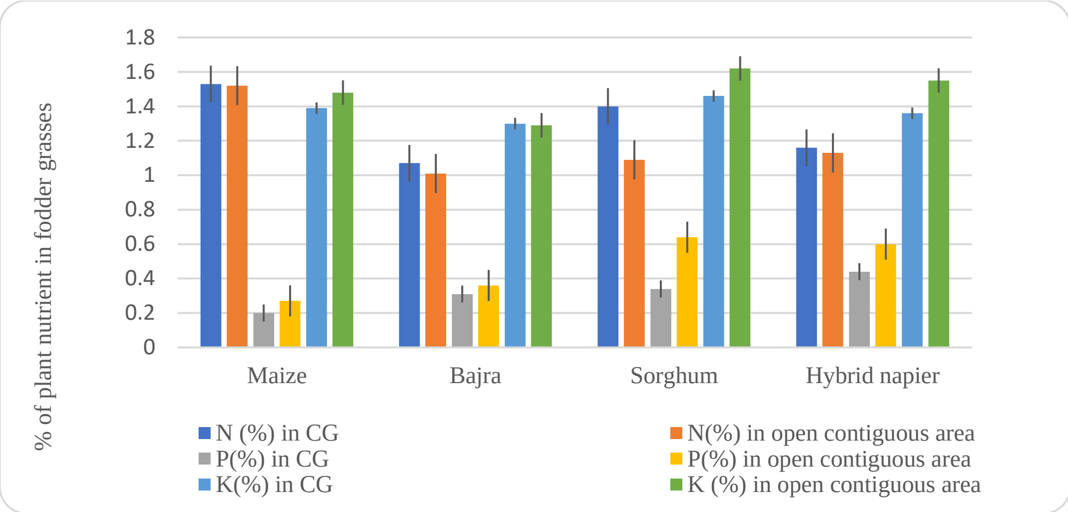

Fig 10. Plant nutrient content of fodder grasses in coconut garden (CG) and open contiguous area during rabi season.

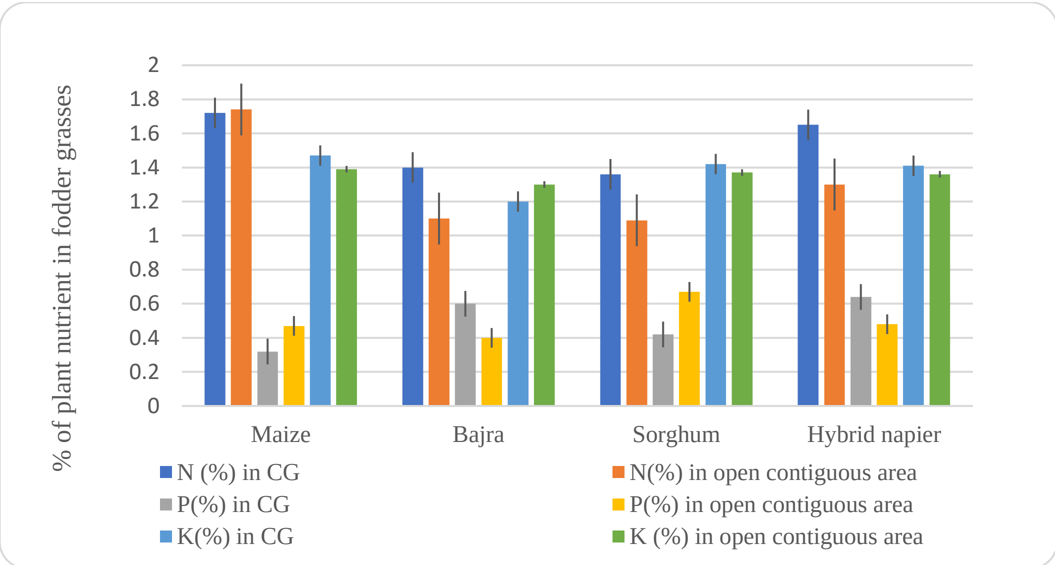

Fig 11. Plant nutrient content of fodder grasses in coconut garden (CG) and open contiguous area during summer season.

5.1.12 Understorey PAR availability in coconut garden

Diurnal differences in understorey Photosynthetically Active Radiation (PAR) in coconut garden was distinct during rabi and summer season (Table 9, Fig 11 and 12). The mean daily PAR transmittance in the coconut garden during the summer season (56.83 per cent) was observed to be slightly higher than the rabi season (55.74 per cent). The mean midday PAR transmittance in coconut garden during rabi and summer season was high as 1374 and 1222 μ moles m^{-2} sec^{-1}This might be one of the reasons for high productivity in coconut garden during both seasons. Generally, the availability of light, its interception, and the efficiency with which the intercepted light is converted to biomass determine biomass yield of understorey (Gao *et al*., 2013). Pandey *et al.* (2014) also recorded that above the canopy of intercrops in a coconut garden-based intercropping system, the coconut intercepted only 30-32 per cent of the sunlight. Braconnier (1998) recorded that PAR transmission in a coconut garden was about 29 per cent only. He has also observed that a simple direct relationship exists between the yield of maize and available PAR in the coconut garden. In coconut-based intercropping system, on average up to 70 per cent of the total available PAR reached the understorey. Pandey *et al.* (2014) also recorded a PAR transmittance of 68 and 70 per cent in nutmeg-coconut based system and clove-coconut based system respectively.

5.1.13 Economics

Economics and benefit: cost ratio for the cultivation of different fodder grasses in coconut garden and open contiguous areas during rabi and summer season are given in Table 10 and 11. Generally during the study, the B: C ratio was more in open conditions as compared to coconut garden due to the increased rate of production in open areas. The B: C ratio of maize was recorded the highest in coconut garden (2.14 in rabi and 1.99 in summer) and open area (2.31 in rabi and 2.25 in summer) during the two seasons. The B: C ratio of sorghum falls below one in both land-use systems throughout the study period which indicates the non-profitability of the crop. During the summer season, the B: C ratio of bajra in the coconut garden (0.77) dropped below one. This might be due to the increased cost of production during summer (particularly irrigation costs). In the current study, the B: C ratio of hybrid napier was also noticed higher in open contiguous areas (1.24 and 1.36) than coconut garden (1.16 and 1.23) during rabi and summer season respectively. Subramanian and Thamban (2014) observed a B: C ratio of 1.64 when hybrid napier CO3 was cultivated as intercrop in coconut garden under red sand loamy soil. Thankamani *et al.* (2011) recorded that intercropping of hybrid napier in coconut garden has a high benefit: cost ratio of 3.7.

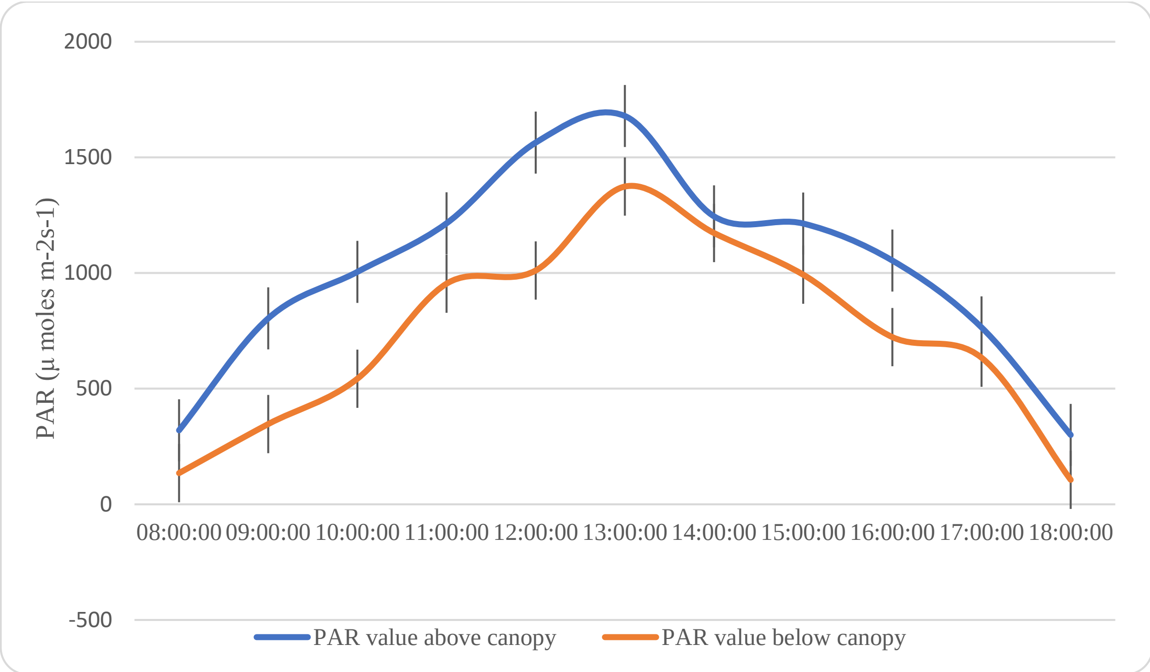

Fig 12. Mean daily-integrated values of Photosynthetically Active Radiation (PAR) in coconut garden and open contiguous area during rabi season.

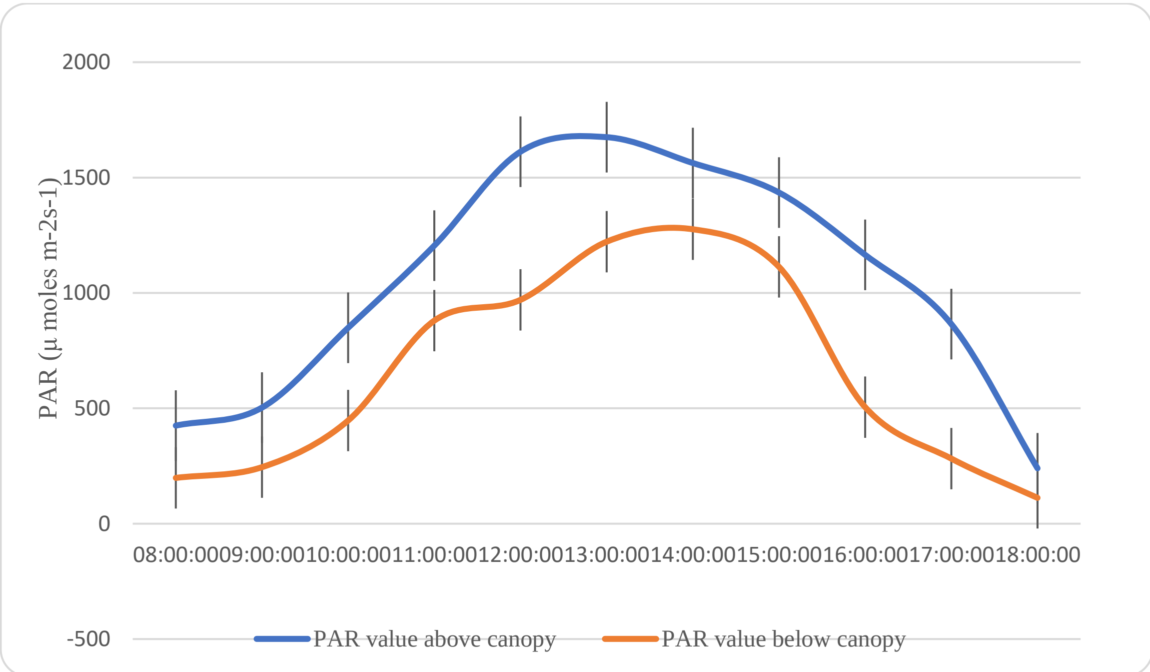

Fig 13. Mean daily-integrated values of Photosynthetically Active Radiation (PAR) in coconut garden and open contiguous area during the summer season.

5.2 GROWTH AND YIELD PARAMETERS OF CEREAL AND GRASS FODDERS UNDER HOMEGARDEN AND CONTIGUOUS OPEN AREA IN RABI AND SUMMER SEASON

5.2.1 Plant height of fodder grasses

Plant growth and development are controlled by both genetic (endogenous) and environmental (exogenous) factors. Though genetic factors mainly define specific physical characteristics of a plant, gene expression is frequently altered by environmental factors (Brown *et al*., 2014). In the current study, maximum plant height was observed in open grown fodder grasses across all the harvests during rabi and summer season (Table 12 and Fig. 13). Raai *et al.* (2020) also noted that the non-shaded plants were noticed to have increased growth and had better physiological responses than the shaded plants. The reduction in yield under shade will be roughly proportionate to the amount of shade experienced (Wilson and Wild, 1991).

The reduction in plant height in homegarden as compared to open area during rabi in maize, sorghum, bajra, and hybrid napier is 29.62, 35.61, 66.55, and 15.37 per cent respectively, while in summer the reduction was 33.16, 43.43, 68.98, and 40.27 per cent respectively. Mandal *et al.* (2014) also found similar results that the plant height of maize in intercropping condition was lower when compared to a pure stand. Reduced plant height of sorghum in shaded condition is also evident in the study. It is also observed by Akhtar *et al.* (2013) that forage sorghum grown under sole cropping produced maximum plant height. Among the different fodder grasses grown in homegarden, maize noticed to have maximum plant height followed by sorghum, hybrid napier and bajra during both seasons. While in open area, bajra and sorghum recorded the maximum height during rabi and summer season respectively (Table 12).

Shade generally has a beneficial influence on the height of hybrid napier. For example, Antony and Thomas (2016) observed that the plant reached to its maximum height when exposed to 50 per cent shade. Contrary to this, the homegarden grown hybrid napier exhibited characteristically lower height than open conditions. The lower light intensities under heavy shade prevailing in homegarden might have resulted in reduced growth and vigour in the understorey grasses that might have reflected in the height growth also. The average daily PAR transmittance observed in homegarden during rabi and summer season is 31.72 and 49.18 per cent respectively (Table 12).

Plant height is regarded as a plant trait that is genetically controlled and modified less as a response to environmental factors. The obvious differences in plant height of fodder grasses may be explained based on genetic influence. The increased height noticed during summer season in all fodder grasses might be due to the increased PAR transmittance during the season as compared to rabi season.

5.2.2 Number of leaves

Production of leaves was found to be linearly related to incident light and PAR transmittance. During the study period, the maximum number of leaves was produced in open contiguous areas in summer season (Table 12 and Fig 14). Gautier *et al.* (1999) discovered that shading inhibits the rate of leaf development in plants due to delayed phyllochron. The dominance of open contiguous area in leaf production during summer season is due to the higher PAR transmittance whereas the reduced leaf production in fodder grasses in homegarden may be related to shade induced reduction in growth.

In hybrid napier cultivars, Antony and Thomas (2016) reported an inverse relationship between leaf production per clump and increased shade level. The significant variability in leaf production seen between grass species could be attributed to a genotypic influence.

The decrease in leaf production during the summer season compared to the rabi season might be attributed to greater PAR transmittance during the summer season (Table 9).

5.2.3 Number of tillers

Tillering in grasses is a complex process caused by a combination of genetic, physiological, and environmental factors (Assuero snd Tognetti, 2010). In the current study, open contiguous areas produced the most tillers when compared to home gardens (Table 12). In addition, tiller production was higher in the summer than in the rabi. Throughout the study period, an inverse relationship between tiller production and rising shade levels was detected. Higher shade intensities, according to Gautier *et al*., (1999) may diminish tillering rate by delaying the development of tiller buds into tillers. There is wide evidence demonstrating that increasing light intensities on canopies results in increased tillering in grasses (Evans *et al.,* 1960). The physiological basis for the increase in tillering is that under high light intensity increased carbon availability normally leads to higher root development and proliferation and thereby tillering may be aided through increased cytokinins transport from roots (Mitchell and Coles, 1955).

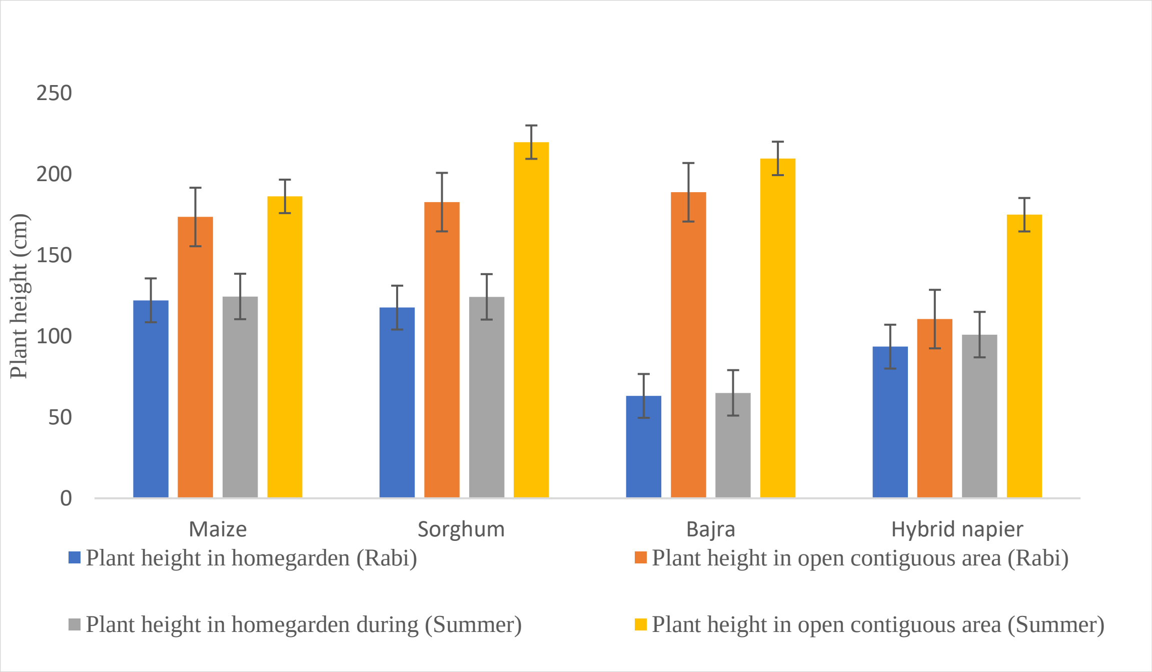

Fig 14. Plant height of fodder grasses in homegarden and open contiguous area during rabi and summer season.

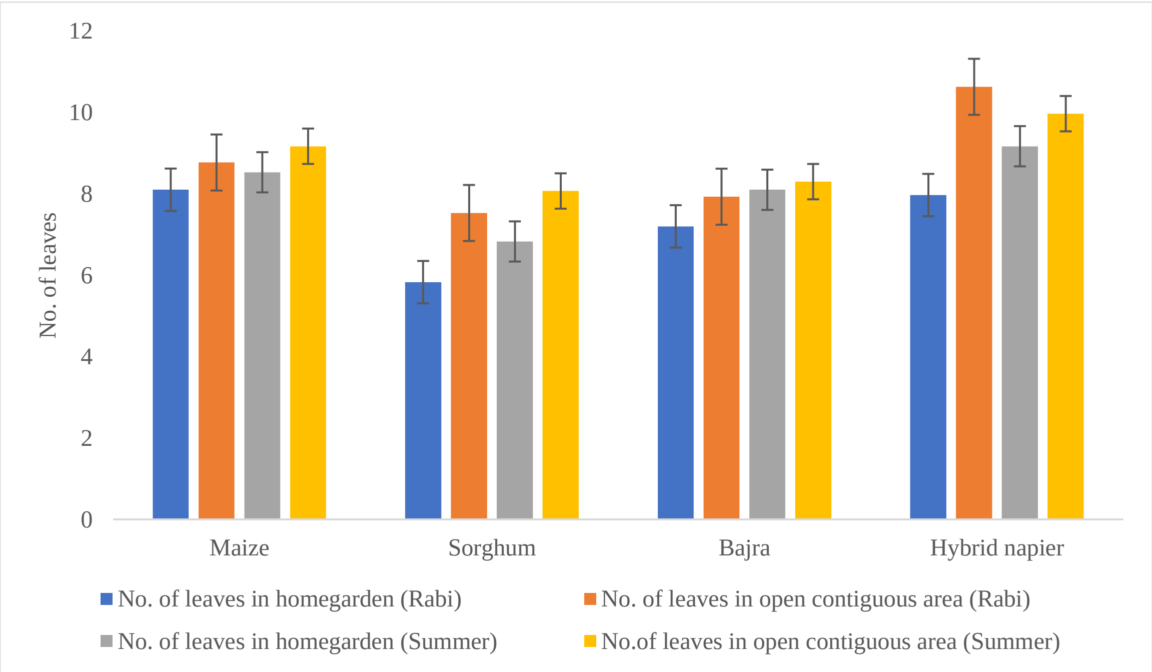

Fig 15. Number of leaves in different fodder grasses in homegarden and open contiguous area during rabi and summer season.

5.2.4 Green fodder yield

In the present study, open contiguous area consistently showed a significantly higher green fodder yield than homegarden in rabi and summer season (Fig 15 and 16). Among the cultivated fodder grasses in open contiguous area, maize noticed to have the maximum yield followed by hybrid napier, bajra and sorghum during both seasons. The cumulative green fodder yield of maize during rabi and summer season were 93.27 Mg $ha^{-1}$and 93.32 Mg ha^{-1} (Table 13 and 14). Manoj *et al*., (2020) also observed comparable green fodder yield of 103 Mg $ha^{-1}yr^{-1}$ in southern dry zone of Karnataka. Productivity in the open contiguous area indicates the natural potential for growth and yield when light is not a constraint. As a result of the favourable development conditions, the treeless open plot had the highest biomass fresh weight (Kumar *et al.*, 2001). Sorghum variety COFS-31 showed a green fodder yield of 156.17 Mg $ha^{-1}yr^{-1}$ during an on-farm trial experiment at Karnataka by Patil *et al.* (2020).

The amount of biomass produced in the understorey is determined by the proportion of Photosynthetically Active Radiation (PAR) that reaches the ground. Despite the fact that grasses are fairly shade tolerant, there was a reduction in forage production under strong shade, particularly when the intensity of shade exceed 50 per cent of the incident radiation (Garcezneto *et al.*, 2010; Soares *et al.*, 2009). Low light intensity affects quality of fodder grasses, and extreme reduction in light reduce photosynthetic production and plant growth. The amount of shade and the degree of shade adaptation determine the level of decline in growth (Singh *et al.*, 1995). In the current study, the considerable reduction in green fodder yield in homegarden may be due to the lower mean daily PAR transmittance in the system (31.72 % in rabi and 49.18 % in summer). In homegarden, the maximum green fodder was obtained by hybrid napier followed by maize, bajra and sorghum. The reduction in green fodder yield due to shade factor in homegarden is noticed to be maximum in sorghum (47.37 % in rabi and 45.55 % in summer season) and minimum in hybrid napier (14.20 % in rabi and 7.18 % in summer). The shade tolerance of fodder grasses is in the order; Hybrid napier> Maize> Bajra> Sorghum.

Ravi *et al.* (2009) also observed a 23.40 per cent reduction in relative fodder yield of sorghum when intercropped under *Ailanthus triphysa* based agroforestry system. Antony and Thomas (2016) observed that for every 25 per cent reduction in light intensity, the percentage reduction in fodder yield of hybrid napier was around 10 per cent. The relative percentage reduction in yield is also determined by cultivars.

In the present study, an area of 8100 sq. m was available under homegarden for the cultivation of fodder grasses (excluding the area occupied by other components in the homegarden). Therefore, the cumulative yield of maize, sorghum, bajra and hybrid napier as understorey components in 1 ha homegarden was found to be 46.30, 15.00, 27.04, and 48.94 Mg ha^{-1} respectively during the rabi season, while in summer season the yield was estimated as 59.53, 17.33, 40.10, and 59.54 Mg ha^{-1} respectively.

5.2.5 Dry fodder yield

Dry fodder yields also followed the same trend as that of green fodder yield. Open contiguous area consistently exhibited maximum dry weight when compared to homegarden throughout the study period. According to Antony and Thomas (2016) shading reduced the dry fodder yield of hybrid napier cultivars under rainfed system. This can be discussed on the same basis as for green fodder yield. Shade induced reduction in tillering and leaf production prevailed in homegarden accounted for the lower dry fodder yield.

Among the cultivated fodder grasses, hybrid napier and maize exhibited better performance in homegarden and open contiguous area respectively. The percentage reduction in dry fodder yield in homegarden noticed to be maximum for sorghum and minimum for hybrid napier. Fodder maize and bajra have shown approximately 35 per cent reduction in dry fodder yield in homegarden.

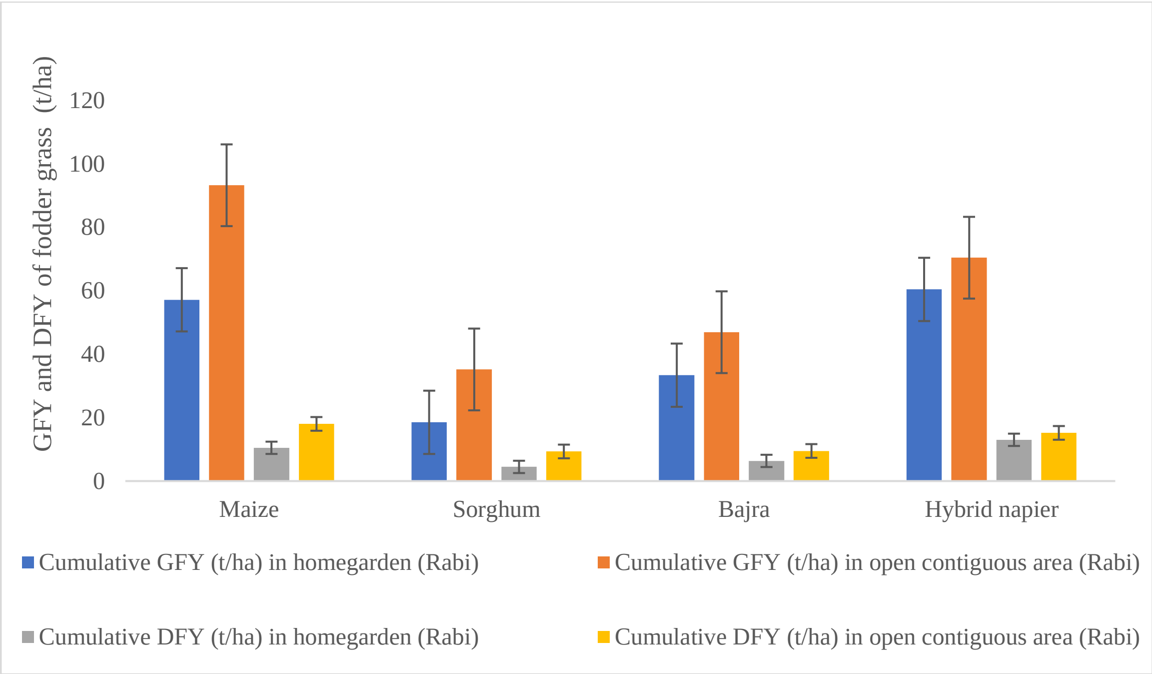

Fig 16. Cumulative green fodder yield (GFY) and dry fodder yield (DFY) of fodder grasses in homegarden and open contiguous area during rabi season.

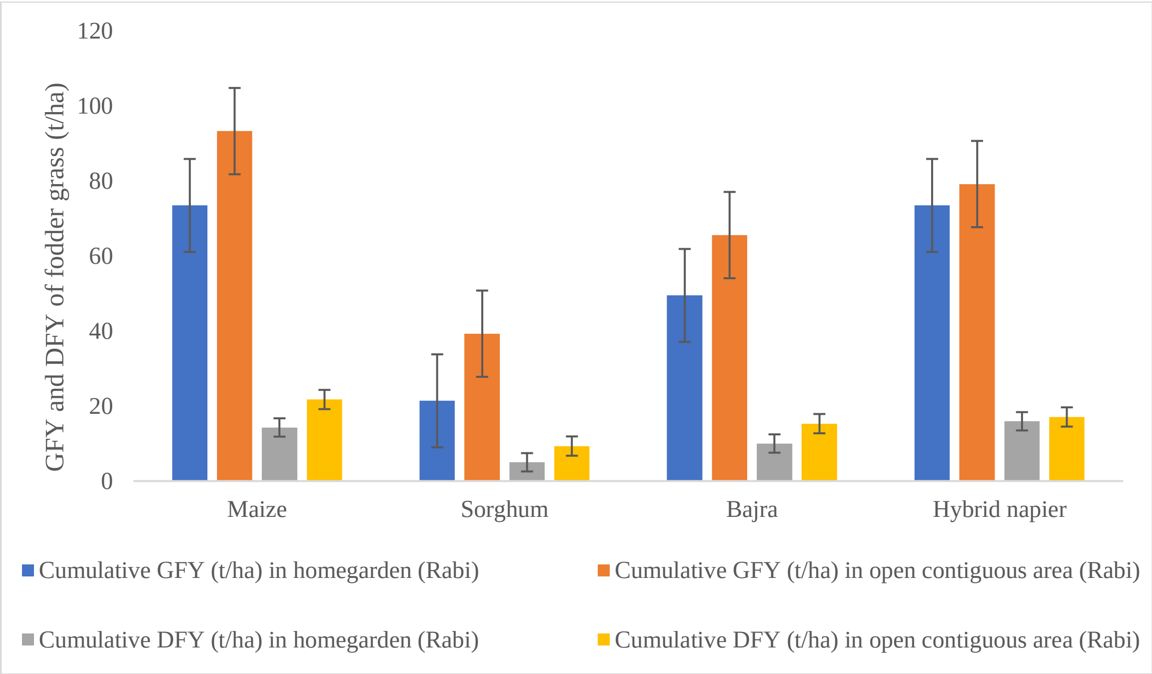

Fig 17. Cumulative green fodder yield (GFY) and dry fodder yield (DFY) of fodder grasses in homegarden and open contiguous area during summer season.

5.2.6 Per day productivity and duration of fodder grasses

The time taken for harvesting of fodder grasses varies between species and land management systems. Generally, the grasses grown in open contiguous area have shown relatively less duration and more per day productivity (Table 15). Maria *et al.* (2019) observed that increase in level of light intensities will gradually increase the growth rate of crops and reduce the crop duration. The relative rate of increase in growth parameters such as plant height and tillering in open conditions with respect to shaded situations is the reason for less duration taken by fodder crops for harvesting. During rabi and summer season, maize and bajra showed the maximum per day productivity in open contiguous area due to its high productivity and less duration for harvest. While in homegarden, during rabi season maize and bajra observed to have the highest per day productivity but in summer season, hybrid napier out performed maize as well as bajra. This could be explained due to the fact that hybrid napier, being annual fodder initially takes longer duration for first harvest after that subsequent harvests takes lesser duration only. The average duration of maize and bajra in the open contiguous areas was about 55 and 45 days, while in the homegarden, the duration of these crops increased by about 10 and 15 days respectively. Kumar *et al*. (2012) also stated that the first cut for hybrid napier is taken at 75-80 days after planting and subsequent cuttings can be made at 30-40 days interval.

5.2.7 Dry matter

Dry matter content of fodder grasses didn't show significant variations in different species and land management systems across the study period. In general, dry matter content was found to be more in open contiguous area due to the less moisture content in grasses cultivated in open conditions (Fig 17 and 18). Among the different fodder grasses, sorghum fodder observed to have the highest dry matter percentage followed by hybrid napier, bajra and maize. The higher dry matter percentage of sorghum about 23.01 per cent is noted by Manoj *et al*. (2020). Weerasinghe *et al.* (2021) reported 20.3 per cent dry matter in hybrid napier CO5. Kanduri *et al.* (2016) also studied the proximate composition of African tall fodder maize and reported dry matter percentage of 22.38. Singh *et al*. (2020) observed dry matter percentage in African tall maize as 24.77 per cent. COFS-31 variety of sorghum recorded to have a dry matter percentage of 25.9 per cent by ICAR (2016).

5.2.8 Crude protein

The fodder grasses grown in homegarden exhibited higher crude protein content than in open contiguous area (Fig 17 and 18). This observation is in line with the findings of numerous authors (Norton *et al*., 1991; Kaushal *et al*., 2000; Sebetha *et al.,* 2010) who also claimed that crude protein content of the fodder grasses generally increases with shade. Lin *et al.* (2001) also observed a linear relationship between crude protein content and increasing intensities of shade. The rise in crude protein percentage as PPFD decreased can be attributed to either a decrease in rate of photosynthesis, resulting in a rise in nitrogen concentration, or to an increase in soil organic matter mineralization under trees, which provided more nitrogen for grass uptake (Wilson and Ludlow, 1990). According to da Silva *et al*. (2012) also the Photosynthetically Active Radiation (PAR) indirectly influences the crude protein content of fodder grasses.

On comparison of fodder grasses, maize fodder had more crude protein content followed by hybrid napier, bajra and sorghum throughout the study period in both land management systems. Manoj *et al*. (2020) observed a high crude protein content of 9.90 per cent in African tall fodder maize variety during a field experiment in southern dry zone of Karnataka. Jose *et al.* (2019) also observed a crude protein content of 9.98 per cent in CO5 hybrid napier during a field study. Kanduri *et al.* (2016) reported the proximate composition of African tall fodder maize and reported crude protein content of 10.83 in open field conditions. The crude protein content of African tall maize recorded by Singh *et al*. (2020) was about 10.62 per cent. COFS-31 has a crude protein content of 9.85 per cent (ICAR,2016).

5.2.9 Crude fibre

The statistical analysis of the data on crude fibre content of fodder grasses reveals that there were no significant differences exist among the species in both land management systems. Although they are statistically found to be insignificant, in general the fibre content was relatively lower in homegarden as compared to open contiguous area (Fig 17 and 18). Pierson *et al.* (1990) stated that the reduction in the availability of PAR retards the ontogenic development of fodder grasses and plant maturity thereby lowering fibre content. Also, when the availability of light was lowered below 50 per cent, significant changes in crude fibre content were seen in forages grown in agroforestry systems (Lin *et al*., 2001). The significantly lower PAR transmittance in homegarden during rabi and summer season may have resulted in lower crude fibre content. Kanduri *et al.* (2016) also studied the proximate composition of African tall fodder maize and reported a crude fibre content of 27.55 in open field conditions. Singh *et al*. (2020) observed crude fibre content of 29.24 per cent in African tall maize. The crude fibre content in COFS-31 is about 19.80 (ICAR, 2016)

5.2.10 Ash content

Fodder grass species showed significant variations in ash content in the fodder biomass during rabi and summer season. Generally, the ash content is found higher in open contiguous area as compared to homegarden during both seasons (Fig17 and 18). This may be due to the reason that the rate of photosynthesis would be more in open conditions and consequently more mineral accumulation might happened in open plot grown fodder grasses.

On comparison of different fodders, maize observed to have more ash content followed by sorghum, hybrid napier and bajra. Manoj *et al*. (2020) also observed a comparatively higher ash content in maize fodder of about 10.28 per cent during a field experiment in southern dry zone of Karnataka. Ramya *et al.* (2017) also estimated the percentage of ash content in hybrid napier and sorghum at 45 DAP as 13.11 and 8.31 per cent. The lower ash content of 8.10 per cent is observed by Manoj *et al*. (2020) also in bajra fodder. The ash content of African tall fodder maize was estimated by Kanduri *et al.* (2016) and recorded 10.02 per cent in open field conditions.

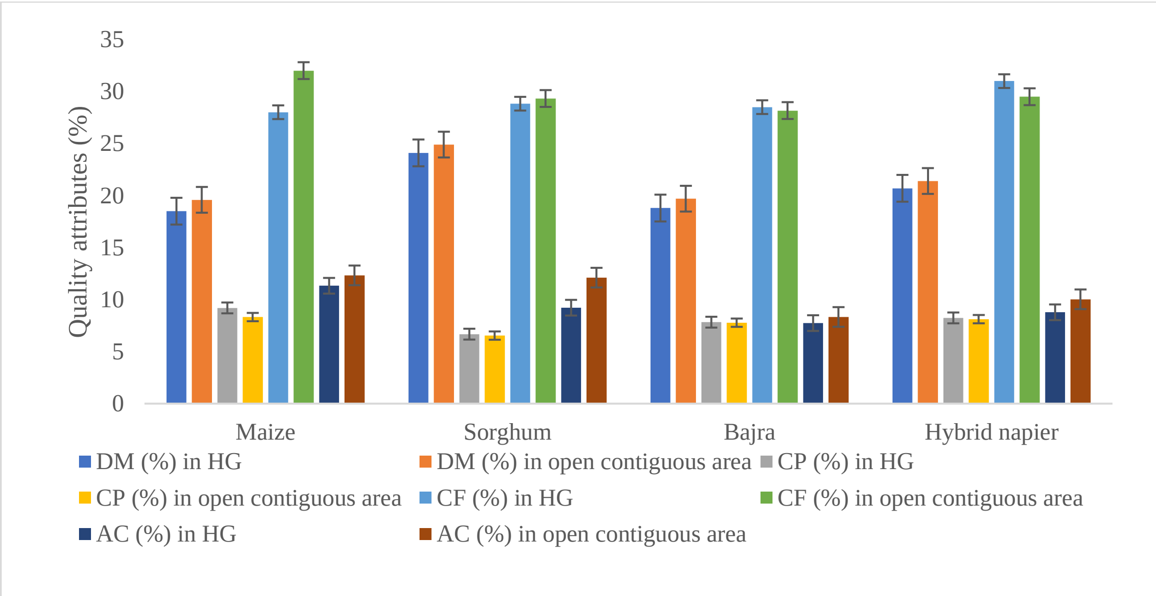

Fig 18. Quality attributes of fodder grasses in homegarden (HG) and open contiguous area during rabi season

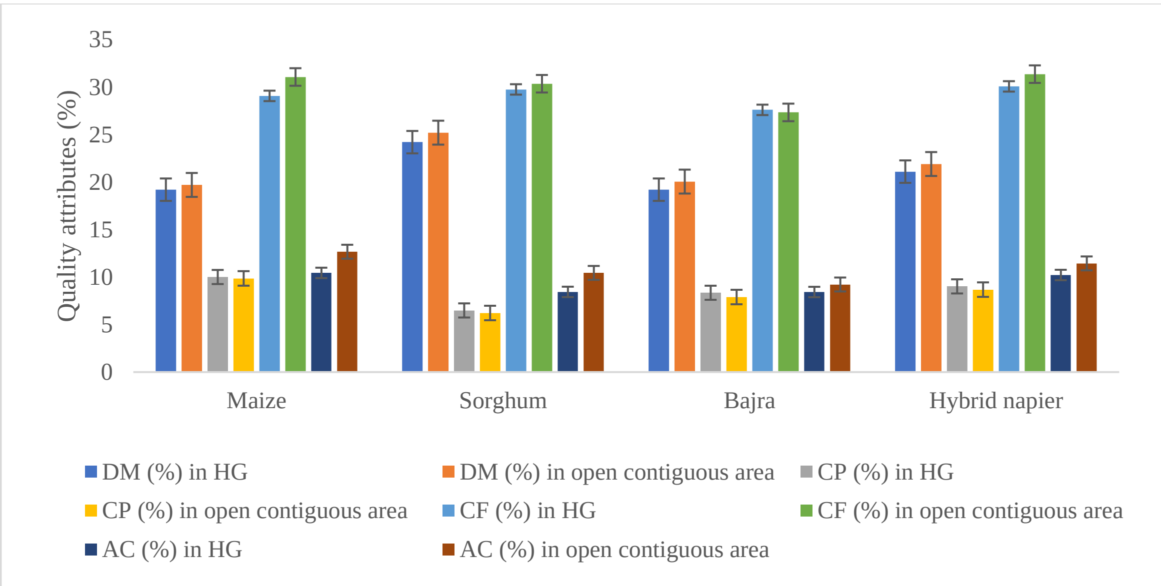

Fig 19. Quality attributes of fodder grasses in homegarden (HG) and open contiguous area during summer season.

5.2.11 Nitrogen, Phosphorous and Potassium content of fodder grasses during rabi and summer season

Fodder grass species showed considerable variation on N and K content during rabi and summer seasons. However, the content of P in different grasses under study was found to be insignificant (Table 19 and 20). N content was generally higher in homegarden as compared to open contiguous area throughout the study period. Among the cultivated fodder grasses, N content was significantly higher in maize followed by hybrid napier, bajra and sorghum. K content in fodder grasses was comparatively more in open conditions than shaded situations. The highest K content was observed in bajra followed by hybrid napier, sorghum and maize. The N, P and K content in African tall variety was recorded by Singh *et al.,* (2020) as 1.70, 0.25 and 0.72 per cent respectively.

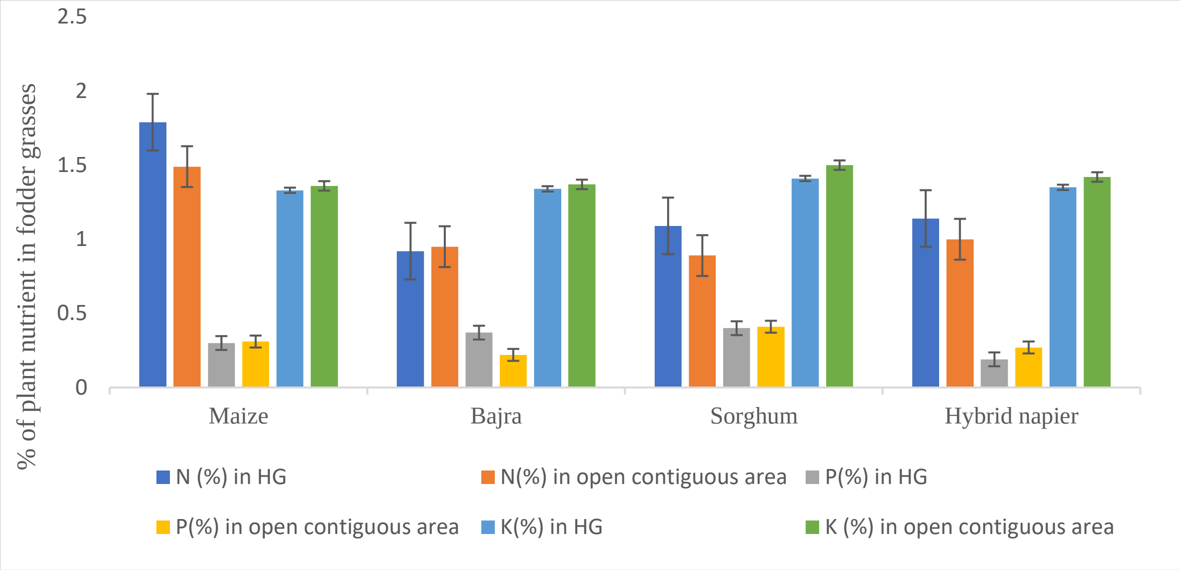

Fig 20. Plant nutrient content of fodder grasses in homegarden (HG) and open contiguous area during rabi season.

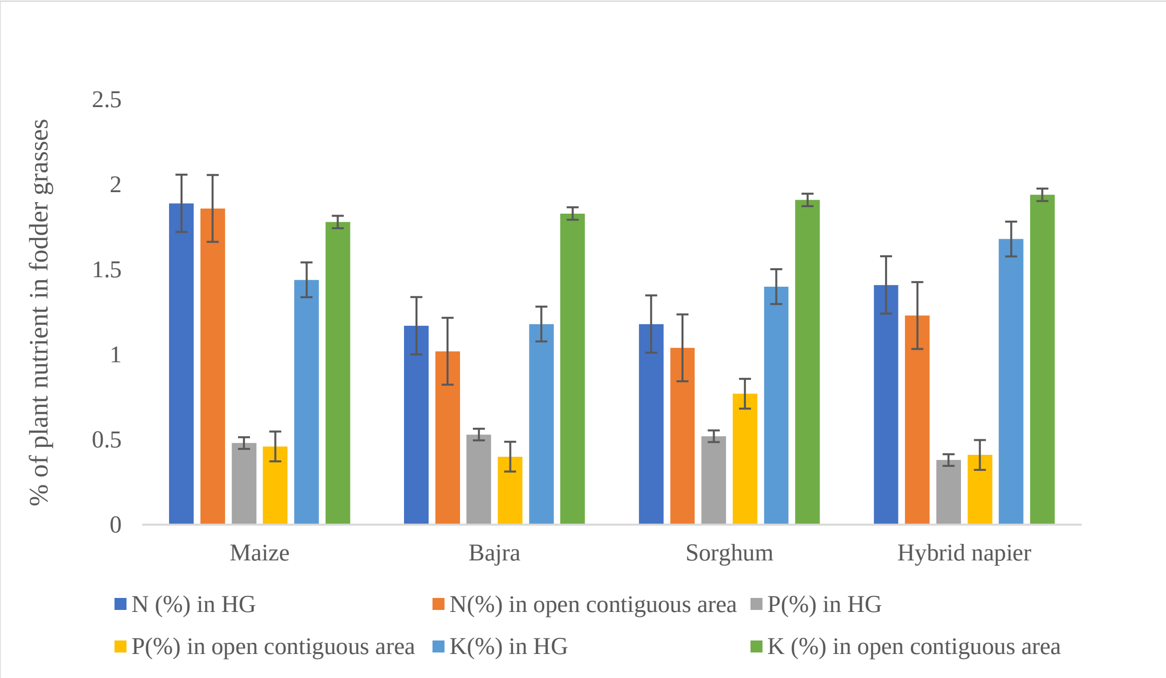

Fig 21. Plant nutrient content of fodder grasses in homegarden (HG) and open contiguous area during summer season.

5.2.12 Understorey PAR availability in homegardens

Diurnal variations in understorey Photosynthetically Active Radiation (PAR) in homegarden was distinct during rabi and summer season (Fig 21 and 22). The mean daily PAR transmittance in homegarden during summer season (49.18 per cent) was observed to be more than rabi season (31.72 per cent). This might be the reason for increased productivity in homegarden during summer season. In general, the available light, its interception, and the efficiency with which the intercepted light is converted to biomass determine understorey biomass yield (Gao *et al*., 2013). Most of the homegardens in Kerala have less PAR availability to the extent of 50 to 52 per cent, which has adversely affected the yield of tree fodder banks (Patric, 2019). In a homegarden, throughout the day, the incident light intensity gradually decreased from the crown layer to the middle and lowest layers at the ground (Gajaseni and Gajaseni, 1999). In a multistorey agroforestry system in Bangladesh, light interception by the middle and lower story crops were only 55.5 and 30.8 per cent respectively (Miah *et al*., 2018). In a bamboo-based agroforestry system in Kerala, with increase in the planting density of bamboo, the proportion of PAR reaching the understorey declined and productivity hence reduced (Kittur *et al.*, 2015). Kumar *et al.* (2001) recorded that depending on the stocking level and time of measurement in an *Ailanthus tryphysa* based agroforestry system PAR flux value ranged from 26 to 96 per cent of full light. Canopy architecture and dimensions are also important factors of understorey light regimes. Kumar *et al.* (2001) noted that *Acacia auriculiformis* with a dense crown intercepted more light, however *Casuarina equisetifolia* with its needle-like cladophylls and small crown allowed higher light penetration into the understorey of a silvopastoral system. In the current study area, the arboreal components include *Artocarpus heterophyllus*, *Tamarindus indica* and *Mangifera indica*. The wide spread crown of these species might have resulted in lower PAR transmittance in the system.

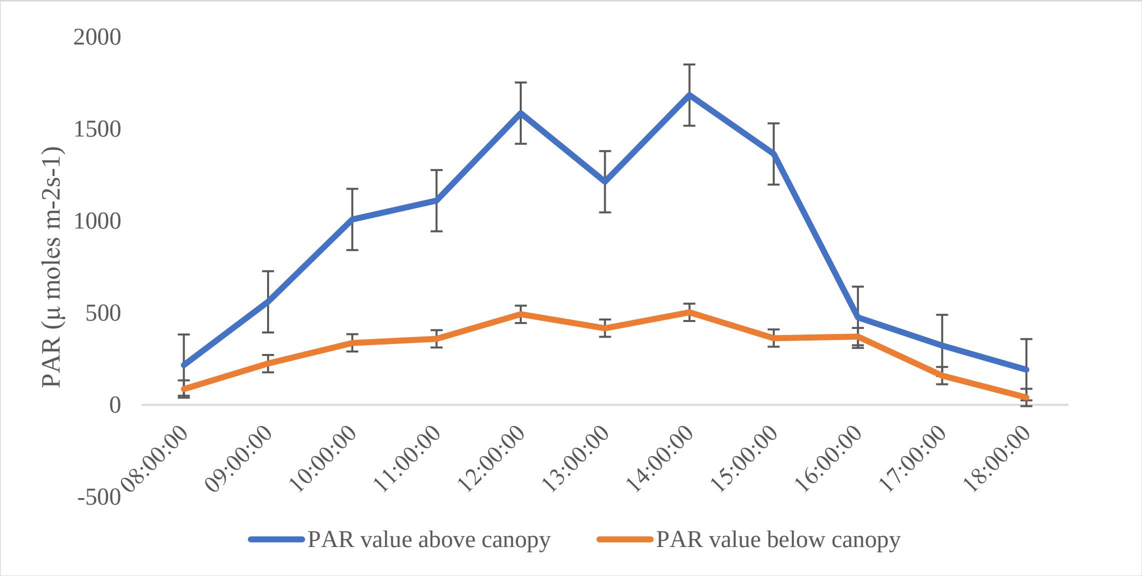

Fig 22. Mean daily-integrated values of Photosynthetically Active Radiation (PAR) in homegarden and open contiguous area during rabi season.

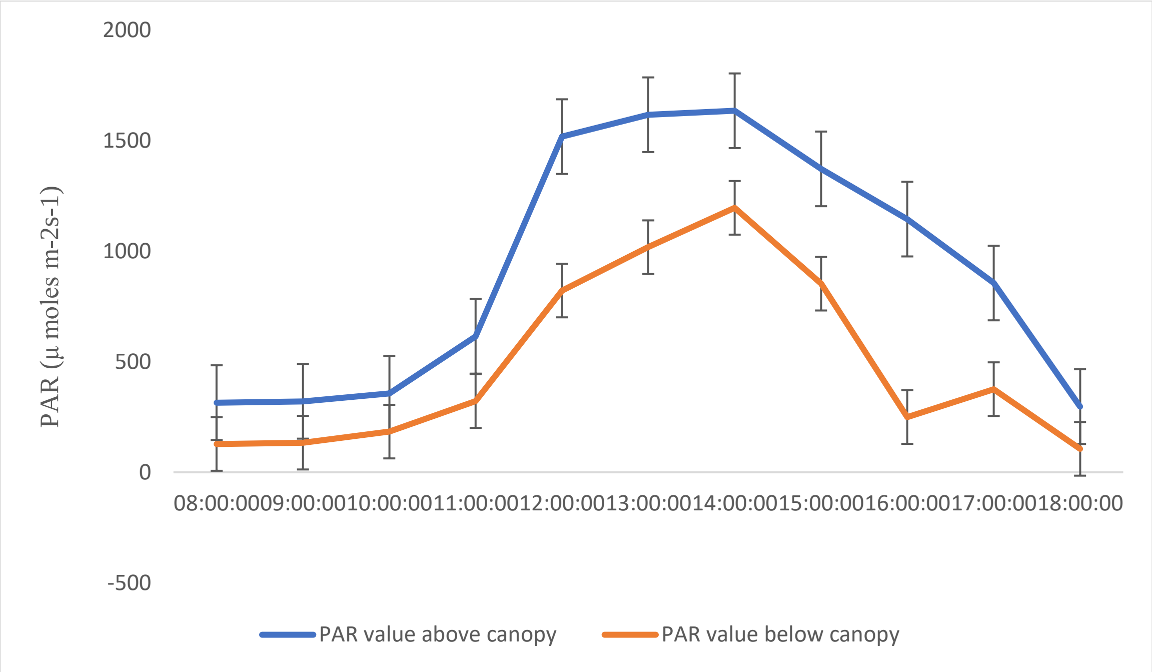

Fig 23. Mean daily-integrated values of Photosynthetically Active Radiation (PAR) in homegarden and open contiguous area during summer season.

5.2.13 Economics

Economics and benefit: cost ratio for cultivation of various fodder grasses in homegarden and open area during rabi and summer season are given in Table 21 and 22. In general, the B: C ratio was observed higher in open contiguous area for a crop as compared to homegarden due to the increased productivity in open plots. The B: C ratio was significantly higher for maize during both the season in homegarden as well as open area. During rabi season, B:C ratio of maize and hybrid napier in homegarden was more than one. While in open area, B: C ratio was less than one only in sorghum. However, during summer season, sorghum is the only crop in open and homegarden whose B: C ratio falls below one. Inspite of having higher productivity during summer season, the B: C ratio didn’t show relatively higher value during the season due to the increased cost of production, especially on irrigation. Ginwal *et al.* (2019) recorded B: C ratio of 1.78 for fodder maize and cowpea intercropping system.

Summary

6. Summary

The research work entitled “On-farm evaluation of selected cereal fodders in prominent land use systems of Kerala” was undertaken during 2020-21 at Madakkathara panchayat, Thrissur, Kerala, to assess the forage yield and nutritive value of selected cereal fodders viz., maize, bajra, and sorghum in homegarden, coconut garden, and open contiguous areas. The study also examined the productivity and quality of cereal fodders compared to hybrid napier, the popular fodder grass in Kerala. The study was conducted as two separate experiments in homegarden and coconut garden during the rabi and summer season. Growth parameters, yield, and quality attributes of fodder crops were analysed and recorded. The salient findings of the study are summarised as follows:

6.1 Evaluation of cereal fodders and hybrid napier in coconut garden and open contiguous areas.

1. The growth parameters of fodder grasses reported significant variations between coconut garden and open contiguous area during the rabi and summer season.
2. In coconut garden, fodder bajra attained maximum plant height (141.08 and 144.83 cm) followed by maize (121.75 and127.41 cm), sorghum (109.75 and 124.00 cm) and hybrid napier (97.16 and 126.83 cm) during rabi and summer season respectively. The open area grown grasses also showed a similar trend in the height of plants. The maximum percentage reduction in plant height due to shade is observed in fodder sorghum (32.14 % in rabi and 33.66 % in summer).
3. Number of leaves was observed more in open contiguous areas than in coconut garden. Considering the different fodder grasses in the coconut garden, the number of leaves was present maximum in hybrid napier (8.50 and 10.30) followed by bajra (7.91and 9.10), maize (6.83 and 8.16), and sorghum (4.91 and 5.87) during rabi and summer season respectively. Fodder grasses cultivated in the open contiguous area also exhibited a similar pattern. The reduction in leaves number was maximum in sorghum (19.2 %) followed

by hybrid napier (17.71 %), maize (8.9 %), and bajra (3.9 %) during rabi season. However, in the summer season, the maximum reduction was seen in sorghum (25.30 %) followed by maize (22.51 %), hybrid napier (7.21 %), and bajra (5.16 %).

4. The maximum tiller production was noted in open contiguous areas with full sunlight throughout the study period. Among the cultivated fodder grasses in the coconut garden, sorghum (6.13 and 10.30) was noticed to have the maximum number of tillers followed by hybrid napier (2.08 and 5.53) and bajra (4.25 and 4.60) during the rabi and summer season respectively. The reduction in tillering was maximum in bajra fodder (35.41 %) during the summer season and hybrid napier (37.21 %) during rabi season in coconut garden as compared to open plots. The minimum reduction in tillering was recorded in sorghum during rabi (16.14 %) as well as the summer season (11.44 %). Maize fodder variety African tall didn't show any tillering in both land management systems across the study period.
5. In the current study, open contiguous areas consistently exhibited a significantly higher green fodder yield than coconut garden in the rabi and summer season. In the coconut garden, the maximum green fodder yield was obtained in maize (71.60 and 77.35 Mg ha^{-1}) followed by hybrid napier (56.45 and 67.80 Mg ha^{-1}), bajra (47.67 and 34.71 Mg ha^{-1}), and sorghum (28.02 and 30.12 Mg ha^{-1}) during rabi and summer season respectively. The reduction in green fodder yield in coconut garden as compared to open contiguous area was least in hybrid napier (6.20 and 8.91 %) followed by maize (7.49 and 11.79 %), bajra (20.51 and 25.43 %), and sorghum (34.16 and 29.31 %). The shade tolerance of fodder grasses in the coconut garden was in the order of hybrid napier> maize > bajra > sorghum.
6. The dry fodder yield of different fodder grasses was significantly higher in open contiguous areas as compared to coconut garden throughout the study period. Among the fodder grasses, maize exhibited better performance in the coconut garden as well as open contiguous areas. In the coconut garden, the maximum cumulative dry fodder yield was noticed in maize (13.27 and 17.84

Mg ha^{-1}) followed by hybrid napier (11.65 and 13.18 Mg ha^{-1}), bajra (9.84 and 9.10 Mg ha^{-1}), and sorghum (6.85 and 7.03 Mg ha^{-1}) during rabi and summer season respectively. Also, the reduction in dry fodder yield was observed maximum in sorghum (30.24 %) and minimum in hybrid napier (9.65 %) during rabi season. However, the percentage reduction was maximum in bajra (11.82 %) during the summer season and the least reduction was observed here also in hybrid napier (9.10 %).

7. Per day productivity of fodder grasses was more in open contiguous areas as compared to coconut garden. The maximum per day productivity was obtained by bajra (0.7 and 0.76 Mg ha^{-1}day^{-1}) followed by maize (0.6 and 0.64 Mg ha^{-1}day^{-1}), hybrid napier (0.35 and 0.38 Mg ha^{-1}day^{-1}), and sorghum (0.21 and 0.24 Mg ha^{-1}day^{-1}) in the coconut garden during the rabi and summer season respectively. A similar trend was obtained in open contiguous areas also. The average duration of maize and bajra in the open contiguous areas was about 55 and 45 days, while in the coconut garden, the duration of these crops increased by about 5 days.
8. Dry matter content of fodder exhibited significant differences only during summer season. Generally, dry matter content was recorded more in open contiguous areas than in coconut garden. On considering the different fodder grasses in open contiguous areas, the percentage of dry matter was maximum in fodder sorghum (25.20 and 24.70 %) followed by hybrid napier (21.00 and 21.72 %), bajra (19.70 and 19.98 %), and maize (19.55 and 19.61 %) during rabi and summer season respectively. A similar trend was observed in the coconut garden also. The reduction in dry matter in coconut garden during rabi season as compared to open conditions in maize, sorghum, bajra, and hybrid napier was 4.43, 1.78, 4.60, and 0.64 percent respectively.
9. Crude protein content was considerably higher in fodder crops cultivated under coconut garden. Among the cultivated fodder grasses in the coconut garden, maize fodder (9.57 %) had more crude protein content followed by hybrid napier (7.23 %), bajra (5.90 %), and sorghum (5.54%) during rabi season. The increase in crude protein content of fodder grasses in coconut

garden as compared to open areas was maximum in hybrid napier (29.74 and 14.37 %), followed by maize (23.80 and 25.74 %), bajra (8.64 and 10.84 %), and least in sorghum (6.58 and 5.64 %) during rabi and summer season respectively.

10. Crude fibre content was found less in the coconut garden as compared to the open contiguous area. In the coconut garden, crude fibre content was noticed minimum in maize (25.00 and 24.33 %), followed by bajra (29.50 and 25.33 %), sorghum (31.00 and 30.23%), and hybrid napier (31.17 and 33.00 %) during rabi and summer season respectively.

11. In general, the ash content was higher in open contiguous areas than in coconut garden. Considering the different grasses in the coconut garden, ash content was noticed maximum in maize (15.11 %) followed by bajra (13.00 %), sorghum (9.44 %) and hybrid napier (8.89 %) during rabi season. However, in the summer season, hybrid napier (12.11 %) outperformed both sorghum (9.56 %) and bajra (11.11 %).

12. In general, the grasses cultivated under the coconut garden show more N content. In the coconut garden, the N content was more in maize (1.53 &) followed by bajra (1.40 %), hybrid napier (1.16 %), and sorghum (1.07 %). A similar pattern of results was also observed in open contiguous areas.

13. The phosphorus content of fodder grasses varied significantly only in rabi season in coconut garden and open contiguous areas. In general P concentration was more in open-grown fodder grasses than coconut garden during the rabi season. P concentration was maximum in hybrid napier (0.44 %) followed by bajra (0.34 %), sorghum (0.31 %), and maize (0.20 %).

14. The potassium content was noticed more in open contiguous areas as compared to coconut garden. But sorghum fodder exhibited more K content in the coconut garden than open areas. In coconut garden, the K is found maximum in bajra (1.46 %) followed by maize (1.39 %), hybrid napier (1.36 %), and sorghum (1.30 %) during rabi. The open contiguous area also

followed a similar result. Insignificant differences existed in summer in the K content of fodder grasses in both land management systems.

15. Mean mid-day understorey Photosynthetic Photon Flux Density (PPFD) levels in open contiguous were 1564 μ moles m^{-2} sec^{-1} in rabi and 1612 μ moles m^{-2} sec^{-1} in the summer season. In the coconut garden, mean mid-day PPFD levels were 1011 μ moles m^{-2} sec^{-1} and 970 μ moles m^{-2} sec^{-1}. The mean daily transmittance in coconut garden during the rabi and summer season was 55.74 and 56.83 percent respectively.

16. Among the cultivated fodder crops, fodder maize recorded a high B: C ratio in coconut garden (2.14 in rabi and 1.99 in summer) as well as open contiguous area (2.31 in rabi and 2.25 in summer). The B: C ratio of fodder sorghum was noticed by less than 1 in both land use systems during the rabi and summer season. In both land use systems, hybrid napier and bajra fodder showed B: C ratio greater than 1.

17. In general, maize exhibited clear superiority in growth, yield, and quality attributes underneath coconut garden and in open contiguous areas followed by hybrid napier, bajra, and sorghum as compared to all other fodder species.

6.2 Evaluation of cereal fodders and hybrid napier in homegarden and open contiguous areas.

1. The growth parameters of fodder grasses exhibited significant variations between homegarden and open contiguous areas during the rabi and summer season.
2. In homegarden, maize attained maximum plant height followed by sorghum, hybrid napier, and bajra during both seasons. While in open contiguous areas, maximum height was exhibited by sorghum and bajra. The reduction in plant height in homegarden as compared to open area during rabi in maize, sorghum, bajra, and hybrid napier is 29.62, 35.61, 66.55, and 15.37 per cent respectively, while in summer the reduction was 33.16, 43.43, 68.98, and 40.27 per cent respectively.

3. The number of leaves per plant was observed higher in open contiguous area, with more leaves in hybrid napier followed by maize, bajra, and sorghum. While in homegarden, the number of leaves was in the order; maize>hybrid napier>bajra>sorghum. The reduction in the number of leaves in homegarden as compared to open areas was maximum in hybrid napier (25.02 %) followed by sorghum (22.58 %), bajra (9.20 %), and maize (7.63 %) during rabi season. However, in the summer season the reduction was maximum in sorghum (15.37 %) followed by hybrid napier (8.02 %), maize (6.98 %), and bajra (2.41 %).
4. Tillering was significantly higher in open contiguous areas during both seasons. In homegarden, maximum tillering was observed in sorghum, followed by hybrid napier and bajra during rabi as well as summer season. The reduction in tillering was maximum in bajra (38.38 percent), followed by hybrid napier (25.20) and sorghum (22.12 percent) during rabi. In the summer season, hybrid napier (56.18 %) exhibited maximum reduction followed by bajra (51.45 %) and sorghum (17.54 %). The African tall variety of fodder maize didn’t show any tillering throughout the study period.
5. In the present study, plants in the open field consistently showed significantly higher green fodder yield than under homegarden in the rabi and summer season. Under open conditions, maize recorded the maximum cumulative green fodder yield (93.27 Mg ha^{-1}in rabi and 93.32 Mg ha^{-1}in summer) followed by hybrid napier (70.42 Mg ha^{-1}in rabi and 79.20 Mg ha^{-1}in summer), bajra (46.93 Mg ha^{-1}in rabi and 65.60 Mg ha^{-1}in summer) and sorghum (35.19 Mg ha^{-1}in rabi and 39.30 Mg ha^{-1}in summer). In homegarden, the green fodder yield of hybrid napier (60.42 Mg ha^{-1}in rabi and 73.51 Mg ha^{-1}in summer) and maize (57.16 Mg $ha^{-1}$and 73.50 Mg ha^{-1}) was on par during both the seasons. The reduction in cumulative green fodder yield in homegarden is noticed to be maximum in sorghum (47.37 % in rabi and 45.55 % in summer season) and minimum in hybrid napier (14.20 % in rabi and 7.18 % in summer) and in maize the reduction was estimated at 38.72 and

21.23 per cent in rabi and summer season respectively. The shade tolerance of fodder grasses is in the order; hybrid napier>maize >bajra >sorghum.

6. The dry fodder yield of different fodder grasses consistently showed higher values in open contiguous areas as compared to homegarden throughout the study period. In open contiguous areas, maximum cumulative dry fodder yield was obtained by maize (18.03 Mg ha^{-1} in rabi and 21.75 Mg ha^{-1}in summer) followed by hybrid napier (15.19 Mg ha^{-1} in rabi and 17.09 Mg ha^{-1} in summer), bajra (9.49 Mg ha^{-1}in rabi and 15.31Mg ha^{-1} in summer) and sorghum (9.33 Mg ha^{-1} in rabi and 9.33 Mg ha^{-1} in summer). In homegarden, hybrid napier (13.01Mg ha^{-1} in rabi and 15.94 Mg ha^{-1} in summer) yielded more cumulative dry fodder yield and was noted as on par with maize (10.49 Mg ha^{-1} in rabi and 14.29 Mg ha^{-1} in summer). The reduction in dry fodder yield in homegarden with respect to open contiguous area of maize, sorghum, bajra, and hybrid napier is 41.82, 52.09, 32.98, and 14.35 per cent respectively in rabi season, while in the summer season, it was about 34.30, 46.30, 34.62 and 6.73 per cent respectively.
7. Per day productivity of fodder grasses was more in open contiguous areas as compared to homegarden. The maximum per day productivity was obtained by bajra (0.58 and 0.50 Mg $ha^{-1}day^{-1}$) followed by maize (0.52 and 0.69 Mg $ha^{-1}day^{-1}$), hybrid napier (0.35 and 0.88 Mg $ha^{-1}day^{-1}$), and sorghum (0.18 and 0.16 Mg $ha^{-1}day^{-1}$) in homegarden during rabi and summer season respectively. A similar trend was obtained in open contiguous areas also. The average duration of maize and bajra in the open contiguous areas was about 55 and 45 days, while in the homegarden, the duration of these crops increased by about 10 and 15 days respectively.

8. Dry matter content was generally higher in open conditions than in homegarden. Among the different fodder grasses in open contiguous areas, sorghum fodder (24.90 and 25.20 %) was observed to have the highest dry matter percentage followed by hybrid napier (21.40 and 21.90 %), bajra (19.70 and 20.05 %) and maize (19.59 and 19.70 %) during rabi and summer season respectively. A similar trend was also obtained in homegarden. The

reduction in dry matter in homegarden compared to open conditions was maximum in maize (5.56 and 8.78 %) followed by bajra (3.27 and 4.24 %), hybrid napier (3.27 and 3.97 %) and sorghum (1.21 and 3.65 %) during rabi season and summer season respectively.

9. The fodder grasses grown in homegarden exhibited higher crude protein content than in open contiguous areas. Maize fodder (9.20 and 10.01 %) had more crude protein content followed by hybrid napier (8.24 and 9.02 %), bajra (7.83 and 8.35 %) and sorghum (6.68 and 6.49 %) during rabi and summer season respectively in homegarden. Open area cultivated fodder grasses also exhibited a similar trend in CP content; maize (8.32 and 9.86 %) >hybrid napier (8.12 and 8.68 %) > bajra (7.78 and 7.90 %) > sorghum (6.54 and 6.22 %) during rabi and summer season respectively.
10. The crude fibre content was found lower in homegarden than open contiguous areas. In homegarden, the CF content was in the order; maize (28.01 and 29.07 %) <bajra (28.50 and 27.60 %) <sorghum (28.83 and 29.75 %) <hybrid napier (31 and 30.07%) during rabi and summer season respectively. In open contiguous areas also, a similar pattern was observed.
11. Generally, the ash content was found higher in open contiguous area as compared to homegarden during both seasons. On comparison of different fodders, maize (11.33 % in rabi and 10.44 % in summer) was observed to have more ash content followed by sorghum, hybrid napier and bajra in both land use systems in rabi as well as summer season.
12. N content in fodder grasses also varied significantly between fodder grasses in homegarden and open contiguous areas. Fodder grasses cultivated in homegarden were noticed to have higher N content than open cultivated grasses. The N content in maize (1.79 % in rabi and 1.89 % in summer) and hybrid napier (1.14 % in rabi and 1.41 % in summer) was significantly higher during the study.
13. Insignificant variations existed in P content in fodder grasses during the rabi and summer season in both land management systems.

14. There were no discernible changes recorded in the K content of fodder grasses cultivated in the homegarden during rabi and season. However, in open conditions, K content was significantly higher in bajra (1.91% in rabi and 1.50 % in summer) and hybrid napier (1.42 % in rabi and 1.50 % in summer). The K content of maize was 1.33 and 1.44 % in homegarden during rabi and summer.

15. Mean mid-day understorey Photosynthetic Photon Flux Density (PPFD) levels in open contiguous areas were 1556 μ moles m^{-2} sec^{-1} in rabi and 1518 μ moles m^{-2} sec^{-1}in the summer season. In homegarden, the corresponding PPFD levels were 492 μ moles μ moles m^{-2} $sec^{-1}$and 822 μ moles m^{-2} sec^{-1}. The mean daily transmittance in homegarden during rabi and summer season was 31.72 and 49.18 percent respectively.

16. Among the cultivated fodder crops, fodder maize recorded a high B: C ratio in homegarden (1.87 in rabi and 1.91 in summer) as well as the open contiguous area (2.52 in rabi and 2.43 in summer). The B: C ratio of fodder sorghum was noticed by less than 1 in both land use systems. In both land use systems, hybrid napier also showed B: C ratio greater than 1.

17. In general, fodder maize can be considered as a compatible cereal fodder in homegarden owing to its good shade tolerance, better growth, yield, and nutritive value in terms of crude protein and ash content, and good palatability owing to low fibre content. Maize also exhibited better productivity and quality than hybrid napier, especially during the initial year of planting. However, sorghum and bajra exhibited poor shade tolerance and suffered severe yield loss under homegarden cultivation.

Thus, the study indicates that cereal fodder maize can be successfully and cost effectively cultivated in partially shaded tree based systems like homegardens and coconut gardens with minimum yield loss. In comparison, yield reduction was higher under homegarden with low PAR transmission (41 percent) than that of coconut garden with higher light availability (56 percent). The study also indicated that maize outperformed hybrid napier both quantitatively and qualitatively under coconut garden with more light availability, whereas it showed a comparable response in homegarden with intense shade indicating higher shade tolerance of hybrid napier than maize. Bajra showed moderate performance under shady situations whereas sorghum yielded very poor results.

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Appendix

Appendix 1

Mean monthly weather parameters during June 2020 – May 2021 of the study area recorded by Department of Agricultural Meteorology, College of Agriculture, Vellanikara, Kerala

Months	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)	Relative Humidity (%)
June 2020	31.10	23.70	427.20	85.00
July 2020	30.50	23.20	563.00	87.00
August 2020	30.20	23.10	607.70	87.00
September 2020	30.00	22.40	587.60	88.00
October 2020	31.00	21.50	310.30	82.00
November 2020	33.00	22.00	56.10	70.00
December 2020	32.00	21.90	7.70	65.00
January 2021	32.30	21.30	45.70	64.00
February 2021	34.60	21.60	0.00	54.00
March 2021	36.80	23.00	31.80	59.00
April 2021	34.90	23.60	72.40	73.00
May 2021	32.70	22.90	550.50	83.00

8. ABSTRACT

The field study entitled "On-farm evaluation of selected cereal fodders in prominent land use systems of Kerala" was carried out as two separate experiments in homegarden and coconut garden with livestock component in Madakkathara panchayath, Thrissur, Kerala during 2020-21. The study aimed to evaluate the forage yield and nutritive value of three cereal fodders viz., maize, sorghum, and bajra in major land use systems of Kerala viz., homegarden, coconut garden, and under open conditions with full sunlight. The study also assessed the relative performance of cereal fodders with hybrid napier, the popular fodder grass in Kerala. In each system, the treatments were laid out in Randomized Block Design replicated three times. The crops were cultivated during two different seasons viz., rabi and summer.

In homegarden trial, all the crops established well in homegarden and contiguous open areas. In general, the growth parameters of crops were better in the open field. Among crops, maize showed better growth followed by hybrid napier, bajra, and sorghum. In open field, maize recorded significantly higher cumulative green fodder yield (93.27 Mg ha^{-1}in rabi and 93.32 Mg ha^{-1}in summer) followed by hybrid napier (70.42 Mg ha^{-1}in rabi and 79.20 Mg ha^{-1}in summer), while in homegarden, the yield of maize (57.16 Mg ha^{-1}and 73.50 Mg ha^{-1}) and hybrid napier (60.42 Mg ha^{-1}in rabi and 73.51 Mg ha^{-1} in summer) was on par. The productivity of sorghum and bajra was poor in both land use systems. The shade tolerance of fodder grasses in homegarden is in the order; hybrid napier>maize >bajra >sorghum. Dry fodder yields also followed a similar trend. The fodder production was generally higher during the summer season than in rabi. The per day productivity was higher for bajra and maize in both land use systems. The PAR availability in homegarden as compared to open conditions during rabi and summer season was 31.72 and 49.18 percent respectively.

Considering the quality aspects of fodder, the crude protein content was higher and crude fibre content was lower in homegarden than in open field, whereas

the dry matter and ash content showed the reverse trend. In homegarden and open field, maize had more crude protein content followed by hybrid napier, bajra, and sorghum during both seasons. The order of CF content in homegarden was in the order; maize<bajra <sorghum <hybrid napier. Maize also had more ash content compared to other fodders. Fodder grasses in homegarden had higher N content than open cultivated grasses. Insignificant variations existed in P and K content in fodder grasses in both land management systems. In the present study, fodder maize recorded the highest B: C ratio in homegarden as well as in open contiguous areas.

In coconut garden trial, fodder crops showed growth and yield reduction underneath coconut as compared to open field. The maximum green fodder yield in coconut garden was obtained in maize (71.60 and 77.35 Mg ha^{-1}) followed by hybrid napier (56.45 and 67.80 Mg ha^{-1}) during both seasons. The order of shade tolerance of fodder grasses was in the order: hybrid napier> maize > bajra > sorghum. The dry fodder yields also followed a similar trend. Per day productivity of fodder grasses was noticed more in open contiguous areas as compared to coconut garden. The maximum per day productivity was obtained by bajra and maize in both land management systems. The mean daily PAR transmittance in coconut garden during the rabi and summer season was 55.74 and 56.83 percent respectively.

In the second experiment also, the crude protein content was higher and crude fibre content lower in coconut garden, whereas the dry matter and ash content observed more in open fields. In coconut garden, maize had more crude protein content followed by hybrid napier and the crude fibre content was minimum in maize. The ash content was also maximum in maize. The grasses in the coconut garden showed more N content and were recorded highest in maize. The P and K content recorded higher values in open conditions than in coconut garden. The P concentration was maximum in hybrid napier, while K content was highest in fodder bajra. In both systems, maize recorded the highest B: C ratio followed by hybrid napier.

Thus, the study indicates that cereal fodder, maize can be successfully and cost effectively cultivated in partially shaded tree-based systems like homegardens and coconut gardens with minimal yield loss. In comparison, yield reduction was higher under homegarden with low PAR transmission (41 percent) than that of coconut garden with higher light availability (56 percent). The study also indicated that maize outperformed hybrid napier both quantitatively and qualitatively under coconut garden with more availability of light, whereas it showed a comparable response in homegarden with intense shade indicating higher shade tolerance of hybrid napier. Bajra showed moderate performance under shady situations whereas sorghum yielded very poor results.

ON-FARM EVALUATION OF SELECTED CEREAL FODDERS IN PROMINENT LAND USE SYSTEMS OF KERALA

by

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ABSTRACT OF THE THESIS

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സംഗ്രഹം

2020-21 കാലയളവിൽ കേരളത്തിലെ തൃശ്ശൂരിലെ മാടക്കത്തറ പഞ്ചായത്തിൽ കന്നുകാലി ഘടകത്തോട് കൂടിയ ഹോം ഗാർഡനിലും തെങ്ങിൻ തോപ്പിലും രണ്ട് വ്യത്യസ്ത പരീക്ഷണങ്ങളായി "കേരളത്തിലെ പ്രമുഖ ഭൂവിനിയോഗ സംവിധാനങ്ങളിലെ തിരഞ്ഞെടുത്ത ധാന്യ കാലിത്തീറ്റകളുടെ ഫാം വിലയിരുത്തൽ" എന്ന ശീർഷകത്തിൽ ഫീൽഡ് പഠനം നടത്തി. കേരളത്തിലെ പ്രധാന ഭൂവിനിയോഗ സംവിധാനങ്ങളായ വീട്ടുമുറ്റം, തെങ്ങിൻതോട്ടം, പൂർണ്ണ സൂര്യപ്രകാശമുള്ള തുറന്ന സാഹചര്യങ്ങൾ എന്നിവയിലെ മൂന്ന് ധാന്യ കാലിത്തീറ്റകളായ ചോളം, സോർഗം, ബജ്റ എന്നിവയുടെ കാലിത്തീറ്റയും പോഷകമൂല്യവും വിലയിരുത്താനാണ് പഠനം ലക്ഷ്യമിടുന്നത്. കേരളത്തിലെ പ്രശസ്തമായ കാലിത്തീറ്റ പുല്ലായ ഹൈബ്രിഡ് നേപ്പിയറിനൊപ്പം ധാന്യ കാലിത്തീറ്റകളുടെ ആപേക്ഷിക പ്രകടനവും പഠനം വിലയിരുത്തി. ഓരോ സിസ്റ്റത്തിലും, ചികിത്സകൾ ക്രമരഹിതമായ ബ്ലോക്ക് ഡിസൈനിൽ മൂന്ന് തവണ ആവർത്തിക്കുന്നു. റാബി, വേനൽ എന്നിങ്ങനെ രണ്ട് വ്യത്യസ്ത സീസണുകളിലാണ് വിളകൾ കൃഷി ചെയ്തിരുന്നത്.

ഹോംഗാർഡൻ ട്രയലിൽ, എല്ലാ വിളകളും ഹോം ഗാർഡനിലും തുറസ്സായ സ്ഥലങ്ങളിലും നന്നായി സ്ഥാപിച്ചു. പൊതുവേ, വിളകളുടെ വളർച്ചയുടെ പാരാമീറ്ററുകൾ തുറന്ന പ്രദേശങ്ങളിൽ മികച്ചതായിരുന്നു. വിളകളിൽ, ചോളം മെച്ചപ്പെട്ട വളർച്ച കാണിച്ചു, തുടർന്ന് ഹൈബ്രിഡ് നേപ്പിയർ, ബജ്റ, സോർഗം. ഓപ്പൺ ഫീൽഡിൽ, ചോളത്തിൽ ഗണ്യമായ ഉയർന്ന ക്യുമുലേറ്റീവ് ഗ്രീൻ കാലിത്തീറ്റ വിളവ് രേഖപ്പെടുത്തി (93.27 Mg ha^{-1}; റാബി സീസണിൽ ; 93.32 Mg ha^{-1}; വേനൽക്കാലത്ത്), തുടർന്ന് ഹൈബ്രിഡ് നേപ്പിയർ (70.42 Mg ha^{-1}റാബി സീസണിൽ; 79.20 Mg ha^{-1} വേനൽക്കാലത്ത്), എന്നാൽ ഹോംഗാർഡനിൽ, ചോളത്തിന്റെ വിളവ് റാബിയിൽ 57.16 Mg ha^{-1}

ഉം വേനൽക്കാലത്ത് 73.50 Mg ha^{-1} ഉം ആയി കാണപ്പെട്ടു. ഹൈബ്രിഡ് നേപ്പിയർ ഉത്പാദനം റാബിയിൽ 60.42 Mg ha^{-1} ഉം വേനൽക്കാലത്ത് 73.51 Mg ha^{-1} ഉം ആയിരുന്നു. രണ്ട് ഭൂവിനിയോഗ സംവിധാനങ്ങളിലും സോർഗം, ബജ്റ എന്നിവയുടെ ഉത്പാദനക്ഷമത മോശമായിരുന്നു. വീട്ടുമുറ്റത്തെ കാലിത്തീറ്റ പുല്ലുകളുടെ തണൽ സഹിഷ്ണുത ഈ ക്രമത്തിലാണ്; ഹൈബ്രിഡ് നേപ്പിയർ>ചോളം>ബജ്ര>സോർഗം. ഉണങ്ങിയ കാലിത്തീറ്റ വിളവും സമാനമായ പ്രവണത പിന്തുടർന്നു. വേനൽക്കാലത്ത് റാബിയേക്കാൾ കാലിത്തീറ്റ ഉൽപ്പാദനം പൊതുവെ കൂടുതലായിരുന്നു. രണ്ട് ഭൂവിനിയോഗ സംവിധാനങ്ങളിലും ബജ്റയ്ക്കും ചോളത്തിനും പ്രതിദിന ഉൽപ്പാദനക്ഷമത കൂടുതലായിരുന്നു. റാബിയിലും വേനൽക്കാലത്തും തുറന്ന സാഹചര്യങ്ങളുമായി താരതമ്യം ചെയ്യുമ്പോൾ ഹോംഗാർഡനിലെ സൂര്യപ്രകാശ ലഭ്യത യഥാക്രമം 31.72 ഉം 49.18 ശതമാനവുമാണ്.

കാലിത്തീറ്റയുടെ ഗുണമേന്മയുള്ള വശങ്ങൾ പരിഗണിക്കുമ്പോൾ, അസംസ്കൃത പ്രോട്ടീന്റെ അംശം കൂടുതലും അസംസ്കൃത നാരിന്റെ അംശം തുറസ്സായ സ്ഥലത്തേക്കാൾ കുറവുമായിരുന്നു ഹോംഗാർഡനിൽ, അതേസമയം ഉണങ്ങിയ പദാർത്ഥത്തിന്റെയും ചാരത്തിന്റെയും ഉള്ളടക്കം വിപരീത പ്രവണത കാണിക്കുന്നു. ഹോം ഗാർഡനിലും തുറന്ന പ്രദേശങ്ങളിലും, ചോളത്തിൽ കൂടുതൽ അസംസ്കൃത പ്രോട്ടീൻ അടങ്ങിയിട്ടുണ്ട്, തുടർന്ന് രണ്ട് സീസണുകളിലും ഹൈബ്രിഡ് നേപ്പിയർ, ബജ്റ, സോർഗം എന്നിവ യഥാക്രമം രേഖപ്പെടുത്തി. ഹോംഗാർഡനിലെ ക്രൂഡ് ഫൈബർ ഉള്ളടക്കത്തിന്റെ ഈ ക്രമത്തിലായിരുന്നു; ചോളം<ബജ്ര <സോർഗം <ഹൈബ്രിഡ് നേപ്പിയർ. മറ്റ് കാലിത്തീറ്റകളെ അപേക്ഷിച്ച് ചോളത്തിൽ ചാരത്തിന്റെ അംശം കൂടുതലായിരുന്നു. ഹോം ഗാർഡനിലെ കാലിത്തീറ്റ പുല്ലുകൾക്ക് തുറന്ന കൃഷി ചെയ്യുന്ന പുല്ലുകളേക്കാൾ ഉയർന്ന നൈട്രജൻ ഉള്ളടക്കം ഉണ്ടായിരുന്നു. രണ്ട് ലാൻഡ്

മാനേജ്മെന്റ് സിസ്റ്റങ്ങളിലെയും കാലിത്തീറ്റ പുല്ലുകളിലെ പി, കെ ഉള്ളടക്കത്തിൽ നിസ്സാരമായ വ്യതിയാനങ്ങൾ നിലനിന്നിരുന്നു. നിലവിലെ പഠനത്തിൽ, ഹോം ഗാർഡനിലും തുറസ്സായ പ്രദേശങ്ങളിലും കാലിത്തീറ്റ ചോളം ഏറ്റവും ഉയർന്ന ബി: സി അനുപാതം രേഖപ്പെടുത്തി.

തെങ്ങിൻ തോട്ടം പരീക്ഷണത്തിൽ, തീറ്റപ്പുൽ വിളകൾ തുറന്ന നിലത്തെ അപേക്ഷിച്ച് തെങ്ങിന് താഴെ വളർച്ചയും വിളവ് കുറവും കാണിച്ചു. തെങ്ങിൻ തോട്ടത്തിൽ ഏറ്റവും കൂടുതൽ പച്ചപ്പുല്ല് വിളവ് ലഭിച്ചത് ചോളം (71.60 Mg ha^{-1} റാബി സീസണിൽ 77.35 Mg ha^{-1} ;വേനൽക്കാലത്ത്), തുടർന്ന് ഹൈബ്രിഡ് നേപ്പിയർ (56.45 Mg ha^{-1} റാബി സീസണിൽ , 67.80 Mg ha^{-1}; വേനൽക്കാലത്ത്). കാലിത്തീറ്റ പുല്ലുകളുടെ തണൽ സഹിഷ്ണുതയുടെ ക്രമം ഈ ക്രമത്തിലായിരുന്നു: ഹൈബ്രിഡ് നേപ്പിയർ> ചോളം> ബജ്റ> സോർഗം. ഉണങ്ങിയ കാലിത്തീറ്റയുടെ വിളവും സമാനമായ പ്രവണത പിന്തുടർന്നു. തെങ്ങിൻ തോട്ടത്തെ അപേക്ഷിച്ച്, തുറസ്സായ പ്രദേശങ്ങളിൽ തീറ്റപ്പുല്ലിന്റെ പ്രതിദിന ഉൽപ്പാദനക്ഷമത കൂടുതലായി ശ്രദ്ധയിൽപ്പെട്ടു. രണ്ട് ലാൻഡ് മാനേജ്മെന്റ് സിസ്റ്റങ്ങളിലും ബജ്റയും ചോളവും ഉപയോഗിച്ചാണ് പ്രതിദിനം പരമാവധി ഉൽപ്പാദനക്ഷമത ലഭിച്ചത്. റാബിയിലും വേനൽക്കാലത്തും തെങ്ങിൻ തോട്ടത്തിലെ ശരാശരി പ്രതിദിന സൂര്യപ്രകാശ ലഭ്യത യഥാക്രമം 55.74 ഉം 56.83 ശതമാനവുമാണ്.

രണ്ടാമത്തെ പരീക്ഷണത്തിലും, തെങ്ങിൻ തോട്ടത്തിൽ അസംസ്കൃത പ്രോട്ടീന്റെ അംശം കൂടുതലും അസംസ്കൃത നാരിന്റെ അംശം കുറവുമായിരുന്നു, അതേസമയം ഉണങ്ങിയ ദ്രവ്യത്തിന്റെയും ചാരത്തിന്റെയും അംശം തുറന്ന വയലുകളിൽ കൂടുതലായി കാണപ്പെടുന്നു. തെങ്ങിൻ തോട്ടത്തിൽ, ചോളത്തിൽ കൂടുതൽ അസംസ്കൃത പ്രോട്ടീൻ അടങ്ങിയിട്ടുണ്ട്, തുടർന്ന് ഹൈബ്രിഡ് നേപ്പിയർ അടങ്ങിയിട്ടുണ്ട്, കൂടാതെ ചോളത്തിൽ

അസംസ്കൃത നാരുകളുടെ അംശം കുറവാണ്. ചോളത്തിലും ചാരത്തിന്റെ അംശം പരമാവധി ഉണ്ടായിരുന്നു. തെങ്ങിൻ തോട്ടത്തിലെ പുല്ലുകൾ കൂടുതൽ നൈട്രജൻ ഉള്ളടക്കം കാണിക്കുകയും ചോളത്തിൽ ഏറ്റവും കൂടുതൽ രേഖപ്പെടുത്തുകയും ചെയ്തു. പി, കെ ഉള്ളടക്കം തെങ്ങിൻ തോട്ടത്തേക്കാൾ ഉയർന്ന മൂല്യങ്ങൾ തുറന്ന സാഹചര്യങ്ങളിൽ രേഖപ്പെടുത്തി. പി ഏകാഗ്രത ഹൈബ്രിഡ് നേപ്പിയറിലാണ് കൂടുതലുള്ളത്, അതേസമയം കെ ഉള്ളടക്കം ഏറ്റവും കൂടുതലുള്ളത് കാലിത്തീറ്റ ബജ്റയിലാണ്. രണ്ട് സമ്പ്രദായങ്ങളിലും, ചോളത്തിൽ ഏറ്റവും ഉയർന്ന ബി: സി അനുപാതം രേഖപ്പെടുത്തി, തുടർന്ന് ഹൈബ്രിഡ് നേപ്പിയർ.

അതിനാൽ, ധാന്യ കാലിത്തീറ്റയായ ചോളം വിജയകരവും ചെലവ് കുറഞ്ഞതുമായ രീതിയിൽ തണലുള്ള ഹോം ഗാർഡനിലും തെങ്ങിൻ തോട്ടങ്ങളിലും ഫലപ്രദമായി കൃഷി ചെയ്യാമെന്ന് പഠനം സൂചിപ്പിക്കുന്നു. താരതമ്യപ്പെടുത്തുമ്പോൾ, ഉയർന്ന പ്രകാശ ലഭ്യതയുള്ള (56 ശതമാനം) തെങ്ങിൻ തോട്ടത്തേക്കാൾ (41 ശതമാനം) കുറഞ്ഞ PAR ട്രാൻസ്മിഷൻ ഉള്ള ഹോംഗാർഡനിൽ വിളവ് കുറയുന്നു. വെളിച്ചത്തിന്റെ കൂടുതൽ ലഭ്യതയുള്ള തെങ്ങിൻ തോട്ടത്തിനു കീഴിലുള്ള ചോളത്തിന്റെ ഉത്പാദനം അളവിലും ഗുണത്തിലും ഹൈബ്രിഡ് നേപ്പിയർ-ക്കാളും മികച്ച പ്രകടനം കാഴ്ചവെച്ചതായും പഠനം സൂചിപ്പിക്കുന്നു, അതേസമയം ഹൈബ്രിഡ് നേപ്പിയറിൻറെ ഉയർന്ന നിഴൽ സഹിഷ്ണുതയെ സൂചിപ്പിക്കുന്ന തീവ്രമായ തണലുള്ള ഹോംഗാർഡനിൽ ഇത് താരതമ്യപ്പെടുത്താവുന്ന പ്രതികരണം കാണിക്കുന്നു. തണലുള്ള സാഹചര്യങ്ങളിൽ ബജ്റ മിതമായ പ്രകടനം കാഴ്ചവച്ചു, അതേസമയം സോർഗം വളരെ മോശമായ ഫലങ്ങൾ നൽകി.